Title
Rainfed Agriculture and Climatic Variability in Oaxaca, Mexico

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Publication Date
2013

Peer reviewed|Thesis/dissertation

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by

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A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy

in

Environmental Science, Policy, and Management

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Miguel A. Altieri, Chair
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Professor Nathan Sayre

Fall 2013

Abstract

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by

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Doctor of Philosophy in Environmental Science, Policy, and Management

University of California, Berkeley

Professor Miguel A. Altieri, Chair

The study of agriculture practiced by the Mixtec people, or "the people of the rain" (*Ñuu savi*), in the highlands of southern Mexico reveals successful adaptation strategies for growing rainfed crops in an unpredictable and ever changing climate. Both culture and environment have been shaped by a long and challenging history, which continues to bear relevance in this era of globalization and climate change.

My research from 2009 – 2011 focused on farmer strategies for dealing with climatic variability in the Mixteca Alta Region of Oaxaca, Mexico. It was the product of a close collaboration with the farmer-to-farmer training network, the Center for Integrated Small Farmer Development of the Mixteca Alta (*Centro de Desarrollo Integral Campesino de la Mixteca Alta*, CEDICAM). I was impressed by the depth of farmer knowledge about sustainable agriculture. In fact, what appeared lacking was the grassroots mobilization and political action needed to foster dignified rural livelihoods and environmental stewardship. This topic deserves much greater attention in future research by agroecologists.

My dissertation is organized in four chapters. Chapter 1 contextualizes my research by examining farming traditions of the Mixteca Alta that originated in different historical moments. I also provide a summary of the political economy of labor and sustainable farming.

Chapter 2 examines the social, environmental, and cultural conditions of farming in the Mixteca Alta. Based on in-depth interviews with farmers from two communities, I trace how changes in farming systems has reflected both traditions of farming and an increasingly globalized economy.

I found that a combination of agroecological strategies were important for families to approach self-sufficiency in grain production under highly variable rainfall conditions. Important changes in cropping systems were occurring, particularly shifts towards more precocious crop varieties. It appears that changes in cropping systems have been the result of social disintegration, soil degradation, and climatic changes.

The farmers that I interviewed understood the ecology of their systems. However, were not necessarily farming sustainably. Shift in farming systems were concentrating agricultural labor into the rainy season, thus allowing farmers to work outside their communities

for several months during the dry season. While such changes were ostensibly be intended to save labor, they may in fact accomplish the exact opposite. New farming could potentially increase costs in terms of time and money for families, thus diverting attention away from sustainable agricultural practices. Stemming the labor squeeze from farming regions such as the Mixteca Alta likely will require concerted political action, including grassroots mobilization.

Chapter 3 describes participatory research with farmers in the CEDICAM network, as well as climatic studies, that aimed to place climate change mitigation and adaptation into the hands of small farmers. I facilitated workshops in which groups of small farmers described how they had adapted to and prepared for past climate challenges. Farmers reported that their cropping systems were changing for multiple reasons: more drought, later rainfall onset, decreased rural labor, and labor-saving technologies. Examination of climate data found that farmers' climate narratives were largely consistent with formal climatology data products. There have been increases in temperature and rainfall intensity, and an increase in rainfall seasonality that is likely perceived by farmers as later rainfall onset.

Farmers identified 14 indicators that they subsequently used to evaluate the condition of their agroecosystems. Farmers ranked landscape-scale indicators as more marginal than farmer management or soil quality indicators. From this analysis, farmers proposed strategies to improve the ability of their agroecosystems to cope with climatic variability. Their recommendations, as well as the methodology used in the workshops, holds relevance for farmers and their allies. Notably, they recognized that social organizing and education are required for landscape-level indicators to be improved. This outcome suggests that climate change adaptation by small farmers involves much more than just a set of farming practices, but also community action to tackle collective problems.

I conclude with Chapter 4, which highlights CEDICAM's contribution to mobilizing farmers in the Mixteca Alta region. They are taking action to reforest territories and advance agroecological farming. This chapter also reflects on how collaborative research outcomes contributed to CEDICAM's future outlook on farmer led research. CEDICAM was particularly interested in improving soil cover management and crop selection. CEDICAM as a network continues to promote the social conditions for agroecology to flourish.

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0.1 Preface

Agroecology encompasses a scientific discipline, principles for sustainable farming, and a platform for social change (Wezel et al. 2009). My objective as a scholar is to advance theoretical and applied understandings of agroecology through participatory research. I study how agrosilvopastoral systems incorporate diverse cropping cycles, polycultures, the planting of multiple fields, and diversified income strategies. Such measures spread out risk through spatial, temporal, and economic linkages. My research, particularly as applied in Chapter 3, is closely tied to a pedagogy that prioritizes the grassroots mobilization of small farmers and indigenous people, who in many instances have become leaders in the agroecology movement.

My involvement in Latin America dates back to my undergraduate years at UC Berkeley. Following studies in Brazil as part of the Brazil-US Consortium on Agroecology and Sustainable Rural Development (CASRD), I lived, worked, and volunteered in different parts of Latin America for over four years. In the summer of 2005 while I worked for a community in Las Yungas of La Paz, Bolivia, indigenous peoples chose to organize through labor and political networks for greater recognition by the Bolivian State. The outcome of their activism was the resignation of then-President Carlos Mesa and election six months later of current-President Evo Morales. My witness to the vast indigenous political networks that catapulted Morales, a labor organizer, to presidency was an inspirational example of how to achieve substantive social change.

In that same year, I supported the Landless Rural Worker's Movement (MST) in Brazil. Considered the largest social movement in Latin America, the MST has advocated since the early 1980's for land reform. My collaboration with the MST included the translation of an MST publication from Portuguese to English, participation in numerous workshops on the political economy of agriculture, support during land occupations, and volunteering for the *Escola Nacional Florestán Fernandes* in the Brazilian state of São Paulo. These among many other formative experiences shaped my perception of agroecology as a project for social transformation. To this day I participate in Latin American initiatives for agroecology, in particular with my colleagues of the Latin American Scientific Society of Agroecology (SOCLA).

My agroecological perspective also developed through extensive contact with small farmers and organic producers. That journey started well before living in Latin America. As an undergraduate at UC Berkeley, I worked part-time with the ASUC Composting Project (AKA Berkeley Worms), a non-profit worker's collective that initiated the important service of food scrap collection for University Services and campus housing. Berkeley Worms provided a critical service of recycling nutrients back into urban gardens and parks years before the City of Berkeley instituted similar food scrap collection services.

From 2006 to 2007, I managed a Community Supported Agriculture (CSA) program at the Agriculture and Land-Based Training Association (ALBA) in Salinas, California. The CSA program provided locally-grown organic fruits and vegetables produced by aspiring farmers in ALBA's training program to families in Monterey and Santa Cruz Counties. ALBA offers opportunities for local farm workers to start up small farming businesses by providing access to affordable farmland, training in organic agriculture, and market access through their affiliated distribution company, ALBA Organics. Farmers developed their small businesses while sustaining farming traditions that many brought with them from their countries of origin.

My doctoral studies at UC Berkeley presented an opportunity to engage with issues that extended from my background in social organizing and organic farming. I applied my unique perspective, shaped by years of engagement in agroecology initiatives, to the pressing issue of climate change. Agroecologists for decades have recognized the ingenious strategies that small farmers use to cope with limited resources and marginal environmental conditions. However, policy makers and researchers have yet to seriously consider the potential for agroecology research and farmer movements to contribute to climate change adaptation and mitigation for agriculture. Often overlooked are the ways that farmers have prepared for climatic variability. My dissertation aims to widen a space for dialogue about what agroecology can contribute to issues facing small farmers.

Acknowledgments

I wish to express my gratitude to the farmers at CEDICAM, in particular Abelino Célis, Anastasia Velasco López, Eleazar García Jiménez, Estela Rosendo Palacios and Jesús León Santos. My committee chair, Miguel A. Altieri, as well as committee members, Marta Astier, Ignacio Chapela, and Nathan Sayre, contributed their guidance and insight throughout my graduate studies. Andrew R. Friedman collaborated on the climate study that is presented in Chapter 3. I supervised numerous student interns who worked on field research in the Mixteca Alta. They contributed to the greater research project that has been documented in various reports and undergraduate theses. By name, they are Aida Carmen Ríos Colín, Jessica Parra-Fitch, Leslie López, Luis Suárez, Maya Stanton, Michelle Roses, Natalia García-Pasmanick, Silvia Victoria Ruiz Narváez, Soledad Loreily Soto Sarmiento, Víctor Bautista Vásquez, and Xochitl Victoria Juárez Martinez. I was also graced by guidance from Brigitte and Daniel Cullem, Claude and Shelley Rogé, Gabriel Córdova Gámez, Jutta Blauert, Shoshana Perrey, and Tamara Ortiz-Ávila. The following institutions provided financial support for this research:

- 2010 – 2011 Garcia Robles-Fulbright Scholarship
  Enhancing the resilience of rainfed agroecosystems to climatic variability in Oaxaca, Mexico
- 2010 UC MEXUS Small Grant
  Importance of social networks in resilience theory: case studies from rural Mexico
- 2009 – 2010 UC MEXUS – CONACYT Grant
  Climate change research in Mexico: testing and scaling-up best-bet agroecological practices to enhance the resiliency to climatic stress of campesino farming systems in the Mixteca Region of Mexico
- University of California, Berkeley
  - Graduate Division
  - Department of Environmental Science, Policy, and Management (ESPM)

Chapter 1

Introduction

If the sustainability of agroecosystems are difficult to predict beyond the "test of time" (Holt-Giménez 2002), and agroecosystems constantly readjust to emerging social and environmental conditions (Miguel A Altieri 1983; Lefroy, Bechstedt, and Rais 2000; Sands and Podmore 2000), what is left to guide efforts toward more sustainable food systems? This question becomes ever more critical in an era of climate change.

Holt-Giménez (2002) coordinated a pioneering effort in participatory research following an extreme climatic event, Hurricane Mitch, that severely affected central America in October of 1998. The farms that had integrated with the Nicaraguan Farmer-to-Farmer Movement (*Movimiento Campesino a Campesino*, MCAC) were compared to neighboring farms in terms of the immediate biophysical and economic impact following the hurricane.

This provided Holt-Giménez, 19 non-governmental organizations, and 800 farmers the rare opportunity to measure what difference 10 years of promoting agroecological practices in the region could make. The research team found that on average, farms that were integrated with MCAC had more topsoil, higher field moisture, less erosion, and lower economic losses in comparison to their neighbors. While Holt-Giménez (2002) does credit these findings to the many years of hard work by farmers and the farmer-to-farmer movement, the discussion of the article mostly emphasizes the effectiveness of agroecological practices and frameworks for participatory evaluations to an international readership.

A possibly more important lesson that underlies this study is the critical role that MCAC itself played in realizing such an outcome. The same practices promoted through different social institutions might not have had the same effect. When discussing matters of climate change adaptation, the important role that groups of farmers working collectively play in addressing ever changing problems cannot be underestimated. While identifying proven agroecological, ecologically-based, and traditional farming practices that do enhance the resistance and resilience of systems to climate change is important, so too is recognizing how agroecological movements affect social conditions that would otherwise prevent climate change adaptation in the first place. While my dissertation weaves many narratives, this issue is at the crux of my argument.

In 1982, farmers organized to address the environmental and social crises affecting the

Mixteca Alta Region of Oaxaca, Mexico with support from the international non-governmental organization World Neighbors (Blauert and Quintanar 2000, 34). This group's current manifestation, the farmer-led Center for Integral Rural Development of the Mixteca Alta (CEDICAM), continues to garner international recognition for promoting sustainable agriculture, appropriate technology, and gender equality through a farmer-to-farmer training network (Boege and Carranza 2009, 102–113). CEDICAM works to adapt the sustainable elements of traditional agriculture to modern conditions through "improved" indigenous technologies (Jesús León Santos, personal communication). CEDICAM invited me to join them in the struggle to improve rural livelihoods and curb severe environmental degradation in their region. Our collaboration identified meaningful actions that farmers can take to reach greater agricultural sustainability.

My research began with a gaze towards farmer adaptation to climatic variability. However, it became evident that social collapse caused by internal and external factors were fundamental issue to also address. I therefore begin with a summary of the historical and contemporary challenges for land stewardship in the Mixteca Alta that have been studied by multiple academic disciplines (pages 5 and 10). These sections bring together the research of archaeologists, political economists, and anthropologists who have studied the historical fluctuations of stewardship and degradation in this fragile and unpredictable environment.

Chapter 3 studies social conditions of farmers and their agricultural management at a very fine resolution in the two communities of the Mixteca Alta. I conducted this research to discern changes in farming systems that were apparent on the landscape and also the subject of much informal conversation with farmers in the region, but not fully documented in the literature. Farmers have adjusted their cropping systems to concentrate labor temporally, thus enabling them to seek employment when needed outside of their communities.

I aimed to collect rich details that could serve as a benchmark for future research and document farmer knowledge that most likely will change in the future. I struck a balance between household surveys and farmer narratives that would not oversimplify complex realities, but also would describe some quantitative measure of change. Farmer knowledge has a life of its own in the sense that it grows, changes, and may in some cases die out. As one farmer told me with regard to old trades practiced in their community, "our grandfathers have past away and we have lost the knowledge." It was hoped that such a study would interest the communities, especially the outmigrated youth who may one day wish to read about farming, or to those who remain that are better educated and globally aware than ever before. All respondents were coded to respect the privacy of those families who spoke with me, though the codes are provided to the reader in the spirit of transparency.

Subsequently, I provide in chapter 3 an example of how participatory agroecological research can support the efforts of farmer networks to achieve dignified rural livelihoods. The outcome of my participatory research with CEDICAM went beyond the adoption of any one farming practice by individual farmers. Organization at the community level for improved environmental stewardship was expressed. This research was founded on the premise that the farmers with whom I engaged were reliable experts on matters of farming and local climate in the Mixteca Alta. Future agroecological studies might potentially explore the scientific basis of farmers observations, but that would require different methodological approaches inspired by different objectives.

This dissertation takes a close look at the agroecological knowledge of farmers for dealing with climatic variability through a collaboration with three communities from the Nochixtlán District of the Mixteca Alta Region: San José Zaragoza (Zaragoza), El Rosario, and San Pedro Coxcaltepec Cántaros (Coxcaltepec, Figure 1.1). Leaders in the CEDICAM network who lived in Zaragoza, Coxcaltepec, and Huautla graciously facilitated my stays in their communities. Trust and respect were integral to our interactions that spanned over 3 years. I also recognize that the struggle for rural communities may be a more fundamental one of reproducing social cohesion to articulate and sustain agroecological practices.

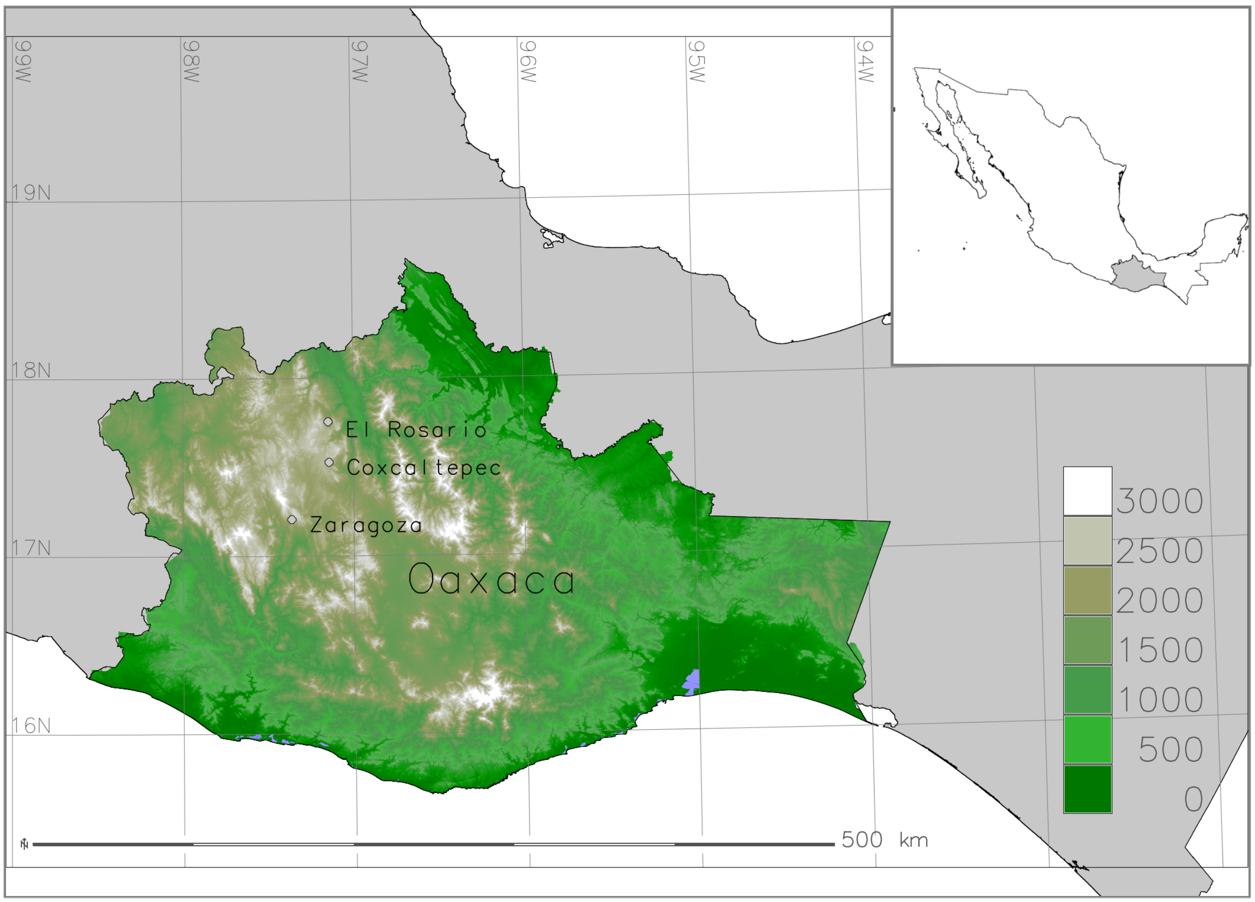

Figure 1.1: A map that shows the communities from the Mixteca Alta region of Oaxaca, Mexico that participated in this case study: San José Zaragoza (Zaragoza), El Rosario, and San Pedro Coxcaltepec Cántaros (Coxcaltepec).

1.1 Climate and Geography

The Mixteca Alta Region of Oaxaca, Mexico is both a political entity and a part of the larger geographical area predominated by the Mixtec people. Due to its high elevation (much of it above 2,000 meters), the Mixteca Alta is largely classified as a subtropical dry winter climate (Cwb) according to the Köppen-Geiger system, though it lies within the tropics (Kottek et al. 2006). Most precipitation occurs from June through September, with a mid-summer decrease known as the *canícula* (Magaña, Amador, and Medina 1999). The highest average temperatures are in April and May, before the heaviest summer rains, and frosts are common from October through March at higher elevations. Figure 1.2 shows the monthly average temperature and rainfall from 2005 – 2010 for a $1° \times 1°$ region surrounding the communities (96.5 – 97.5°W, 17 – 18°N).

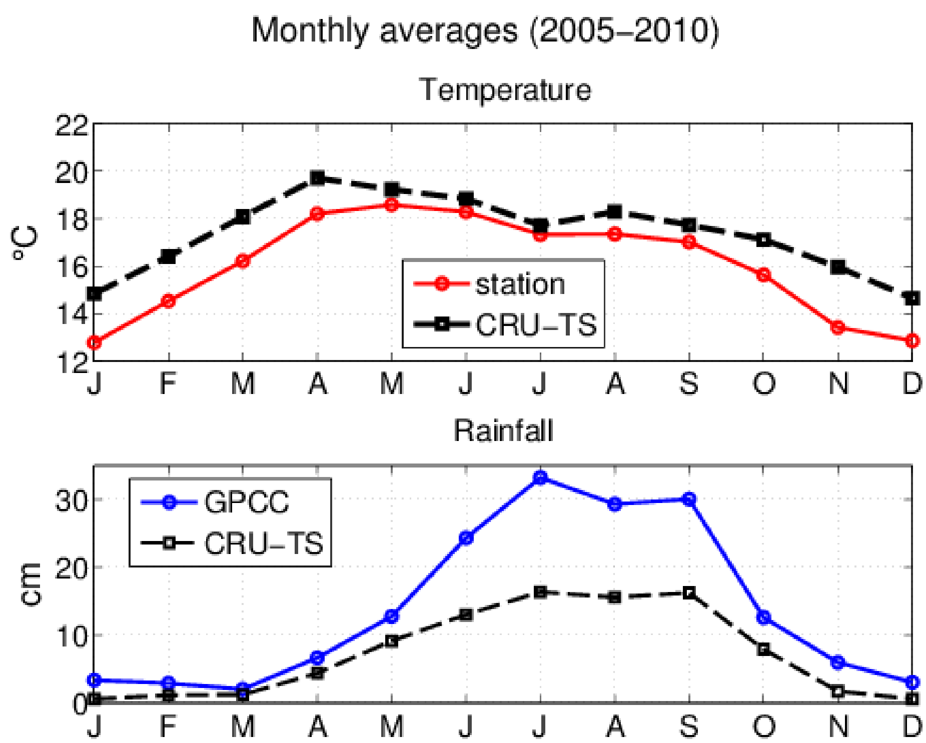

Figure 1.2: 2005 – 2010 monthly averages from the Nochixtlán meteorological station (17°26′ N, 97°15′ W, 2040 m) and gridded averages over 96.5 – 97.5° W, 17 – 18° N. Top: Temperature (°C) from the Nochixtlán meteorological station (red solid) and CRU-TS (black dashed). Bottom: Rainfall (cm) from GPCC (blue solid) and CRU-TS (black dashed). Figure produced by Andrew R. Friedman with input from Paul Rogé.

Crises of poverty and aging demographics also marked the Mixteca Alta due to increasing out-migration by youth (Boege and Carranza 2009, 90–98). The National Institute of Statistics and Geography (*Insituto Nacional de Estadística y Geografía*, INEGI) ranked the

State of Oaxaca at the lowest relative socio-economic level in the nation along with Guerrero to the west and Chiapas to the east (INEGI 2004). Moreover, residents in the municipalities where I conducted research were ranked in the lowest two relative rankings (Table 1.1). Populations in these municipalities have steadily decreased in recent decades (Figure 1.3), a sign of a diminishing rurality in an era of globalization. In the past twenty years, the most dramatic reductions in rural populations were observed by youth and adolescents, while the elderly population moderately increased (Figure 1.4). In this context, my central motivations were to understand how the farming systems of economically disadvantaged communities responded to global challenges, and to what extent research could support local action in the region.

Table 1.1: Percent of the population ranked in terms of socioeconomic wellbeing from 1 (low) to 7 (high) in the three municipalities in the Mixteca Alta Region of Oaxaca, Mexico that participated in this case study: Santiago Tilantongo (community of Zaragoza), San Pedro Coxcaltepec Cántaros, and San Miguel Huautla. Data source: INEGI 2004.

Municipality	**1 (low)**	**2**	**3**	**4**	**5**	**6**	**7 (high)**
Santiago Tilantongo	19%	81%	0%	0%	0%	0%	0%
San Pedro Coxcaltepec Cántaros	76%	24%	0%	0%	0%	0%	0%
San Miguel Huautla	100%	0%	0%	0%	0%	0%	0%

1.2 Agrarian History

Arguments that explain historical cycles of adoption and abandonment of sustainable farming practices in the Mixteca Alta have been represented in the literature as adaptation cycles of social-ecological resilience (Perez Rodriguez and Anderson 2013), institutional failure (García-Barrios and García-Barrios 1990), and cultural norms and dominance (Edinger 1996). First, this section presents a narrative of the Mixtec agrarian history as a backdrop to my research. Secondly, I focus on the theoretical arguments of (García-Barrios and García-Barrios 1990), who provide a more politically engaged point of departure. I had initiated this research from the perspective of resilience theory, but later found it problematic for framing issues of natural resource stewardship and social action by small farmers.

Despite challenging environmental and social issues, indigenous communities in Mixteca Alta have practiced farming that takes root in the very origins of agriculture. The Mixteca Alta is located midway between the Tehuacán Valley and Oaxaca Valley where the oldest evidence of maize domestication has thus far been identified (Benz 2001; Benz and Iltis 1990). The Mixtec people, who call themselves "the people of the rain" (*Ñuu savi*), developed highly sophisticated maize production systems over the millennia. Their production systems to this day are by-and-large dependent on and adapted to the regional rainfall patterns.

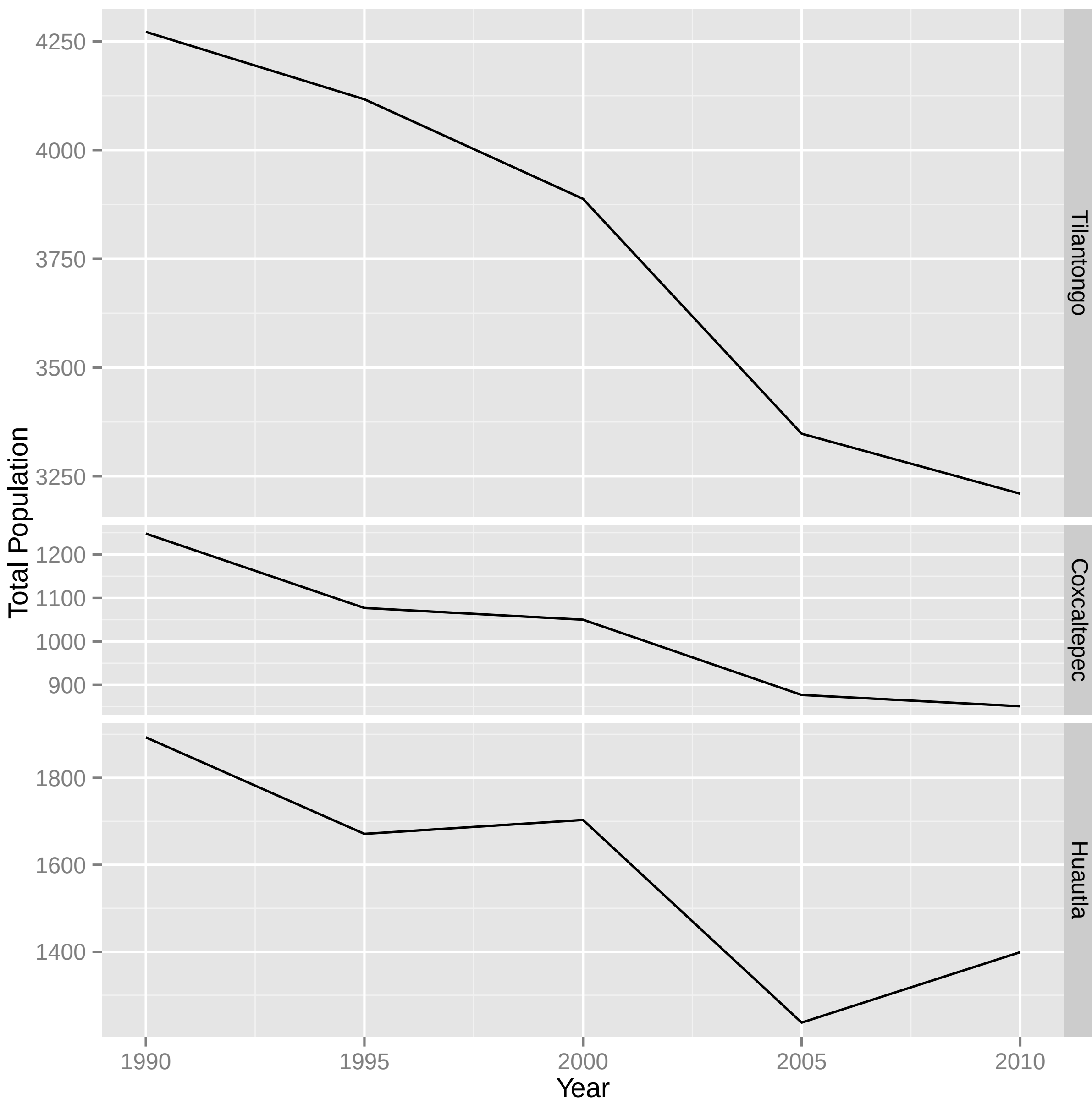

Figure 1.3: Total populations (1990 – 2010) of the three municipalities in the Mixteca Alta Region of Oaxaca, Mexico that participated in this case study: Santiago Tilantongo (community of Zaragoza), San Pedro Coxcaltepec Cántaros, and San Miguel Huautla. Data source: INEGI 2005 and INEGI 2010.

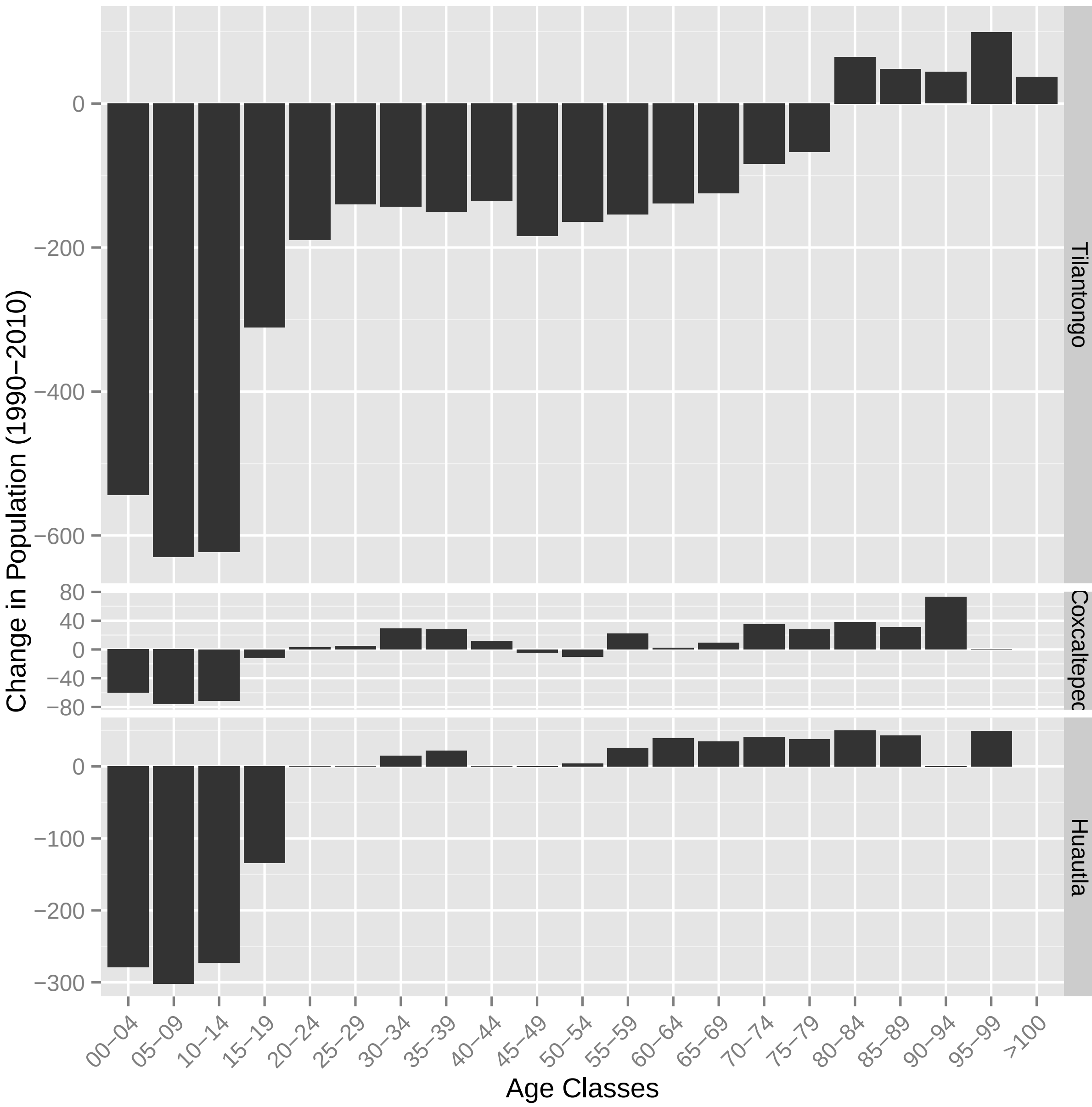

Figure 1.4: Demographic change over the past twenty years (1990 – 2010) of the three municipalities in the Mixteca Alta Region of Oaxaca, Mexico that participated in this case study: Santiago Tilantongo (community of Zaragoza), San Pedro Coxcaltepec Cántaros, and San Miguel Huautla. Data source: INEGI 1990 and INEGI 2010.

Rainfed agriculture – particularly maize, beans, and wheat – were widely practiced in the Mixteca Alta (Altieri et al. 2006, 62; Velásquez 2002, 3-4). Two important rainfed cropping systems in the Mixteca Alta have been cajete maize (*maíz de cajete*) and seasonal maize (*maíz de temporal*). The two maize systems have differed significantly in their requirements for labor, technology, and social organization. Groups of farmers would sow cajete maize at the end of the dry season between February and March, using a two-sided digging tool (*pico y coa*) to locate residual soil moisture. Sowing cajete maize involved much of the community and required coordination throughout the winter months (Rivas Guevara 2008, 146-158; García Barrios, García Barrios, and Álvarez-Buylla 1991, 25-31). In contrast, families individually would sow seasonal maize along with beans and squash at the beginning of the rainy season between May and July. These cropping systems are the primary subjects for much of the dissertation that follows, and more specifically key measures of how farming has changed to accommodate new social and environmental conditions.

Archaeological evidence supports that agrarian communities flourished as early as 1400 B.C.E. (Blomster 1998; Kowalewski et al. 2009, 287; Spores 1967, 1972, 1983, 2007). García-Barrios and García-Barrios (1990) summarize three major agronomic elements of the Mixteca Alta that originated in pre-Conquest periods:

- *Diversity management* to reduce the impact of crop failure and increase agroecosystem performance;
- *Cajete maize*, a farming system that was sown during the dry season to avoid flooding during the rainy season and frosts at the end of the rainy season; and
- *Landscape modification*, such as leveling, terracing, and land containers for enhancing agricultural productivity and sustainability.

According to García-Barrios and García-Barrios (1990), Mixteca Alta farmers managed risk through the classification of agricultural environments and the management of biodiverse crops based on complex taxonomies. Also, equitable land distribution across agricultural environments provided families with access to enough agricultural output in any given year. Cajete maize in particular was sensitive to the quantity and quality of labor, which was motivated by status as good sowers of cajete (*cajeteros*) and incentives of food and alcohol. The elevated upfront costs to sow cajete required social norms of reciprocity between closely related families.

Finally, landscape transformation demanded elevated investment over extended time periods to create suitable soil conditions for the cajete system and hillside agriculture. Terracing was a Mixtec innovation that increased maize yields and expanded agriculture from valleys to hillsides. The earliest evidence of terracing dates to around 300 B.C.E. (Spores 1969). To this day, terracing has persisted as a strategy to farm the mountains of the Mixteca Alta, albeit often with faltering maintenance (Perez Rodriguez and Anderson 2013).

Intensive hillside terracing first gained prominence in the Mixteca Alta region at the same time that complex societies with urban centers were established on hilltops during the Late to Terminal Formative (Early Ramos Phase, 300 – 100 B.C.E.). Two forms of early terracing are described by Spores (1967): contour terraces that ran perpendicular to hillside slopes, and check dam terraces (*lama-bordo*) that were built in mountain drainages. Remnants of the earliest known *lama-bordo* terracing date back to 1050 B.C.E. (Mueller, Joyce, and Borejsza 2012).

In the pre-Conquest Mixtec cultural hierarchy, kings were at the centers of political power. Royal blood lines (*caciques*) ruled fiefdoms. Priests were in close contact, though subservient to the *caciques*. Commoners (*macehuals*) were a distinct social class that, besides relations of indebtedness, enslavement, and sacrifice to *caciques*, developed their own cultural heritage. Community lands managed communally fed the *macehuals*. Edinger (1996, 21) points out that today a strong egalitarian subculture has persisted in rural communities of the Mixteca Alta: the boundaries of one's family were flexible, while if a person were to earn the reputation of a *cacique*, they would quickly be forced to leave the town.

Agricultural disruption in the Mixteca had occurred in pre-Conquest periods. Terrace construction, occupancy, and abandonment fluctuated with the movement of settlements and changes in populations between the Late Ramos Phase until the Late Postclassic Phase (1521 C.E.; Kowalewski et al. 2009, 297-303, 345-346). The collapse of social institutions during the Late Classic period that had sustained terrace systems was likely due to the rigidity of social structures in Mixtec society, as well as to social upheaval in other regions of Mesoamerica (Perez Rodriguez and Anderson 2013). Trade, conflict, and elevated populations were characteristic of the Postclassic period (900 – 1521 C.E.). By Spanish contact, the population of 700,000 had terraced the majority of hillsides and drainages (Cook and Borah 1968; Romero Frizzi 1996, 144; Perez Rodriguez and Anderson 2013).

A key moment of social and environmental crisis occurred immediately following European contact. As a result of conquest, epidemics, and colonial living conditions, the Mixteca Alta population plummeted from 700,000 in 1520 C.E. to 20,000 – 25,000 in 1620 C.E. (Cook and Borah 1968). Following military defeat, the *caciques* conspired with the Spaniards to exploit the *macehuals*. The Spanish imposed an *encomienda* system that required forced labor of the poor for the wealthy (*encomenderos;* Edinger 1996, 38). The Dominican order was also complicit in dismantling Mixtec religious institutions, including writing, music, and art. Urban settlements were relocated from hilltops to valley floors, following the European model of urbanization (Perez Rodriguez and Anderson 2013). Farmers from the highlands who had maintained terrace systems resettled to the lowlands, abandoning their terraces to the process of erosion (Pastor 1987).

The post-Conquest periods (Colonial, historic, and modern times) introduced silk and cochineal pigment production, as well as by animal husbandry (Romero Frizzi 1996, 157-158). Crops such as wheat were introduced, along with the Egyptian plow.[1] Terraces were widened or removed to accommodate animal traction (Perez Rodriguez and Anderson 2013). These changes reduced the need for agricultural labor, which contributed in their own ways to ecological degradation in the Mixteca Alta.

[1] For a fascinating description of Egyptian plows used in Oaxaca, as well as the sophisticated indigenous science that goes into their design, see González 2001.

With the resettling of farmers to urban centers, the abandoned common lands were further claimed by the Spanish *encomenderos*. As populations recovered following the Colonial period, the Mixteca Alta experienced land privatizations and concentrations that undermined the Spanish rules of common land use (*cofradía*) in the last quarter of 18th to end of 19th century (Pastor 1987). Through this process, societies stratified into three main classes:

- indigenous landlords (still referred to as *caciques*) who held most private land;
- merchants who linked indigenous communities to regional and national markets; and
- large numbers of poor indigenous who had few assets.

The rich landlords concentrated economic and political power and influenced the labor of poor Mixtecos through necessity and debt mechanisms (Pastor 1987). Goat rearing and maize production were distinguishable in their management dynamics during this period. Goats were grazed on common lands that were increasingly under the control of the wealthy. Commons were overgrazed by the herds of the wealthy minority who were seeking cash profits (García-Barrios and García-Barrios 1990).

In contrast, maize production was the basis of the internal moral economy of communities. Those poor families would exchange loans of maize for their future labor (García-Barrios and García-Barrios 1990). This encouraged the recuperation of fragile lands, which were subsequently sown with cajete system as a means of absorbing abundant labor. The surplus production of maize beyond the community's need was unnecessary given high transportation costs for maize (Pastor 1987). Therefore, the sustainable production of maize occurred due to incentives to be self-sufficient in maize at the community-level, as well as its limited marketability, the capacity of the wealthy to absorb local labor, and the interests of the wealthy in labor-intensive agricultural technologies that they controlled through social requirements (García-Barrios and García-Barrios 1990).

Ecological recuperation was initiated in some parts of the Mixteca during the 18th and 19th centuries as social stratification peaked in the lead up to the Revolution of 1910 when the tensions between rich and poor would finally be expressed (García-Barrios and García-Barrios 1990). By that time, terraces had been once again recuperated and lowlands drained for agricultural production. Unfortunately, the removal of wealthy from power was not accompanied by the replacement of a viable alternative for rural communities to sustain local maize economies beyond self-sufficiency at the family-level.

1.3 Modern Times

Market integration of the Mixtec people in the 20th century at ever greater spatial scales has provoked a crisis of local labor and has weakened indigenous institutions that in other times induced sustainable resource management either through coercion or consensus (García-Barrios and García-Barrios 1990). Edinger (1996, 58-121) tells in rich ethnographic detail of how Mixtec farmers were inserted into a global economy against their will and in spite of their active resistance. In the Mixteca, this occurred due to devastating soil erosion and exploitation through history, as well as the undercutting of local economies from outside forces. Increasingly, divided economies have developed between local agriculture aimed at family self-sufficiency in combination with paid labor. In comparison to the labor extraction of 500 years ago, modern labor relations have become more complex in that they do not cover all of the farmers' needs (Edinger 1996, 32), nor do they occur within the same geographical regions.

Following the revolution of 1910, greater family autonomy also eliminated security measures for poor families. These measures had been embedded in social norms of reciprocity, but also unjust social relations, such as as income inequality, indebtedness, and even slavery. However, with the disintegration of such labor relations and the introduction of anti-agricultural and anti-farmer government policies at national levels, outmigration from the Mixteca Alta began in the 1930's (García Barrios, García Barrios, and Álvarez-Buylla 1991, 69-83). Early destinations included the coastal sugar plantations of Veracruz. With the opening of the Pan-American Freeway in 1945, migration extended to Puebla and Mexico City. Thus, monetary remittances from family members to communities in the Mixteca Alta have produced a somewhat contradictory lifeline between the *campesino* and wage-labor lifestyles that continue to the present.

García-Barrios and García-Barrios (1990, 1569) argue that "rural development that increases the integration of poor peasants into organized labor and commodity markets has eroded or destroyed those sociotechnical institutions through which conservation or productivity-enhancing technology could be engendered." Industry and urban-focused capitalist development throughout the Global South have greatly impacted local rural economies (De Janvry et al. 1986). García-Barrios and García-Barrios (1990) argue that rural underpopulation in the Mixteca Alta is tied to ecological disruption and agricultural crisis. They also recognize that local governance bodies responsible for resource management have failed to stem environmental degradation.

The absorption of labor from rural areas has drastically changed the local availability of labor, land, and resources. García-Barrios and García-Barrios (1990) describe the complex interactions between decision making of the collective and of individual households; the decision by a family to migrate may be the result of rational collective decision making at different levels (family, kin, or community), but also may be an act of necessity, authority, or independence by individual families (Murray 1987). Exogenous shocks that affect kin and community relationships often provoke individual or familial migration, thus increasing the amount resources for those who remain and chaning local economies of labor (García-Barrios and García-Barrios 1990).

Despite better access to modern technologies and access to more arable land per family, farming has suffered from environmental degradation and stagnation primarily due to rural labor shortages. In the Mixtec municipality of San Andrés Laguna where García-Barrios and García-Barrios (1990) conducted their research, they found that sustainable agricultural practices were lost with patterns of migration that redefined local resources as land was abandoned, thus increasing land management per household due to land sharing and share-cropping, decreased population numbers and household sizes, and highly monetized production and consumption patterns.

The transfer of the local maize economy from community-level self-sufficiency to the level of the family has had serious consequences for indigenous resource stewardship: "*... households will exert pressure to increase their resource productivity of maize or reduce their costs of production only to the extent that these resources are liberated for other uses, and not to increase the total production of maize.* Beyond assuring family self-sufficiency, the costs of acquiring and organizing the cooperative powers of labor will be avoided" (García-Barrios and García-Barrios 1990, 1578). This provides a counter-argument to the assumption of smallholder farming systems that "the holding is so small that if some members ... obtained other employment, the remaining members could cultivate the holding just as well" (Lewis 1954, 141). Historically, large rural populations were required to sustain the labor and technical requirements of agriculture. The combined effect of a reorganized local labor relations into smaller units and the disintegration of social safety nets resulted in incentives for poor families to shed their excess labor to industrial and urban centers. "... contrary to Lewis' predictions, development that first created and then destroyed surplus labor induced the decay of agricultural productivity and sustainability because of the collapse of rural institutions" (García-Barrios and García-Barrios 1990, 1581).

In this social context, farmer knowledge has been reduced to a means to accommodate environmental degradation and labor scarcity; the remnants of past sustainable farming systems that persisted were those that required the minimum amount of resources to produce acceptable outcomes (García-Barrios and García-Barrios 1990). Agriculture was focused on the fields closest to the homesteads while more distant parcels were relegated to herding or simply abandoned to erosion. Community-level projects, even those with government financial backing, often failed due to a lack of long-term commitment. Farmers avoided investing in their production systems, such as the construction of water containers and irrigation systems in rainfed regions.

Maize production was thus affected by labor shortages and social disintegration in three ways (García-Barrios and García-Barrios 1990):

1. suppressed yields due to reductions in the number of cultural practices in maize production;

2. lower quality work from paid labor subsidized by remittances; and

3. agronomic changes, such as incorporation of tractors but with limited diffusion of modern technologies and without increased land productivity (Masera Cerutti 1990).

Farmer knowledge for sustainable agriculture would appear to require specific social and economic conditions to flourish. This narrative provides a historical perspective to interpret current realities facing small farmers in the Mixteca Alta region. Agroecology as a path to the more resistant and resilient food systems to climate change – or other process of global change – will inevitably confront complex social, economic, and historical legacies. Chapter 2 deepens this discussion about farmer knowledge and farming systems in the Mixteca Alta. I characterize local family economies and farming systems to validate the importance of farmer knowledge in processes of adaptation to climatic variability. However, this is only the first part of my argument; Chapter 3 shows the importance of community action and social organizing to achieve more sustainable food systems.

Chapter 2

Farming Systems

Small farmers face challenges posed by climate change, industrial agriculture, and globalization. These issues intertwine cause and effect to shape the major environmental and social challenges of the Mixteca Alta today. Along with its eroded landscape and high rates of outmigration, the Mixteca Alta has experienced low annual rainfall with high interannual variability (Liverman 2000; Boege and Carranza 2009, 90-95). In this context, the future of the largely self-sufficient small farmer, or *campesino*, appears uncertain.

Meteorological extremes, such as drought and flood, are natural phenomena whose impact is socially mediated (Endfield, Fernández Tejedo, and O'Hara 2004). Such events are recorded in peoples' psyche and in historical annals more by the impact that they have than by their absolute magnitude. The community stores of capital – whether biophysical, human, social, or economic – provide communities with the capacity to cope, recover, and even anticipate climatic perturbations. Thus, the impacts of meteorological events are mitigated by adaptation strategies and institutional capacity. In the case of agriculture, farmers' experiences with meteorological fluctuations in some cases may lead to sophisticated adaptation strategies.

Projections of anthropogenic climate change predict that the magnitude and frequency of climatic variability will increase into the future. Researchers expect shortened growing periods, decreased water availability, and poor vernalization that globally will result in a 10% decrease in yields by 2080 due to climate changes (Parry, Rosenzweig, and Livermore 2005). The same authors warn that, "These results suggest we should be looking not just to avoid a warmer world, but also looking for ways to adapt to a more uncertain world where in certain regions the risk of crop failure on a year-to-year basis is likely to increase." Rainfed agriculture is affected by the concept of climate marginality, that small changes in mean temperature or rainfall due to climate change will be felt by an increased frequency or magnitude of potentially disastrous climatic events (Wigley 1985).

Farmers that depend on rainfed agriculture in Mexico experience crop failures due to numerous climatic factors, but especially drought (Eakin 2000). These dynamics are important to consider since indigenous farmers in Mexico manage the majority of arable lands approximating 5 million hectares (Hernández Xolocotzi 1988). It is also estimated that 72%

of rural properties are managed by subsistence farmers who supplement their income with off-farm labor (UN and ECLAC 1982). Crop failure due to climatic variability affects food security for the rural poor in the absence of social safety nets.

While a comparison between farmers' recollections of past climatic events and the climate record is discussed in Chapter 3, the sections that follow present the social and biophysical context of farming in the Mixteca Alta. This is especially important given the immensity of challenges facing rural communities, as well as the source of perseverance grounded in farmer knowledge. I describe the social and biophysical requirements of cropping systems throughout this chapter. More specifically however, I explore causes for the shift from cajete maize and animal husbandry towards other seasonal crops. Have farmers' explanations for changes in their farming affected their vulnerability to climate? The diversity of rural livelihood activities may affect how well families cope with climatic variability.

2.1 Methodology

I interviewed farmers in two communities that presented interesting case studies of traditional agriculture, climate dynamics, and changes in farming practices. I lived for over a year in the municipality of San Miguel Huautla (Huautla), in the neighborhood of El Rosario. Huautla was appealing as a study location for several reasons. Its small geographical extent was easily navigable for a newcomer. Moreover, it was a relatively well-populated territory in comparison to others. Municipal authorities estimated that approximately 300 families resided in the municipality. Despite its small size, Huautla encompassed a wide elevational gradient with diverse soil types that provide the environmental conditions for diverse agroecosystem typologies. More specifically of interest from an academic perspective, farmers suffered a serious drought from 2005 – 2009 that all but forced families to rely on wheat over maize for their tortillas, with many losing their indigenous maize landraces.

The second community studied, San José Zaragoza (Zaragoza), belongs to the much larger municipality of Santiago Tilantongo. This municipality was made famous by the ancient ruins of Monte Negro, the center of political power for the Mixtec Empire in eras gone-by (from ca. 500-200 B.C. until Conquest; Balkansky, Rodríguez, and Kowalewski 2004), and whose remains perch in the mountains above Zaragoza. This community was comprised of an estimated 25 families with in a territory with fewer distinct agroecosystems. The small neighboring community of San Isidro was combined with Zaragoza to include families who grew cajete maize. I included Zaragoza in this study because of farmers' comparatively greater reliance on tractor technology, and because of the greater amounts of rainfall – according to farmer testimony – that Zaragoza had received in the last decade compared to Huautla. Unlike Huautla, Zaragoza farmers succeeded in maintaining their seasonal maize landraces for generations, and they considered each family to steward unique varieties. For these reasons, I anticipated that the two communities would provide contrasts in terms of market integration and vulnerabilities to climate.

Following the methods used by Eakin (2006), I initially aimed to interview a representative sample of three groups of farmers in each community:

1. families that primarily grew seasonal crops;
2. families that in addition to seasonal crops grew cajete maize; and
3. families that in addition to seasonal crops tended large herds of animals

After six months of field work, it was obvious that a lot of crossover existed between these groups (Figure 2.1). While the majority of the interviews described similar realities of agrarian life in the Mixteca Alta, some differences were captured between the communities and those families who grew cajete and those who did not.

I conducted twenty-nine in-depth interviews, each lasting between two and three hours, sometimes spread over multiple days. The interviews represented an estimated 10% of Huautla's households and 30% of Zaragoza's households. Interviews were semi-structured. I used a list of guiding questions (Appendix A.1) and a large sheet of paper (Appendix A.2) to direct the course of the interviews. However, I asked questions differently in every interview and allowed our conversation to evolve naturally. Farmers requested that I simply took notes of our conversations rather than record them. In different cases, I interviewed men or women of the household, or both simultaneously (Table 2.1). In certain circumstances, I interviewed men instead of women due to local gender norms.

Table 2.1: Number of interviews with male and female respondents, as well as those that were conducted jointly with both men and women of the household, in the communities of Zaragoza and Huautla (n = 29).

	Male Respondent	**Female Respondent**	**Joint Interview**
Zaragoza	5	3	2
Huautla	13	3	3
Total	18	6	5

While I was unable to accompany or observe the farming activities of every family whom I interviewed, I did contribute to daily activities of my host family in Huautla, such as sowing the *milpa*, broadcast sowing peas, harvesting wheat, collecting corn smut (*huitlacoche*, *Ustilago maydis*), slaughtering animals, steaming tamales, etc. I attended family gatherings, religious and cultural events in the communities, though they were not the subject of my research. I also documented the production of seasonal maize by 18 farmers from 2009 – 2010 as part of concurrent research. In exchange for farmers' time, I agreed to return Spanish-language reports from the interviews to their agencies and municipalities.

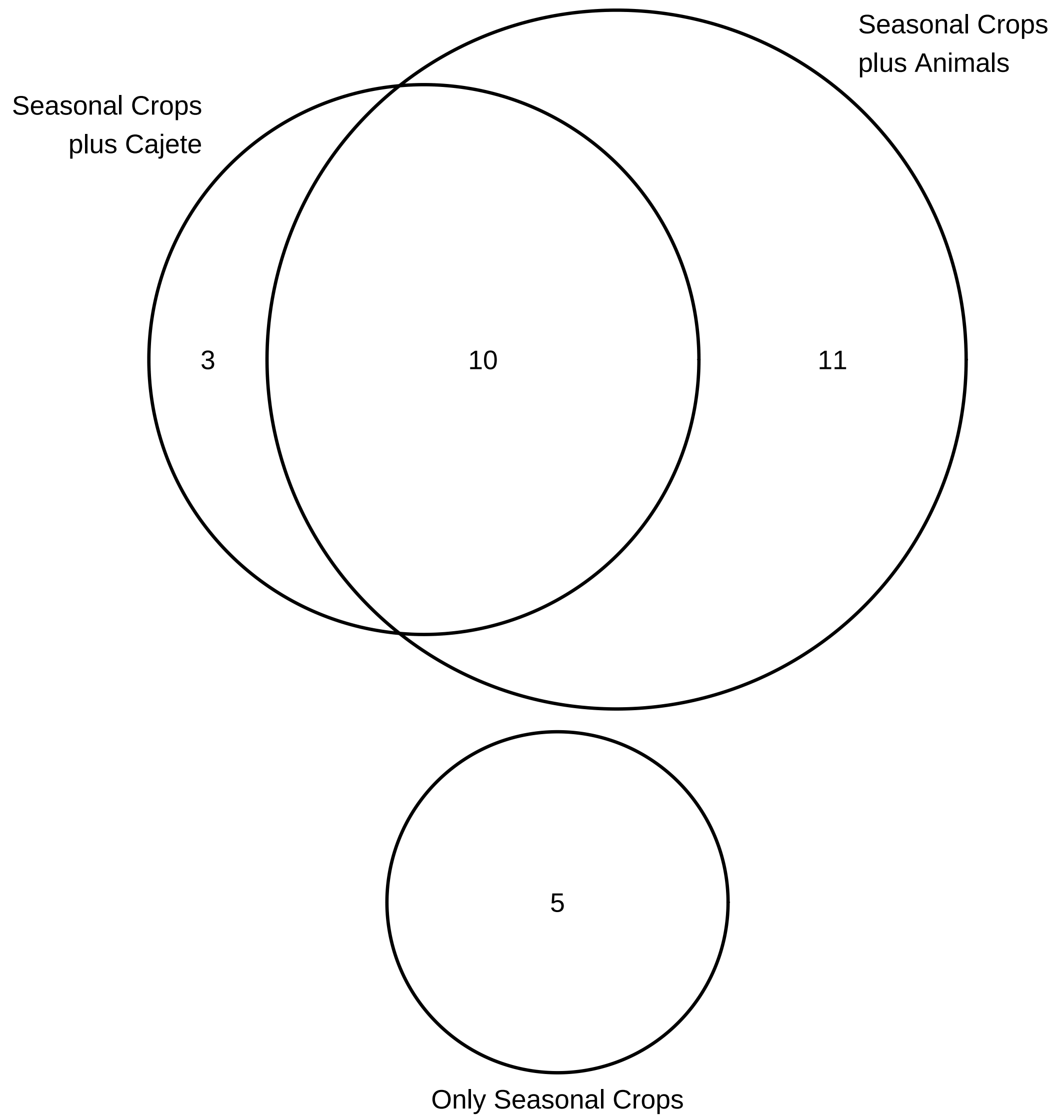

Figure 2.1: The number of families interviewed in Zaragoza and Huautla who only grew seasonal crops (*cultivos de temporal*), who grew cajete maize (*maíz de cajete*) in addition to seasonal crops, and those who raised goats and sheep in addition to seasonal crops (n = 29). Note that all families grew seasonal crops, and the sizable intersection of 10 families who grew cajete maize and raised animals. Circles are to scale.

Respondents are referred to – as any primary source should be – by their code in footnotes: the first letter of the code represents the community (*Z* for **Z**aragoza and *M* for San **M**iguel Huautla); the second letter refers to their classification (*T* for Seasonal [***T****emporal*], *C* for **C**ajete maize, and *G* for Animals [***G****anado*]); and the third letter refers to the alphabetical order in which respondents were interviewed within each community and each category. It should also be noted that all respondents in the *Animals* category were producers of seasonal crops, and not cajete maize. All families in the *Cajete* category grew seasonal crops, and some also practiced animal husbandry.

2.2 Results

Household dynamics

Household structure

The household was the basic unit of comparison in this research (Table 2.2), which reflected what anthropologists refer to as "the domestic mode of production" (Sahlins 1972; Meillassoux 1981; Edinger 1996). According to Edinger (1996, 31), the household unit was clearly defined in Mixtec culture where certain households worked together and others did not. This corresponded to descriptions of households by respondents: close relatives living in proximity to one another (in the same home or hamlet) and sharing common resources (land, animals, agricultural products, monetary income, etc). Median household size in Zaragoza (n = 10) and in San Miguel Huautla (Huautla; n = 19) was 5 individuals. The median age of households interviewed was much younger in Zaragoza (19 years) than in Huautla (35 years), due to a larger percentage of families with children living at home in Zaragoza. While households with children had a median of three children in both communities, 89% of households interviewed in Zaragoza had children living at home compared to 68% in Huautla. Additionally, only 10% of households in Zaragoza had children who lived in the same community compared to 37% in Huautla. Forty percent of families in Zaragoza had children living outside of the community, compared to 68% of families in Huautla.

Table 2.2: Household demographics in Zaragoza and Huautla, including median household size, median household age, percentage of households with children, and median number of children per household with children.

	Median # of People	Median Age	% with Children	Median # of Children
Zaragoza	5	19	90%	3
Huautla	4	35	36%	3

Territory

The indigenous territories of Zaragoza and Huautla were jointly governed by indigenous and Mexican federal institutions. This parallel management was reflected in land tenure. Sixty-seven percent of respondents in Zaragoza and Huautla farmed communal lands (*comunal*), while only 33% held private property titles (*pequeña propiedad*, Table 2.3). Those in Huautla with land under both denominations built their homes on *pequeña propiedad* while they farmed their communal lands.[1] Borders between parcels were delineated by the recognition of neighboring parcels (*colindantes* and *posesiones*), which were enforced by the local land commission (*Comisariado de Bienes Comunales*).[2]

Table 2.3: Percentage of respondents with lands held under *Comunal* and *Pequeña Propiedad* titles in Zaragoza (n = 9) and Huautla (n = 15).

	Zaragoza	**Huautla**	**Total**
Comunal	77%	60%	67%
Pequeña Propiedad	22%	40%	33%

Remunerated labor

Farmers worked in activities with monetary compensation in conjunction with farming and animal husbandry. These included artisan wood carving,[3] bread baking,[4] masonry and carpentry,[5] agricultural labor, such as weeding and harvesting bean fields,[6] taxi driving,[7] and volunteer service to the communities.[8] Public works in communities sometimes provided employment, however these were not regular sources of income.[9]

Families typically built their own homes. Rarely did families hire members of their community, unless through non-monetary exchanges of labor based on reciprocity.[10] All respondents in Huautla dedicated themselves to weaving artisanal palm products, such as floor mats and sombreros. One respondent from Huautla recounted that she had very little when she married her husband and moved to his community.[11] At that time, the productivity of their farming and livestock was low. Their primary source of income was weaving sombreros. She alone wove four dozen sombreros per week. She would go to bed weaving around 11 pm and wake up around 3 am to grind the *masa*. As soon as cooking was done she returned to weaving. It wasn't until her children had grown that they began working together in agriculture and their yields increased. Over time they built their house and improved their standard of living.

[1] MTA, MTB [2] MTC [3] ZCA [4] ZCB [5] ZGA, MCA, MCF, MCJ [6] ZTA [7] MCI [8] MCC, MTA
[9] MCE, MCF [10] MTA [11] MCA

Working outside of the community

Households in both communities supplemented their rural livelihoods with work outside of their communities. However, the nature of this work differed significantly between households. I wished to understand the motivations for why some families chose to stay in their communities while others sought work elsewhere.

A handful of families had never emigrated from their communities. Only one household in Zaragoza had always stayed in their community, explaining that they lacked money to travel and that they preferred to dedicate themselves to artistic endeavors: "there is lots of work in the community. Many people prefer to work in construction [outside of their communities]. These people don't like the country or don't have enough land to farm. In the community, one can harvest everything. In the city, one must purchase everything."[1] In Huautla, 53% of households had never worked outside their community (9 households).[2] Similar to Zaragoza, respondents from Huautla cited their dedication to farming as a livelihood (7 households)[3] and to other artisanal crafts, such as palm weaving.[4] Some respondents expressed a deep sense of belonging to their community.[5] "This is our town. We are from here and do not want to leave."[6] Their land was an inheritance to be looked after.[7] Respondents felt a sense of responsibility to serve in their community's governance bodies[8] and to provide for their children's education and development.[9]

Still, 70% of families in both communities had children that worked or studied outside of their community. Several respondents in both Zaragoza (2 households)[10] and Huautla (5 households)[11] resided outside their communities, but had since returned. Respondents from Zaragoza had worked in Vera Cruz year-to-year and in Mexico City for extended periods.[12] One family lived for 20 years in Mexico City where the husband worked in construction, as a police officer, and as a soldier.[13] Similarly in Huautla, respondents had worked in Mexico City for decades in the Army, Auxiliary Police, and Federal Police.[14] Another household left their community from 1969 – 1980, first selling soft drinks in Río Blanco, then working in construction in Mexico City, followed by agricultural labor in the Mexican state of Sinaloa. These households left to work out of economic necessity[15] and little paid work in their communities.[16] In some cases, families left due to shortages of maize and beans[17] or to seek out new experiences (*buscar a la vida*).[18]

These families that had returned from work outside of ancestral communities expressed a preference for the rural lifestyle[19] and a desire to retire.[20] Some could not afford to sustain the urban lifestyle, since they had not received social security,[21] or would have burdened their children had they no longer been able to work.[22] They also expressed a spiritual desire to live and die on their own land. "It is for a naïve idea that we must be buried in our community as Huautecos."[23]

[1] ZCA [2] MCA, MCB, MCC, MCE, MCH, MGC, MGD, MTB, MTC [3] MCB, MCE, MCH, MGC, MTB, MTC, MTE [4] MCH [5] MCC, MGC, MTC [6] MCC [7] MTC [8] MGC [9] MGC, MTE [10] ZGA, ZTA [11] MCG, MCF, MCI, MTA, MTD [12] ZGA, ZTA [13] ZTA [14] MCG, MTA [15] ZTA, MCG, MCI, MTA, MTD [16] ZTA, MTD [17] ZGA [18] MTA [19] ZGA, ZTA [20] ZGA, MCG, MCI, MTA, MTD [21] ZTA [22] ZGA, MCG [23] MTD

A need to find work outside of one's community on a regular basis was expressed by 60% respondents in Zaragoza (6 households) and 21% of respondents in Huautla (5 households). The greater percentage of families from Zaragoza that temporarily left their communities for work may reflect better access to urban centers: travel between Zaragoza and the nearest urban center of Asunción Nochixtlán was 45 minutes on a paved road in comparison to 1.5 hours along dirt roads from Huautla.

Respondents described either leaving on occasion[1] or regularly each year.[2] Those that worked on occasion reported leaving for periods of weeks to months for Asunción Nochixtlán,[3] Oaxaca de Juárez,[4] Puebla,[5] Vera Cruz,[6] or Mexico City.[7] Often the motivating factor was a need for money,[8] and they would return to tend their fields and animals.[9] "Here I have my inheritance. I do not pay for a house, water, or wood. I like it here. There are seasons for mushrooms, *nopales*, and grasshoppers. We don't buy them. We live better and risk less. There are no car crashes and people don't go out to the streets. The work is natural and we eat no chemicals."[10]

When asked how farmers combined paid work with farming activities during good years, one respondent said that in general, members of their community work for 1 – 3 months in Oaxaca, Puebla, Mexico City, or the United States during poor years and sometimes they stop sowing, depending on the work that they find.[11] In Zaragoza and Huautla (n = 18), 61% of respondents reported combining paid work in bad years[12] while 22% of respondents reported families working in paid labor that was incompatible with farming[13] and 17% of respondents never combined paid labor with farming.[14]

Those who sought employment during poor years generally left for periods of 15 days to three months when there was less agricultural work in the communities. Respondents that worked every year found jobs within close proximity to their communities, such as harvesting beans or working in construction in Asunción Nochixtlán,[15] cleaning homes in Oaxaca de Juárez,[16] repairing freeways in Mitlatongo,[17] or working in construction in Mexico City.[18] The exact dates of departure and return varied, from 15 days after sowing in July[19] to after harvest in December.[20] Common months when outside work was found included October – November[21] or February – April.[22] Men typically went to work alone and the women tended their children and farming activities at home.[23] "It is very difficult," said one respondent. "We abandon the family."[24] Family members who were away the entire year would occasionally visit their community during holidays or come for longer periods when they decided to build a home.[25] Money was required to cover their children's educational expenses,[26] to make payments on agricultural fields,[27] and to supplement insufficient yields.[28] However, they maintained their rural livelihoods because they were able to largely provide for themselves[29] and to care for their animals.[30]

[1] ZCB, ZCC, ZTB, ZTC, MTE, MCJ [2] ZTD, ZTE, MCD, MCF, MGB [3] ZCB, MCJ [4] ZCB [5] ZTC [6] ZTB, ZTC [7] ZTC [8] ZCB, ZCC, ZTB, ZTC, MCJ [9] ZCB, ZCC [10] MCJ [11] MCG [12] ZCB, ZGA, ZTB, ZTC, MCA, MCD, MCE, MCF, MCI, MCJ, MGB [13] ZCC, ZTA, MGC, MGD [14] MCB, MTA, MTD [15] ZTD, MCF [16] ZTD [17] ZTE [18] MCD [19] MCJ [20] ZGA [21] ZTE [22] MCD, MGB [23] ZTC, MCD, MGB [24] ZTC [25] MGD [26] ZTD, MGB [27] ZTE [28] MCF, MGB [29] ZTD, MCD, MCF, MCJ [30] ZTE

Traditions and identity

Social norms of mutual aid between families and to the community were described by respondents as dramatically changed. Traditions of community service (*tequios*) and mutual aid between families (*guetza*) were reported to be less common in Zaragoza than in Huautla. In the case of Zaragoza, respondents reported that they did not do *tequios* anymore.[1] Monetary remuneration was expected for public works of the municipality.[2] Zaragoza families either worked independently,[3] or paid for help to accomplish agricultural activities (*mozos*).[4] However, between close relatives, traditions of guetza still existed.[5]

In contrast, both traditions of *tequios* and *guetzas* without monetary exchange were maintained in Huautla.[6] *Tequios* had diminished with the arrival of heavy machinery, which reduced the need for volunteer labor to the municipality.[7] However, the tradition had been recuperated for some projects, such as cleaning roads.[8] Families also helped each other for agricultural labor, particularly families who planted cajete maize.[9]

When asked what the identity of farmer (*campesina* or *campesino*) meant to them, respondents expressed sincere motivations for their work. Farming was a way of life that they knew and enjoyed.[10] "We like to farm. Leaving our country does not improve anything. We must stay to take care of our lands and fertilize them."[11] In contrast to urban living, "it is an honor. No one bothers us. There is no boss that tells us 'hurry up, it is getting late!' They always complain. Here, no one tells us anything."[12] They were proud to provide for themselves and their families (*es un orgullo*).[13]

Another group expressed farming as a skill set that had been cultivated since childhood, but that comes with its challenges. "I started to farm when I was young."[14] "Advanced technology is good, but skilled manual labor is also important as well."[15] "It is cattle, plow (*yunta*), machete, wheelbarrow, and carry rocks."[16] "It is our life. At best we do not have an education. The hope is to produce. It allows us to live."[17] "Some say we are hopeless, but we are resistant."[18] It was represented as a source of work[19] guided by natural cycles (*una vida girada por el tiempo*),[20] but also as a struggle against weeds[21] and a suffering only rewarded in years of good harvest.[22] To others, farming represented health and security. "We are healthy."[23] "It is good to eat natural things."[24] Moreover, they took care of their community and earned enough with their animals.[25] There was less worry about safety[26] and dependence on money.[27]

They also worked for their families and for their children.[28] Many hoped that their children would continue to make the land productive.[29] "If everyone goes to the city, what will we do?"[30] In contrast, others wished to provide their children with the means to pursue a professional career so that their lives would be different.[31] However, even if children were to find careers, one respondent believed, they would not forget what they had learned as

[1] ZCC, ZTC [2] ZTC [3] ZCB, ZTC [4] ZCB, ZCC, ZGA [5] ZGA, ZTC [6] MCB, MCC, MCD, MCG, MCH, MCI [7] MCC, MCG [8] MCC, MCD [9] MCH [10] ZCB, ZGA ZTD, MCA, MGD [11] ZCB [12] ZTD [13] MCC [14] ZCC, MTC [15] MCC [16] MCD [17] MTD [18] MTC [19] MCE, MGB [20] MCJ [21] MCB [22] MCF [23] ZTA, MGC, MTB [24] MGC [25] ZTB [26] ZTC, MCG [27] ZTC [28] MCH, MCI [29] ZCC, MCD, MCE, MTE [30] ZCC [31] ZTC, MCA, MCB, MTC

farmers in their youth.[1] They wished that their children would contribute their technical skills learned in school and professional sectors to improve their communities.[2]

Family economy

Migration and traditional agriculture

How does outmigration fit within the traditional farming culture of the Mixteca Alta? I describe the impacts on culture and economy of outmigration in the two communities. Respondents held mixed views about migration and work away from their communities.

As described previously on page 20, farmers left their communities out of economic necessity. Rural places were associated with a lack of economy (*falta de economía*)[3] and extreme poverty.[4] The youth increasingly moved away in search of new opportunities.[5] "The youth are better educated. In my time, Primary School was obligatory and now it is High School. For our parents, it was very difficult; they never went to school. Now the youth have a different vision. They leave the community out of necessity and poverty. The salaries in Huautla are too low."[6] People did not always leave willingly.[7] The youth wished to obtain the means to purchase parcels of land in their communities or to support their families.[8] Agriculture was the primary livelihood in the communities, although "those who don't have much must go to work to buy their maize."[9] For some there appeared no other choice but to find work, despite the poor treatment and low pay that they often received.[10]

The life stories of respondents and their children reflected a commitment to improve their standing in their communities. One respondent explained that his children left due to a commitment to their new families: "they married and were obligated to leave. They are thinking of gathering some money and returning to their community."[11] As in the case of one respondent, tired of Mexico City (*nos enfadamos*), he purchased two parcels in their community and built a house.[12] While some respondents viewed this process of outmigration as always having existed, the rate of departure placed a constraint on agricultural activities: "we are few that remain" (*somos pocos aquí*),[13] and those who did stay generally were the elders.[14]

While some community members left with the intention of returning, many became established outside of their communities. Educational opportunities and careers ensured that families would not return.[15] "Our children that left already have their families. They will not return. How would they maintain their families?"[16] Another respondent admitted, "our older children are already used to living away from the community and probably will not return."[17]

Different visions of what constituted a good life colored interpretations of migration by farmers. While to some outmigration "sustains life"[18] and was to "live well,"[19] others described its deleterious impacts on families and community. "I find it sad. My daughter deceived me when she went to the United States. She got the idea to go with a friend and

[1] MCC [2] MTE, MCI, MCJ [3] MCB [4] ZTA, MGD [5] MCH, MTB [6] MGD [7] MCC [8] ZGA [9] ZTE [10] MCD [11] MGD [12] MTA [13] MGD [14] ZTA [15] MGC [16] ZTA [17] MCJ [18] MCI [19] MGB

they said that they were visiting my daughter in Oaxaca [de Juárez], and then they just left. The poor hand always fills the pocket of the rich (*la mano pobre siempre llena la bolsa de los ricos*)."[1] She interpreted her daughter's labor in the United States as a fruitless contribution to her foreign employers. From the perspective of this respondent, everything was gifted in their community and they had all that they required. In contrast, life in the city was very hard since everything was purchased.

Taking shelter in the shadow of commodified labor structures was not without consequence for rural places and farming practices.[2] Often, people sacrificed their best management at home to work for employers.[3] "Abandoned fields with time become degraded and unproductive. Fields that become poor are abandoned while sometimes those that are good still are rented."[4] Another respondent expressed a similar sentiment: "It is very hard. We are left alone. Everything is abandoned... the harvest, people's homes. When fields are abandoned, they become eroded. Yes, we can pasture them, but we can only grow food with permission, normally sharecropped (*a medias*). When fields are abandoned, the soil goes with the rains. Crops don't grow."[5] In other words, cultivated lands suffered less erosion when cared for by farmers than when they were abandoned from one year to the next. Thus the already erosive processes were accelerating in the Mixteca. See page 27 for more on how farmers interpreted rainfall patterns and their impacts on soil conditions. Seemingly, existing social mechanisms did not adequately provide a continuity of management.

Changes in farming practices were also associated with outmigration. Some families abandoned animal husbandry since their children became established outside the community,[6] or left every year to work.[7] Young children typically went to school during the week and tended animals on the weekends.[8] "If our children go, we cannot take care of the animals. It would not be the same to sow. Right now we do not purchase meat to eat, but if our children did go, we would have to start purchasing meat."[9] In the case of one family, their labor was reduced from six to three individuals, which constrained what they could accomplish at home.[10]

The loss of animal manures produced a dependence on synthetic fertilizer to maintain agricultural productivity. Soils dependent on synthetic fertilizers became less productive (*no producen como antes*).[11] Families without enough to eat now purchased their food, but also chemical fertilizer. Respondents recognized the importance that human labor played in their agricultural systems.[12] When families whose children had left did not return to the community, elders sharecropped their harvest (*a medias*) in exchange for the labor of other community members.[13] This was not without consequence however, as described on page 36.

While the impacts of aging populations, reduced labor, and social disintegration affected local communities, respondents understood the risks that faced migrants. The common expression of searching for a life (*buscar a la vida*) was not always found. Migrants encountered economic opportunity, but also failure. People left their communities to find something to bring back with them, but if they did not find work, it was a net loss.[14] This uncertainty was

[1] MCC [2] see García Barrios, García Barrios, and Álvarez-Buylla (1991, 211) for a discussion on the political and economic forces driving this trend [3] ZTD, MCD [4] ZCA [5] ZTC [6] MTC [7] MCD [8] MCF [9] MCC [10] MTD [11] MTD [12] ZCB [13] MTC [14] MCF

expressed by several individuals as "adventuring their luck (*aventurar su suerte*)".[1] "When migrants go far away, their objective is to improve their conditions, but sometimes this is not possible. They fail and must return to where they were before."[2] "They say that it is to find a livelihood (*encontrar a la vida*) but they end up not finding work"[3]

To some, working closer to their communities while continuing their farming presented greater security than moving long distances. "I have preferred to only leave for short periods of time and continue my farming. We conform to the little that we have. When we go, we must pay other people to do the work that we would normally do."[4] The additional cost of finding neighbors to work in the migrant's absence accentuated the risks that farmers faced should they choose to leave their communities for extended periods.

In contrast to the communities where there was more security and tranquility (*no pasa nada*), other regions were perceived as complicated and dangerous.[5] "We never know what might befall us when we go."[6] These sentiments were validated by personal experiences of family members. "It makes me sad. Four of my brothers are in California and they are treated very poorly. For me, I would not go to the other side (*el otro lado*). I would prefer that they returned."[7] The severity of the situation for migrants was escalated to risking one's life (*peligrando a la vida*).[8] Besides the poor treatment and risks that faced migrants, concern for a host of temptations were expressed as "finding the easy life of drugs, prostitutes, and alcohol."[9]

Despite the dire economic situation facing farmers in the Mixteca Alta, hopefulness was very much alive. Respondents said that there were healthy foods and lifestyles in their communities.[10] "What will we eat if we go? We have to work every day. I have a daughter who is a doctor. She goes to work early and there is no rest. Here, once the harvest is in, we can relax. There is a need for money, that is all."[11] Respondents dreamed of receiving support from their governments to build rural industries[12] or simply finding alternative sources of income.[13] One respondent described her small store (*tienda*) like a bank where she invested money when she had it and got money back when it was needed.[14]

Remittances

Much literature cites the importance of the economic resources sent home by migrants, known as remittances, for maintaining families and communities in rural Mexico. To discuss topics of family income, I inquired into support families received from individuals living outside of their communities, as well as other income streams.

Surprisingly, the interviews conducted in the two communities suggested a limited role of remittances, most commonly in small amounts, non-monetary forms of exchange, or for emergencies. Surprisingly, 50% of respondents in Zaragoza and 36% of respondents in Huautla reported not receiving remittances. One respondent explained that each family member

[1] ZCB [2] ZCB [3] MCC. While I recall this quote as such, native Spanish speakers suspect the phrase was "earn a living (*ganarse la vida*)." [4] ZCB [5] MCG [6] ZCC [7] ZTD [8] MTA [9] MCC [10] ZTB, MGC [11] ZCA [12] ZTB [13] ZCA, MCA [14] MCA

earned their own income.[1] Another described how lost remittances in the mail had led their family members to stop sending money.[2]

Thirty percent of respondents in Zaragoza and 47% of respondents in Huautla received economic resources from family members. Only two respondents indicated that remittances of $1,000 – $5,000 pesos per year were significant contributions to the family[3], or that they received regular remittances[4]. The majority of respondents who did receive remittances described them as minimal,[5] intermittent,[6] or for emergencies.[7] One respondent explained that they received only small remittances every 1 – 2 years because their children who had migrated were now supporting their own families.[8] For some families, remittances came in the form of exchange: their children sent clothing and shoes and received a portion of the annual harvest to take back with them to Puebla.[9] Several respondents also received non-monetary support in the form of clothes and shoes, at most 2 – 3 times per year.[10] In two cases, respondents qualified that they only received support during family illnesses.[11]

Government assistance

The large majority of respondents in both communities receive assistance from three programs of the Mexican federal government's Secretary of Social Development (*la Secretaría de Desarrollo Social*, SEDESOL): *Pensión para Adultos Mayores* (referred to as *Tercera Edad*), *Programa de Apoyos Directos al Campo* (PROCAMPO), and Oportunidades. Only one respondent had not received support from these programs. She expressed, with a sentiment of unfair treatment, that "the government always ignore us. They say I don't need it because I go to work."[12] Several families that were interviewed received support from Tercera Edad, a program for senior citizens. Twenty percent of respondents from Zaragoza and 21% of respondents from Huautla received payments through Tercera Edad. The median annual payment reported through Tercera Edad was $6,000 pesos (n = 4).

Sixty percent of respondents from Zaragoza and 42% of respondents from Huautla participated in PROCAMPO, which aimed to improve "high production maize" (*maíz de alta producción*).[13] The median area registered with the local land commission (*Comisariado de Bienes Comunales*) for the PROCAMPO program were 2.75 hectares (n = 12). These farmers had, for the past fifteen years in some cases,[14] received annual payments that subsidized agronomic inputs, such as synthetic fertilizers. In 2010, the median annual payment to respondents was $3,600 pesos. In 2011, the farmers interviewed anticipated that they would receive synthetic fertilizer directly rather than cash payments. More investigation would be needed to determine whether this was PROCAMPO's official policy.

While PROCAMPO aimed to increase agricultural productivity, the program Oportunidades focused on family wellbeing. Women heads of household received payments every two months to subsidize children's school expenses and food purchases. Sixty percent of families interviewed in Zaragoza and 74% in Huautla respondents participated in Oportunidades.

[1] MCD [2] MGB [3] MGD [4] MTD [5] MCG, MCJ, MGC, MTA, MCJ [6] ZGA, ZTB, ZTE, MCI [7] MCC, MCJ [8] MCG [9] MGC [10] ZTE, MCE, MCI, MGC [11] MCC, MCJ [12] ZTD [13] ZCC [14] MCJ

Mothers received a median of $5,400 pesos per year through Oportunidades. Participation in health clinic workshops and in the schools was required to receive funds from this program.

Family expenditures

While the majority of respondents use the payments that they received through PROCAMPO on fertilizers, tractor rentals, farm labor (*mozos*), and pesticides,[1] Tercera Edad and Oportunidades supplemented other revenue sources, such as crafts, for basic household expenditures. These included items such as purified water, soap, salt, bread, oil, chile, milk, meat, and garlic.[2] They also were used to pay for electrical bills, trash collection, clothing, shoes, medical expenses, and educational supplies.[3]

Few respondents reported that they did not purchase any food,[4] or that they decreased their purchase of food items during poor production years.[5] The majority of respondents said that they did not change their purchase of food items in poor production years,[6], while another large group reported increasing the purchase of basic grains in poor production years.[7] Families purchased grains from other community members,[8] intermediaries,[9] state-subsidized stores within the communities,[10] or from the Sunday market in Asunción Nochixtlán.[11]

Interpreting climate

Good and bad years

The following section builds on the characterization of family economies and social dynamics to discuss the pressing issue of how climate affected respondents' farming practices. Respondents described what to them represented good and bad years. I then asked several questions that aimed at understanding how farmers interpreted past years, how their farming had changed based on good or bad years, and how their family economies accommodated these fluctuations.

Respondents defined good years in terms of different parameters of crop yield and weather. Crop yields defined good years for 80% of respondents in Zaragoza and 53% of respondents in Huautla. Of these, 44% of respondents described a good year as when they harvested all that was sown.[12] "In a good year we harvest green beans, squash, dry beans, and maize,"[13] and "a good year is when we harvest a little of every crop."[14] Twenty-eight percent of the respondents who associated good years with yield described them in terms of specific crops: maize and beans,[15] maize and wheat,[16] and maize.[17] This reflected differential sensitivities of these crops to adverse climatic conditions, as well as the agroecological principle that diversifying production minimizes vulnerability to crop failures. Twenty-two percent of the

[1] ZCC, ZGA, ZTA [2] ZCA, ZCB, ZCC, ZGA, ZTB, ZTE, ZTF, MCB, MCD, MCE, MCG, MCI, MCJ, MGB, MGC, MTA, MTB, MTC [3] ZTA, ZTC, ZTD, MCC, MCF, MCH, MGC, MGD, MTB, MTD, MTE [4] MTC, MTD [5] ZCA [6] ZCB, ZCC, ZGA, ZTC, ZTD, MCA, MCC, MCD, MCE, MCG, MCF, MCH, MCI, MGA, MTA [7] ZTA, ZTB, ZTE, ZTF, MCB, MGB, MGC, MTB, MTE [8] ZTA [9] MCB, MGC [10] MCB, MGC, MGB [11] ZTB [12] ZCB, ZCC, ZGA, ZTB, ZTE, MCB, MCI, MGC [13] ZGA [14] MCB [15] ZCA, ZTA [16] MGA [17] MTA, MTB

respondents who referred to crop yield defined them as sufficient grain to feed their families through the entire year.[1] Only one farmer reported that a good year was when they produced enough to sell.[2]

Good years were also associated with the climatic conditions by 40% of respondents from Zaragoza and 37% of respondents from Huautla. Within these, 64% described a good year as evenness and moderation of rainfall during the growing season.[3] "In a good year rains come, but separate from each other. There are breaks in rain and the soil recuperates."[4] The farmer meant by recuperation that soil moisture would fluctuate enough to allow for soil cultivation and to allow oxygen to reach the plants' roots. This relates to soil characteristics, which are discussed further on page 34. Low frost damage at the end of the season was listed by 27% of respondents as characteristic of a good year.[5] Nineteen percent of those who mentioned climatic factors specified that the early onset of the rainy season indicated a good year.[6] This pointed to the shortening growing season in recent years. The few farmers that had access to irrigation from streams and rivers were better able to produce despite climatic problems.[7]

Similarly to good years, bad years were distinguished in terms of yield, climatic factors, and economic considerations. Fifty percent of respondents from Zaragoza and 15% of respondents from Huautla cited yields as their measure of bad years. Within these, 75% of respondents[8] described a bad year as when "only vegetation grows," or "we don't harvest." In bad years "our investments are wasted," and "there is not maize, beans, or money. We only recuperate from them by selling our animals." Animal husbandry thus was a diversification strategy for recuperating from poor years. Twenty-five percent of the respondents who measured bad years in terms of single crop failures: "Bad years are when we don't harvest maize,"[9] and "beans are very tricky because they are sown during the *canícula*. If the soil is still moist, the cattle-drawn plow (*yunta*) compacts the soil as they walk and the beans do not develop."[10] See page 30 for a description of the *canículas*.

Forty percent of respondents from Zaragoza and 63% of respondents from Huautla described bad years in terms of climatic conditions. Of these, 63% of respondents referred to either drought or heavy rainfall patterns causing bad years.[11] Most respondents cited the inability to conduct the necessary labors as resulting in poor crop growth and harvests.[12] Others specified that the late onset of rain would delay soil cultivation and the sowing date.[13] Forty-three percent of respondents who described bad years in terms of climate referred to a broader spectrum of misfortune (*lamenta*),[14] weather, insects, and disease.[15] "It either doesn't rain or it rains too much and the crops rot. Sometimes frosts happen when the *milpa* cobs are maturing, or they get hit by fall armyworm (*gusano cogollero*, *Spodoptera frugiperda*) or white grubs (*gallina ciega*, *Phyllophaga* spp)."[16]

Ten percent of respondents from Zaragoza and 21% of respondents from Huautla included in their description of bad years the necessity to purchase grains.[17] In Huautla, where the supplemental economy to farming was weaving palm, farmers classified bad years as those

[1] ZTA, ZTD, MTE, MGB [2] MTD [3] ZGA, ZTC, ZTE, ZTF, MCA, MCF, MGD [4] ZTF [5] ZTE, MCF, MCJ [6] MCG, MCH [7] MTC [8] ZCA, ZCB, ZCC, ZGA, MCD, MGC [9] ZTA [10] MTA [11] ZTB, ZTC, ZTF, MCE, MCG, MCH, MGB, MGD, MTA, MTE [12] ZTB, ZTC, ZTF, MGB [13] MCE, MCG, MCH [14] MCI [15] ZTE, MCB, MCE, MCF, MCJ, MCI, MTB [16] MCJ [17] ZTD, MCA, MGA, MCJ, MCF

when they were forced to weave in order to buy their maize.[1] One respondent from Huautla defined a bad year as one when they were unable to sell grains.[2] Only a few respondents were self-sufficient in grain, even in poor years.[3]

I asked respondents how many out of the past ten years they considered to be good or bad. Even though farmers cultivated approximately the same area in Zaragoza (3.5 hectares) and Huautla (3.6 hectares), the median response for Zaragoza was 7 good years in the past 10 (n = 10), compared to the lower 5 in Huautla. This reflected a more extreme series of drought years experienced in Huautla compared to Zaragoza in the last decade.

Some respondents also cited examples markedly difficult years. In the case of Zaragoza, 2010 was the most often cited poor year.[4] "2010 was a very hard year. We had to buy wheat, beans, and maize. We spent a lot to purchase food. This was the first year that we had to purchase food."[5] Other bad years remembered by respondents in Huautla were 1999[6] and 2007.[7] Only one respondent remarked that they have not had a good harvest in the past 15 years.[8]

From 2005 to 2009, farmers in Huautla experienced a series of drought years.[9] Very little cajete maize, seasonal maize, or beans were harvested in 2009 and 2010, and families largely depended on irrigated and dry-farmed wheat.[10] Since 2000, respondents noted changes in rainfall patterns.[11] Since 2000, farmers were unable to cultivate fields on time due to the late onset of the rainy season.[12] Some reminisced that in the generation of their parents, rains started on time (*a tiempo*) and followed the *cabañuelas*.[13] For a discussion of the *cabañuelas*, see page 30.

Crops and climate

Respondents in Zaragoza had noted a shift in rainfall. "The climate has changed a lot. Before there was more water, more animals, and more trees. It is now more difficult to farm."[14] Previous generations had experienced a better climate where cajete maize was sown in February[15] and the *milpa* was sown in April or May.[16] Ears of corn would already form by July or August.[17] In the present generation, rains started in May to June and lasted longer.[18] The sowing of cajete maize shifted to March and the sowing of seasonal maize to May or June.[19]

More recently, respondents in Zaragoza observed an increase in extreme climatic events measured in precipitation and temperature. In the last decade, precipitation patterns became more erratic with too much rain or not enough rain.[20] Prior to the 2000's, rainfall events lasted for 1 – 2 days and then would cease. Since 2002 or 2003, rainfall events became more extended.[21] "For the past two years the rains have increased more than normal. Before it had rained a little and then the sun would emerge. But now, it rains all night, and up to three days straight."[22] Between 2009 and 2011, the region experienced a series of heavy

[1] MGA, MCJ [2] MTD [3] MCC, MTD [4] ZCA, ZGA, ZTD [5] ZTD [6] ZCA [7] ZGA [8] ZTB [9] MGD [10] MCA, MTA [11] MCH, MGC, MGD [12] MCH [13] MCH [14] ZTD [15] ZCA [16] ZTA, ZCA [17] ZTA [18] ZCA, ZTC [19] ZCA [20] ZCB, ZTA [21] ZTE [22] ZCA

thunderstorms. On May 14, 2011 the residents of Zaragoza suffered a flood that entered homes and washed away livestock.[1]

In conjunction with the increased intensity of rainfall events, residents of Zaragoza noted an increase in temperatures since 2009. Increased temperatures during both dry and rainy seasons affected their crops[2] and dried out soils to the point of it cracking.[3] Moreover, the dry season (*sequía*) had become extended,[4] and problems with more pronounced frost damage.[5]

Although similar narratives were described between the two communities, Zaragoza respondents observed patterns of greater intensity of rainfall while those from Huautla noted more drying. As in Zaragoza, residents of Huautla said that the rainy season had shifted to later in the year. Elders recalled earlier rainfall in their youth, with rains starting in May or April while more recently rains had not began until June or July.[6] Additionally, the January mists (*neblinas*) ceased after the late 1970's.[7]

The drying trend in Huautla began around the 1980's.[8] An infamous storm in 1967 marked the memories of elders who recalled 40 days and 40 nights of rain that corresponded with a solar eclipse.[9] Other years were remembered for high precipitation included 1987 and 2010.[10] Especially in the last five years, farmers experienced a lack of rainfall[11] and increased heat.[12] Furthermore, reductions in forests influenced water availability and rainfall patterns, since trees roots were thought to retain water.[13]

The changing climate in Huautla led farmers to delay planting cajete maize from February to March and seasonal maize and beans from May or April to June or July.[14] Some even abandoned growing cajete maize in temperate climates of Huautla in the early 1990's due to a lack of rain.[15] Also, farmers abandoned long-season wheat varieties of six months, such as *cantial*, *largo*, *rocomé*, *chino*, *pelón*, *argentino*, and *lerma*, in favor of precocious (*mas violento*) varieties, such as *pavón*.[16] Negative impacts on yields from these climatic changes were felt by drought-sensitive crops, such as seasonal maize, by some farmers as early as 1984[17] and by others since the 1990's.[18]

Only two respondents in Huautla interpreted climate as always being variable in their region and agricultural practices as unchanging since their parents' generation.[19]

Reading the environment

Respondents described reading climatic patterns (*cabañuelas* and *canículas*), as well as other elements in nature to predict weather. The *cabañuelas* referred to the climatic conditions, particularly mists (*lloviznas*) in January, that were more commonly used by their ascendants to predict rainfall patterns for the upcoming season.[20] The first 12 days of January represented the 12 months of the year, and every subsequent two days of January was a confirmation of the first 12 days.[21] Based on whether the cabañuelas were painted (*pintado*)

[1] ZTD [2] ZCC, ZTA, ZTC [3] ZTF [4] ZTF [5] ZTA [6] MGD [7] MTC [8] MGD, MCI [9] MGD, MTC [10] MTC [11] MCJ [12] MTE [13] MCJ [14] MGB, MGD [15] MGD [16] MCI, MCJ, MGB, MGD [17] MCJ [18] MCF [19] MCH, MCI [20] ZCB, ZCC, ZTA, MCA, MCB, MCC, MCD, MCE, MCJ, MTA, MTE [21] MCC

by small clouds (*nublado*) or mists (*lloviznas*), farmers would predict whether the climate that year would be good (*chistosa*) or poor (*mala*).[1]

Only 29% of respondents in both communities reported following the *cabañuelas* (n = 17), with a higher percentage in Huautla (Table 2.4). Regardless of whether or not they were followed, respondents described them as a belief (*creencia*)[2] or tradition (*costumbre*).[3] Those who followed the *cabañuelas* said that sometimes they were effective, such as in 2011 when January was hot and was not painted (*no se pintó*).[4]

Table 2.4: Percentage of respondents in Zaragoza and Huautla who followed the *cabañuelas* to predict yearly weather patterns.

	Zaragoza	**Huautla**	**Total**
n	6	11	17
Percent	17%	36%	29%

Respondents also interpreted weather based on the two periods of the rainy season, referred to as *canículas*: large (*canícula grande*) and small (*canícula chica*). Depending on the year, the *canículas* were either dry (*de calor* or *seca*), or wet (*de agua* or *húmeda*).[5] While some respondents understood the distinction between large and small *canícula* based on the amount of water that it brought,[6] the large majority expressed the *canículas* as discrete periods of time during the growing season. The large *canícula* in both communities was described by 74% of respondents as a one month period from July 15 to August 15 (Table 2.5). The remaining respondents from Huautla described the large *canícula* from August 15 to September 15.[7]

Table 2.5: Percentage of respondents who described the large canícula as a time period from July 15 to August 15.

	Zaragoza	**Huautla**	**Total**
n	6	13	19
Percent	100%	57%	74%

Eighty-one percent of respondents in Huautla and Zaragoza described the small *canícula* as entering in mid-August and exiting in mid-September (n = 16), with slight variations in dates. Farmers described it as a 2 – 3 week period with entering dates ranging from August 15 – August 20, and exiting dates ranging from September 1 – September 15. Other

[1] MCB, MCC, MCE, MCJ, MGD, MTA [2] MCE [3] MTD [4] MTE [5] MCA, MCC, MCD, MCE, MCJ
[6] MCJ, MTB [7] MCC, MCG, MCH, MTA, MTB

periods described by respondents included August 15 to August 30,[1] July 15 to August 15,[2] and September 1 – September 8.[3]

While the *canículas* proved useful to describe severe circumstances where animals suffered and died due to extreme climatic events,[4] they were less commonly used to guide management. As one respondent from Zaragoza described, "since 2008, they don't talk about *canículas*, rather they talk about the number of hurricanes and storms."[5] It was expressed that the *canículas* did not come as they had before[6] and that mostly the older generation understood them better.[7] Nevertheless, the *canículas* were a useful conceptual mechanism for exploring farmers' understanding of intra-annual climatic variability. Respondents communicated clear gradients of impact depending on the dry and wet *canículas*.

The best case scenario was a wet large *canícula* and dry small *canícula*. During these years, families in Zaragoza conducted work in the fields on time and obtained acceptable yields from multiple crops, including seasonal maize. Farmers were not certain to harvest maize, but would likely obtain acceptable yields from beans and wheat. According to Zaragoza farmers, the *milpa* recuperated and sometimes they obtained a harvest[8]. "The plant is reinforced by the first *canícula* and resists the second."[9] However, the *milpa* may suffer or even fail from water stress (*se marchita*), as in 2007.[10] Even in these cases, soils would be protected by sufficient crop growth.[11] Huautla farmers also marked these years as good because fields could be entered to conduct agricultural activities and harvests were normal.[12] Farmers who determined what they would sow based on the rains were able to plant the entire sequence of seasonal crops, starting with maize in June, beans in July, and wheat in August.[13]

The next best scenario was a dry large *canícula* followed by a wet small *canícula*. A mixed scenario for Zaragoza farmers was when crops produced normally,[14] or partial harvests along with stover and straw were obtained.[15] In this case, beans and wheat were certain, but maize was not.[16] Huautla farmers skipped sowing seasonal maize in June or July in favor of sowing beans and wheat in August.[17] Yields were more or less certain,[18] but reduced.[19]

Years with both wet large and wet small *canículas* were considered the third-best scenario. These years were characterized by the rotting of rainfed crops and a dependence on dry farmed wheat sown towards the end of the rainy season. For Zaragoza farmers, crop productivity depended on the levels of precipitation in these years, with varying outcomes from good harvests,[20] to poor harvests of wheat, barley, and maize,[21] or to complete crop failures due to rotting (*aguachinar*).[22] "In 2010 and 2011, we received too much water and could not work in the fields. The milpa rotted and did not produce cobs."[23] Huautla farmers cited being unable to work their fields and failed harvests.[24] In these years, dry farmed wheat and barley (*venturero*) were planted towards the end of the rainy season.[25] The word *venturero* comes from "adventuring," since their late sowing toward the end of the rainy season meant that harvests were even less certain.

[1] ZCA [2] MTA [3] MCC [4] MCC, MCD [5] ZTE [6] MGB [7] MGC, MTD [8] ZCB, ZCC, ZTB, ZTC [9] ZCB [10] ZCA, ZGA [11] ZCA [12] MCE, MCH, MCI, MGD [13] MCE [14] ZCC, ZTB, ZTC [15] ZCA, ZCB [16] ZTB [17] MCE, MCH, MCI [18] MCG [19] MCH [20] ZCA [21] ZCB [22] ZCC, ZGA, ZTB, ZTC [23] ZGA [24] MCE, MCG, MCH, MCI [25] MCE

Finally, the worst scenario communicated by respondents were two dry canículas. In such cases, farmers were unable to sow their crops, animals died and grain yields were severely affected. Farmers described the *milpa* drying out completely, only stover (*zacate* or *caña*) was harvested, and sometimes animals perished.[1] The *milpa* was most sensitive to these conditions while wheat resisted them, as occurred in 2006.[2] Huautla farmers frequently experienced complete crop failures due to two dry *canículas*.[3]

The only deviation from the *canícula* narratives above was from a respondent in Huautla who kept an exceptionally large herd of animals.[4] He described his best case scenario as two wet *canículas*, since there would be abundant water and pasture. In contrast, his second to worst scenario was a dry large *canícula* followed by a wet small *canícula* due to a lack of water and pasture. This demonstrated how favored weather patterns depended on farmers' livelihoods.

Moon cycles, animals and plants

Various other traditions were described for reading the environment. Few respondents mentioned them, but those who did spoke with animation and conviction. Signs in nature guided their agroecological management: "Nature speaks, but not with words."[5] She observed that the elders often were correct in their assessments of nature. She described more signs than I could record with pencil and paper. A productive year for white sapote (*sapote blanco*, *Casimiroa edulis*: Rutaceae) corresponded to good maize yields. For others, when the native palm plant flowered (*zotolín*, Dasylirion spp.), it would be a productive year for peaches and maize.[6]

Farmers also observe animal behaviors.[7] When ground-dwelling animals, such as ants, found refuge in the soil, it would start to rain for 8-15 days. When the *chachalaca* bird (Ortalis spp.) would sing or when turkeys (*guajalotes*) scrape the soil it would rain.

With respect to weather, thick hail (*granizo grueso*) between February and April foretold of a good year for maize, whereas a thin hail meant a good year for wheat.[8] Also, mist (*rocio*) in the morning was sometimes accompanied by rain.[9]

The moon and sun were important guides for respondents, as well. Their ancestors were guided by the moon (*nuestros antepasados se guiaban por la luna*).[10] Farmers timed agricultural activities, such as when to plant, harvest grains, or harvest timber based on lunar phases. They also interpreted rainfall patterns based on the inclination, color, and halo of the moon in specific lunar phases or during particular times of the year.[11] The sun also was a guide. A large red circle around the sun at noon indicated that in three days it will start raining for 8 to 15 days.[12] However, others believed that circles around the sun during any time of the year brought wind but not rain.[13]

[1] ZCA, ZCB, ZCC, ZGA, ZTB, ZTC, MCE, MCG, MCH, MCI, MGD [2] ZGA [3] MCE, MCG, MCH, MCI, MGD [4] MGD [5] MCC [6] MGD [7] MCC [8] MCC [9] MCC [10] MCC [11] ZTA, MGD [12] MCC [13] MCE

Agroecosystems

Microclimate

The primary agricultural environments described in both communities were defined by microclimate: cold (*tierra fría*), temperate (*tierra templada*), and warm (*tierra caliente*[1]). Twenty-two percent of respondents in Zaragoza and 41% of respondents in Huautla cultivated in cold lands (Table 2.6).[2] Cold microclimates were also referred to as moist lands (*tierra húmeda*) due to their higher elevation and also reduced evapotranspiration of crops grown in the region.[3] Lentils were produced in cold lands,[4] but not beans and fruit trees.[5]

Table 2.6: Percentage of agricultural environments delineated by soil and atmospheric temperature where respondents grew crops in Zaragoza and Huautla (n = 38): cold lands (*tierra fría*), temperate lands (*tierra templada*), and warm lands (*tierra caliente*).

	Cold	**Temperate**	**Warm**
Zaragoza	22%	67%	11%
Huautla	41%	45%	10%

Sixty-seven percent of respondents in Zaragoza cultivated in temperate lands at mid-elevations[6] compared to 45% in Huautla.[7] This agricultural zone was well suited to a broad spectrum of crops and fruit trees, however lentils and cajete maize were reportedly not sown in these agricultural environments.[8]

Finally, warm lands (*tierra caliente* or *tierra cálida*) were the least common land cultivated by respondents, 11% in Zaragoza and 10% in Huautla.[9] These low elevation regions were best suited for fruit trees. In Huautla's warmest areas, respondents sowed a special kind of maize,[10] although due to the few respondents who cultivated in warm land, limited information was provided about these cropping systems. The majority of inhabitants resided in mid to high elevations close to the municipality and church, partly due to ongoing territorial conflicts that had lasted with Huautla's neighbor Santa Maria Ixatlán for over 60 years.

Soil Types

Farmers' soil classifications also contributed to understanding agricultural environments. In Zaragoza, farmers described three primary soil types by texture and color. Sandy (*arenosas*) and dry soils (*secas*) were identified as red lands (*tierra colorada* or *tierra roja*).[11] This soil type was located in the low parts of the community near the river *La Labor*[12] and in the

[1] on some occasions referred to as *tierra cálida* [2] ZCA, ZCC, MCA, MCB, MCC, MCD, MCF, MCH, MCI, MGC, MGD, MTI, MTB, MTC [3] MCA [4] MCI [5] MCH, MGA [6] ZCB, ZGA, ZTA, ZTB, ZTD, ZTE [7] MCE, MCG, MCJ, MGA, MGB, MGC, MGD, MTC, MTD, MTE, MCI, MTI, MTB [8] MCI [9] ZTC, MTA,MTI, MTB [10] MGA [11] ZGA, ZTB, ZTD, ZTE [12] ZTD

hillsides.[1] The most common soil type in Zaragoza was a white loam (*tierra blanca húmeda* or *tierra suelta*).[2] It was predominantly located in canyons (*cañadas* or *jollas*)[3] and also near the river *La Labor*. Finally, black clayey soils were located in smaller patches along the slopes of Zaragoza (*negra ceruda* or *negra chicluda*).[4]

Respondents in Huautla used a greater diversity of descriptors for soil structure and color. Huautla soils were described as loose (*suelta*)[5], porous (*porosa*)[6], dry (*resecona*)[7], and sandy (*arenosa*)[8]. These soils were also a variety of colors, including white (*blanca*)[9], red (*colorada* or *roja*)[10], gray (*ceniza*)[11], and black (negra).[12] The Mixtecan name for porous soils in Huautla as told to me was *nyu'gichti*.[13] Greater porosity presented advantages to farmers in high rainfall years and disadvantages in low rainfall.[14] Thorough and repeated cultivation retained their soil moisture in dry years.[15]

A second general category of soils commonly known as *ceruda*[16] were described in Huautla as clayey (*arcilloso*)[17] or sticky (*chicloso*).[18] Soil colors associated with *ceruda* soils included black (*negra*),[19] yellow (*amarilla*),[20] and red (*roja*).[21] In Mixteco, these soils were told to me as *na'kidi*.[22] *Ceruda* soils maintained soil moisture, however they risked compaction with heavy rain and would fracture when dry.[23] With moderate rainfall, they produced well.[24] Most field crops were grown in *ceruda* soils, as was cajete maize in cold lands.[25]

Several other soil categories were cited by respondents in Huautla. Loamy red soils (*blandito*)[26] were described as fertile and with a capacity to retain soil moisture.[27] Rocky soils were referred to as *piedra tendida*.[28] Red clay soils were described as hard (*dura*).[29] They required humidity to cultivate and were considered of poor quality (*delgada*), and lacking fertility (*no tiene abono*).[30] Finally white soils were described as alkaline (*alkalinas*) and containing salts.[31] These soils were only considered appropriate for wheat and beans.[32]

Soil erosion

Soil erosion left a prominent mark on the landscape of the Mixteca Alta. Respondents described how people for decades had failed to conserve their soils. The best soil and manure had washed away with storms (*aguaceros*).[33] In prior generations, soils were more productive.[34] Every year, soils continued to erode with the rains.[35]

While all types of soils were lost to storms,[36] those in agricultural zones, on slopes, and with more clay content displayed the greatest sensitivity to erosion. In Zaragoza, erosion occurred in the canyons (*cañadas*), valleys (*jollas*), and near the river *La Labor*, while the forested hills had hardly lost their soil at all.[37] Sloped fields (*laderas*) in both communities were identified as vulnerable to soil erosion[38]. Clayey soils were most likely to become saturated and slide on steep slopes (*negra ceruda*).[39] Strategies that farmers implemented to

[1] ZTE [2] ZCB, ZCC, ZGA, ZTA, ZTB, ZTE, ZTF [3] ZTF, ZTD [4] ZCB, ZGA, ZTA, ZTB, ZTC, ZTE [5] MCE, MCH, MCJ, MTD [6] MCB, MCG, MCI, MGA [7] MTC, MGA, MTE [8] MCC, MCA [9] MCH [10] MCH, MCI [11] MTC, MCA [12] MGA [13] MGA [14] MGB, MTD, MTE [15] MTD [16] MCA, MCA, MCB, MCC, MCE, MCG, MCI, MCJ, MGC, MGD [17] MCC [18] MTA, MTC, MTA, MTC, MCC [19] MCA, MCE, MTC [20] MCA, MCB [21] MCI [22] MTA [23] MTA [24] MCC, MTC [25] MCE [26] MCD [27] MCD [28] MCF [29] MCD [30] MCF [31] MCC [32] MGC [33] MCI [34] MGD [35] ZTF [36] ZTA, MCA [37] ZTD [38] ZGA, ZTA, MCA, MCI, MCJ, MGC, MTC [39] ZTC, MCG

abate soil erosion included rock bunds (*camellones*) and contour ditches (*zanjas trincheras*), as well as planting perennial vegetation, like cactus.[1] These strategies were reported to considerably reduce soil erosion.[2]

Soil fertility

While productivity was considered more or less the same across agricultural environments, other differences were noted by respondents in Huautla. Cold lands did not require as much rainfall as temperate lands to produce well: "when there is not much rain, temperate land does not produce. It requires much water."[3] Yield was considered equivalent between temperate and warm lands; however, seeds produced from temperate land lasted longer.[4] Soils required different levels of amendments. White humid soils and black clay soils required organic matter and nutrients.[5] In Zaragoza, red and black soils responded well to fertilizers, while white soils required animal manure and organic matter.[6] Animal manures were easily incorporated into clay soils, which cracked during dry seasons.[7]

Soil fertility management in Zaragoza and Huautla was largely based on locally-available inputs such as manures, composts, and green manures (Table 2.7). Only 2% of respondents in Huautla did not apply any soil amendments, which was due to the costs of synthetic fertilizer and constraints on keeping animals.[8] In one case, the respondent described his fields as worn out (*acabados*), sterile (*estériles*), and of low productivity.[9] He could not fallow his fields because it would affect his earnings from the PROCAMPO program. His sharecropper did pasture animals on some of the fields, but these animals returned to their corrals on the sharecropper's land overnight, thus diverting nutrients away from his fields.[10]

Table 2.7: Percentage of soil fertility management strategies reported by respondents in Zaragoza (n = 11) and Huautla (n = 20).

	Zaragoza	Huautla	Total
Animal Manures	55%	52%	53%
Fertilizers	18%	14%	13%
Living Barriers	9%	14%	13%
Green Manures	9%	10%	10%
Composts	9%	0%	3%
Beans	0%	5%	3%
Nothing	0%	2%	7%

Despite these cases, animal manures were the most widely used soil amendment, cited by 53% of respondents. Of these, 50% in Zaragoza[11] and 64% in Huautla[12] used animal

[1] MCC, MCH, MTE [2] MCC, MTE [3] MCB [4] MTB [5] ZTE, MCE, MGC [6] ZCB [7] MGC [8] MTA, MTB [9] MTA [10] MTB [11] ZCA, ZCB, ZTA [12] MCA, MCB, MCF, MCH, MGA, MGB, MTE

manure exclusively to maintain soil fertility. Animal corrals were moved between fields in some cases[1] or placed in the least unproductive or most fragile soils (*débiles* or *delgados*).[2]

In addition to animal manure, 10% of respondents considered beans[3] or the incorporation of spontaneous vegetation[4] to contribute to soil fertility. "Beans give life to fields as if it were chemical fertilizer."[5] Composts,[6] ant nests (*nidos de arriera*),[7] tree leaves,[8] and woodash[9] were other soil amendments used. Finally, living barriers, contour ditches, and bunds were cited to maintain soil fertility by 9% of respondents in Zaragoza and 15% of respondents in Huautla.[10] These families constructed contour ditches and bunds, as well as planted perennial vegetation, such as trees and agave (*maguey*), to keep fertile soil in place.

The 13% of respondents who used synthetic fertilizers applied them depending on soil conditions. Only one farmer applied regular and uniform doses of fertilizer (18-46-00) at 100 Kg per hectare for maize and 50 Kg per hectare for beans.[11] One respondent from Zaragoza applied fertilizers to red and black soils, but not white soils.[12] Others only used synthetic fertilizers occasionally and in small quantities.[13]

Overview of crops and animals

Home gardens included fruit tree species, such as peaches, avocado, and grenadine, as well as vegetable crops, such as cilantro, squash, and radish (Table 2.8). The composition of home gardens was based on local environmental conditions, such as soil type and local climate, as well as access to water sources. In Huautla, respondents from outlying communities reported multiple factors that restricted their sowing of home gardens. One respondent said they were unable to plant fruit trees due to heavy clay soils (*tierra negra ceruda* and *tierra amarilla ceruda*).[14] For other respondents, they lacked access to water to irrigate their gardens.[15] Rainwater harvesting from rooftops had recently been initiated by non-governmental organizations to improve home gardens.[16] There were also government subsidized greenhouse projects for women's groups to grow and sell tomatoes.[17]

All respondents cultivated rainfed crops, but few had access to irrigation. One respondent estimated that only 3% of households in Huautla had access to irrigated fields.[18] Those who practiced irrigated agriculture sold vegetables and wild harvested plants to the weekly farmers' market in Huautla.[19] Respondents also reported wild harvesting a number of plants, fungi, and insects from their territories that contributed to the nutrition of families during different times of the year. In both communities, 45% of respondents produced cajete maize, with 30% in Zaragoza[20] and 53% in Huautla.[21]

Families across both communities had a median of 2 cattle, 9 sheep and goats, and 1 donkey (Table 2.9). The median profile of large animal husbandry in Zaragoza was 2 cattle, 5 sheep and goats, and 2 donkeys. The median profile of larger livestock in Huautla was 2 cattle, 10 sheep and goats, and 1 mule. Goats and sheep were kept by 79% of respondents

[1] ZTA [2] MCD, MCH, MTE [3] ZCC, MCG [4] MCD [5] MCG [6] ZTB [7] MTC [8] MTC [9] MCD [10] ZTD, MCC, MCJ, MGD [11] MTD [12] ZCB [13] ZTC, MTC [14] MCA [15] MCD, MCF [16] MCJ [17] MCH [18] MGD [19] MGA [20] ZCA, ZCB, ZCC [21] MCA, MCB, MCC, MCD MCE, MCF, MCG, MCH, MCI, MCJ

Table 2.8: The number of respondents who reported trees and vegetables grown in their home gardens, as well as wild harvested plants, fungi, and insects in Zaragoza and Huautla.

Fruit Trees		**Vegetables**		**Wild Harvested**	
Name	Number	Name	Number	Name	Number
peaches	13	cilantro	12	*quelites*	10
avocados	6	squash	11	mushrooms	5
grenadine	5	radish	10	*coyúl*	3
capulin cherry	4	lettuce	7	*quintoníl*	3
apple	3	tomatillo	5	*violeta*	3
guava	3	tomato	4	*berro*	3
figs	2	cactus	4	*verdolaga*	2
lemon	2	chilacayota	4	*mostaza*	2
orange	2	beans	3	*acetillo*	1
loquat	1	chayote	3	*banana*	1
quince	1	agave	2	*cetillo*	1
mulberry	1	carrots	2	*chepíl*	1
		chard	2	*flor de venado*	1
		amaranth	1	grasshoppers	1
		chiles	1	*jasmín*	1
		epazote	1	*tepiche*	1
		onion	1		
		oregano	1		

in Huautla[1] and 60% in Zaragoza.[2] Families also raised mules, horses, pigs, turkeys, and chickens in small numbers.

Local breeds and landraces

Local animal breeds and landraces of seed were fundamental to agrarian culture in the Mixteca Alta. They were "sacred"[3] and the basis of the family.[4] Without them, they could not work or would have nothing to sow.[5] Farmers favored local breeds for their known characteristics and adaptiveness to challenging the environment. "Local breeds... are important because they are adapted to our conditions... 'Improved' breeds require lots of care, such as vaccines and antibiotics."[6]

[1] MCA, MCB, MCC, MCE, MCF, MCG, MCH, MCI, MGA MGB, MGC, MGD, MTC, MTD, MTE
[2] ZCA, ZCC, ZGA, ZTB, ZTC, ZTE [3] ZTF [4] MCF [5] MCE, MTC [6] MCC

Table 2.9: Summary statistics of large animals managed per family in Zaragoza and Huautla.

	Cattle	**Sheep and Goats**	**Donkeys**	**Horses**
n	28	29	27	27
Minimum	0	0	0	0.0
1st Quartile	0	0	0	0.0
Median	2	9	1	0.0
Mean	3	17	1	0.9
3rd Quartile	4	21	2	1.0
Maximum	18	90	5	12.0

The same was expressed for landraces; they knew the attributes of their landrace seed,[1] as well as what labors were required to obtain an acceptable harvest.[2] "Other seed does not take."[3] Also, they knew which seeds were long season varieties and which were precocious.[4] The same seed was more reliable than a newly adopted seed that was uncertain to produce at all or that at best would produce with applications of high levels of synthetic fertilizers (*a fuerza*).[5] "If we look for seed elsewhere, the seeds do not develop. They require more water and do not take like the seed from our villages (*rancherías*)."[6]

Specifically, respondents valued their landrace seeds for their adaptiveness to climate, economic benefit, and cultural preference. "We cannot predict what will happen next year."[7] Farmers prioritized maintaining seed stock, even in poor years when grains were scarce[8] so that they would not have to procure seeds for the following season.[9] "Without seed we are nothing."[10] Landraces were to be conserved: "it is important to not contaminate our seedstock."[11] The rather simple statement that successful harvests were important to continue cultivating[12] held great significance to farmers.

There were also economic benefits to saving seed. Farmers save seed to avoid purchasing it, since seed was expensive.[13] Moreover, the seeds from outside of the community were not the same.[14] Local maize has proven to store well,[15] and "we prefer our creole maize (*maíz criollo*) because it tastes better."[16]

Seasonal maize grown in the two communities were mixed landraces that resembled *bolita* and *cónico*, while cajete maize was more closely akin to *chalqueño* (Flavio Cuevas Aragón, INIFAP, personal communication). A farmer in Zaragoza lost the pinto, white, and blue varieties of cajete maize that he had sown twenty years before.[17] This farmer had started experimenting with planting his seasonal maize in the style of cajete. Other farmers still conserved distinct cajete maize seeds, which had a larger grain than seasonal maize.[18] Currently sown varieties of cajete were distinguished in Zaragoza by color, such as white kernels

[1] ZTA [2] ZTA, ZTC [3] ZTE [4] ZGA [5] MTE, MCI [6] ZTD [7] MCG [8] MGC [9] MTD [10] ZTD [11] MCC [12] MCH [13] MCB, MGA, MGB [14] MGA [15] ZCA [16] MCA [17] ZCA [18] ZCB

with a red cob[1] or light yellow.[2]

Huautla farmers described their varieties of cajete maize by morphology, ecology, and culinary characterstics. Kernel colors included blue,[3] pinto,[4] red,[5] white with a white cob (*olote*),[6] and white with a red cob.[7] In comparison to seasonal maize, cajete maize had larger kernels;[8] the cob was longer[9] and thinner;[10] and the plants grew tall, up to an estimated 4 m.[11] Cajete maize was adapted to plantings in March due to its resistance to heat (*calor*);[12] and its growing cycle required 7 – 8 months to reach maturity.[13] The *masa* from cajete maize was dense (*maciza*) and capable of forming large tortillas (*tlayudas*).[14]

Zaragoza farmers stewarded seasonal maize that they distinguished as blue,[15] pinto,[16] red,[17] white,[18] and yellow kernels.[19] White and yellow varieties were the most precocious and common varieties.[20] Meanwhile red, pinto, and blue varieties were less precocious and more sensitive to inclement weather.[21] They were the first varieties sown and the last harvested.[22] Farmers planted red, pinto, and blue varieties in June, otherwise they would be negatively affected by November frosts.[23] Additionally, families described seasonal maize as having smaller kernels than cajete.[24] White varieties had the smallest kernel, followed by blue and pinto that were approximately the same size, and finally red with the largest kernel.[25] Pole bean varieties that accompanied seasonal maize in the *milpa* included: *blandito*;[26] *de ejotes*;[27] *elotero* or *yocote*;[28] *machete*;[29] *pintito enredador*;[30] *poblano*, a smaller plant;[31] *rojito*;[32] *rosita*;[33] and *tablero*, a larger bean.[34]

Huautla farmers described their seasonal maize varieties by kernel color, similar to Huautla: blue,[35] pinto,[36] red,[37] white with red cob (*olote*),[38] white,[39] and yellow.[40] These varieties had small kernels[41] and small[42], thick[43] cobs."They are creole. They have a sweet stalk and a thick cob" (*Son criollo, dulce, y de olote grueso*).[44] Seasonal maize kernels from temperate lands (*tierra templada*) were more an oval shape than the round kernel varieties sown in warm lands (*tierra caliente*).[45] They were also of a six month cycle[46] and were more sensitive to heat (*calor*) than cajete maize.[47] Moreover, they were planted at a higher density than cajete maize: in the distance between two cajete plants fit three bunches (*matas*) of seasonal maize.[48] Tortillas were softer with seasonal maize than cajete maize (*blanditas*).[49] Only one farmer reported planting white hybrid maize.[50]

The most common pole bean that farmers in Huautla accompanied with seasonal maize was called *enredador*,[51] *de la milpa*,[52] or *nduchi ndaviyo*.[53] It contained yellow, red, and black colored grains in the same pod.[54] Other farmers also called pole beans by generic

[1] ZCB [2] ZCC [3] MCE, MCH, MCI, MCJ, MGC [4] MCC, MCE [5] MCE, MCH [6] MCC, MCD, MCE, MCF, MCG, MCH, MCI, MCJ, MGC [7] MCD [8] MCE, MCF, MCG, MCH, MCJ [9] MCE, MCG, MCH [10] MCI [11] MCD, MCE, MCF, MCH [12] MCF [13] MCI [14] MCD [15] ZCC, ZGA, ZTB, ZTD, ZTE, ZTF [16] ZGA, ZTF [17] ZCB, ZGA, ZTB, ZTE, ZTF [18] ZCA, ZCB, ZCC, ZGA, ZTB, ZTD, ZTE, ZTF [19] ZTA, ZTB, ZTE [20] ZTB, ZTC [21] ZTB, ZTC [22] ZTC [23] ZTC [24] ZCB [25] ZGA [26] ZCC, ZGA, ZTE [27] ZTA [28] ZCA, ZTB [29] ZCC [30] ZCB [31] ZTD [32] ZTC [33] ZCB [34] ZCC, ZGA, ZTD, ZTE [35] MCC, MCE, MCI, MCJ, MGC, MTE [36] MCC, MCD, MCE, MCH [37] MCC [38] MCD, MTD [39] MCC, MCE, MCF, MCG, MCH, MCI, MCJ, MGC, MGD, MTE [40] MCC [41] MCD, MCF, MCG, MCJ [42] MCG, MCJ [43] MCI [44] MCI [45] MCI [46] MCI [47] MCF [48] MCD [49] MCD [50] MGD [51] MGC [52] MCC, MCI, MTE [53] MCC [54] MCC, MCI, MGC

names, such as *enredador*,[1] *elotero*,[2] or though without further description. However, they may correspond with the multi-colored bean variety. Finally some farmers cited *pinto*[3] and *zapato*[4] pole beans.

The varieties of bush beans grown by farmers in Zaragoza included: *blanco*;[5] *criollito*, a black bean with a white pod;[6] *delgado*, a small white bean of five months;[7] *flor de mayo*;[8] *frijolón*;[9] *ligero*, a black and large bean of 3 months;[10] *negro caldo espeso* or *de los abuelitos*, with a black pod;[11] *negro chicito*;[12] *negro delgado* or *delgado criollo*;[13] and *rosa*.[14] There may be some overlap in local nomenclature, as many of the bean varieties were named by their shape and color.

Far fewer varieties of bush bean, at least by name, were identified by farmers in Huautla compared to Zaragoza: *blanco delgado*;[15] *negro criollo*;[16] and *negro delgado*.[17]

The varieties of wheat that farmers reported currently sowing in Zaragoza included: *200*, a brown or coffee colored grain better suited for heat;[18] *argentino*, a 7 month variety with large and yellow grain that lacked aristas;[19] *barrigón*, a frost-resistant variety of 5 months that was sown in September with a tall stalk and large seeds that had long aristas;[20] *pavón*, a 5 month variety sown in June or July with a short, clean, shiny, and white grain;[21] *pelón*, a delicate and large plant;[22] and *sin nombre*, a recent variety from Mexico City.[23] Older varieties that farmers no longer grew included some of those mentioned above, as well as others: *200*;[24] *argentino*;[25] *chapingo*;[26] *largo*;[27] *lerma*;[28] *linca 3*, a variety of three months sown with maize in June that was good for weak fields without much weed pressure;[29] *madador*;[30] *pavón*;[31] *pelón*;[32] *quintana*;[33] and *rocomé*.[34] These varieties were either lost due to poor production,[35] or because the seasonal varieties planted in June provided comparatively less protection to soils from erosion than maize.[36]

Wheat varieties that farmers grew in Huautla included: *argentino*;[37] *blanco pavón*;[38] *chaparro* or *chaparrito*;[39] *chino*, a 4 – 5 month variety that resisted diseases (*chahuistle*) and frosts, that was of medium-stature, and that was introduced 6 – 7 years ago;[40] *genáro*, a 4 month variety;[41] *largo*, a seasonal wheat that grew tall;[42] *lerma*;[43] *moreno*;[44] *pavón chaparro* or *pavón blanco*, a 4 month variety that produced high yields, long sheaves, and a round grain (*gavillas grandes y grano bolito*);[45] *pavón*, a 4 month variety;[46] *pelón colorado*, a 6 month, frost-resistant, hard wheat variety that was particularly sown in cold, moist lands (*tierra fría*) in September since it was capable of resprouting (*retoña*) seven times;[47] *pelón guero*, a 6 month variety;[48] *pelón*, an 8 month, tall variety with long aristas that did not yield as high due to its thin sheaves and that took longer to thresh, but it did make high quality pasture and was resistant to drought;[49] *rocomé*, a tall growing variety;[50] and *violento*,

[1] MGC, MCG, MCH [2] MCG [3] MCE, MGD [4] MTD [5] ZTD [6] ZTC [7] ZGA, ZTB, ZTF [8] ZGA, ZTA [9] ZTE [10] ZTF [11] ZGA, ZTC, ZTE [12] ZCA, ZCB, ZTD, ZTE [13] ZCC, ZTA, ZTB, ZGA [14] ZTB [15] MCC, MCE, MCH, MCI, MTD [16] MGD [17] MCC, MCE, MCG, MCH, MCI, MCJ, MGC, MTD, MTE [18] ZTB [19] ZTA [20] ZCA, ZCC, ZGA, ZTB, ZTC, ZTD, ZTF [21] ZCB, ZGA, ZTA, ZTC, ZTE [22] ZTC [23] ZGA [24] ZCA, ZTF [25] ZCA, ZTB [26] ZCA [27] ZCA, ZCB, ZTB [28] ZCA [29] ZTF [30] ZCB [31] ZCA [32] ZCA, ZCC, ZTB [33] ZCA [34] ZCA, ZCB [35] ZCB, ZTB [36] ZCC [37] MCC, MTE [38] MCC [39] MCG, MGC [40] MGC, MGD [41] MCI [42] MCG, MGC [43] MCC [44] MCC [45] MCE, MCH, MCI [46] MGD, MTD, MTE [47] MCF, MCI [48] MGD [49] MCC, MCD, MCH, MCJ [50] MGC

a 5-6 month variety that grew short and thick sheaves (*gavillas*), arriving in the mid-1990's.[1] A handful of respondents did not sow seasonal varieties of wheat, such as *rocomé*[2] and *largo*.[3] "Not *largo* because it takes too long"(*no el largo porque se tarda*).[4]

Seasonal agriculture

While the commonly produced seasonal maize was known as *maíz de temporal*, the cohort of crop species planted during the rainy season were also referred to as *cultivos de temporal*. Respondents recognized that seasonal crops were well adapted, efficient, and diverse. Seasonal maize was well adapted to temperate lands (*tierra templada*), where the risk of frost was low.[5] Certain cold zones, such as between Zaragoza and Galeana, and in the outlying communities of Huautla, experienced more environmental challenges for producing seasonal maize.[6]

Farmer color classifications corresponded to a series of physiological differences between the varieties. Red seasonal maize was also the slowest to develop.[7] One respondent considered both the white and blue kernel (*morada*) varieties that she grew to actually be a cajete maize variety, though they planted it in the style of seasonal maize.[8] She sowed the white variety near her house. It had a small seed and smaller plant. The blue variety that she grew in the hills (*la loma*) made a pretty tortilla and produced a larger kernel and plant in comparison to the white variety. It was also less precocious. Another respondent described the white kernel variety as small-seeded and mealy; the red kernel variety was of a large cob and adapted to any field; the yellow kernel variety was small-seeded and demanding of soil nutrients; and the blue kernel variety was small-seeded and adapted to any field.[9] This farmer sowed red and white seeds in the same field, though most people avoided mixing colors to prevent cross pollination between their varieties.

Farmers decided to plant seasonal maize instead of cajete maize due in part to changes in soil humidity. Late onset rainfall and reduced dry season mists (*neblina*) in temperate land impeded soil cultivation during the dry months of November and December for maize *de cajete*, as was practiced 30 years ago by their ascendants.[10]

The diversity of production was another important reason why farmers chose seasonal maize. Seasonal agroecosystems were diversified (*parcela diversificada*) for multiple food crops and animal forage.[11] Crops associated with the *milpa* system included seasonal maize, beans, squash, fava, and peas.[12] They not only were cultivating a polyculture of seasonal crops, but also a diversity of spontaneous plants, such as *quelites*, *berdolaga*, and *violeta* that grew within the *milpa*.[13]

The diversity of production from rainfed agriculture represented an economic savings to families by minimizing food purchases.[14] Respondents recognized a difference between the density of hybrid or commercial maize and their traditional varieties. "When it rains well there is a good harvest... Both cajete and seasonal maize weigh more than improved seed."[15] Seasonal maize was described as precocious;[16] "our children can eat within 5 months, if the

[1] MCJ [2] MCH [3] MCH, MTE [4] MTE [5] ZTE, MGA, MTA, MCH [6] ZTE [7] ZGA [8] ZTD [9] ZTE [10] MGB [11] ZTC [12] ZTF [13] MCC [14] ZTB, ZTF, MTE [15] ZCA, ZCC [16] MCF

maize does well."[1] The staging of multiple crops during the rainy season further raised the probability of family self-sufficiency in basic grains throughout the year. "If the maize doesn't do well, we have beans, and if not beans, wheat."[2] Rainfed crops were also viewed by farmers as labor-efficient cropping systems. "We save time and have enough to consume."[3] A single family was able to plant seasonal maize, whereas cajete maize required multiple families working together for an extended period (*guetza*).[4]

Additionally, the rainfed *milpa* produced an important source of pasture for animals. Wild oats and legumes (*carretilla*) grew between the *milpa* polyculture.[5] Rainfed maize was viewed as more consumable biomass for animals in comparison to cajete maize whose stalks were tough and thick.[6] The stover of seasonal maize (*zacate*) left to dry in the fields provided forage for animals during the dry season.[7] "Half of the stover we leave in the field and the other half we cut for the animals."[8] Both the stalk (*caña*) and leaves (*hoja*) of seasonal maize were used as forage. Farmers were accepting of even poor grain harvest because of the stover for animals, if not for edible grain. Spontaneous plants were also recognized to improve soil fertility and productivity of seasonal maize.[9]

Disadvantages of rainfed crops included the variability in yield between years, their sensitivity to inclement weather, and the importance of conducting agricultural activities during critical times of the growing cycle. Rainfed crops were reported to be sensitive to wet and dry climatic patterns. Seasonal maize in particular exhibited greater variability in yields from year-to-year when compared to cajete maize (*hay años buenos y años malos*).[10] Seasonal maize required more water (*requiere más agua*)[11] and failed with too much rains (*se encaña*).[12] Excessive precipitation encouraged diseases (*guachinar*).[13] Additionally, wet years impeded mounding (*encajonar*) and weeding (*desenhierbar*) of seasonal crops, which resulted in greatly suppressed yields especially in clayey soils.[14] Likewise, respondents reported that without rain, seasonal maize dried and suffered from complete crop failure.[15] Also, seasonal maize was closely tied to the start of the rainy season, since it did not tolerate the heat of the dry season (*calor*).[16]

Cajete maize

While the production of cajete maize was on the decline, it remained an important farming strategy for cold, high altitude regions that experienced early frosts (*los altos*[17] or *tierra fría*).[18]) One family produced the same cajete maize of their parents, but in smaller areas.[19] In the highland humid soils, dry-farmed crops grew best in clayey soils (*tierra ceruda*) with the slightest rains or mist between November and December (*lloviznas* and *rocios*).[20] Cajete maize was best produced on flat ground with a very well fertilized soil, either by animals or by the nutrients that washed down from forests.[21] Traditionally, cajete was sown in depressions or valleys (*jollas*). One respondent explained that the aerial roots of cajete maize enabled it to absorb nutrients in moist soils when soils were amended or the crops were weeded.[22]

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[1] ZTB, MCF [2] ZTB [3] ZCB [4] MGC, MTD [5] MCC [6] MCE, MCF [7] MCH [8] ZCA [9] MCC [10] MCC [11] MCB [12] ZCA [13] ZTB [14] MCC [15] ZCB, MCA [16] MCI [17] MGB [18] MCH [19] MCH [20] MGB [21] MCA [22] MCC

Soils were carefully managed to capture residual soil moisture that enabled cajete maize to grow on residual soil moisture for several months until the start of the rainy season. Soil tillage with the Egyptian plow multiple times prior to sowing cajete maize trapped residual moisture in the fields.[1] Four tillages occur prior to sowing (*barbechar*, *recortar*, *recruzar*, and *surquear / rayar*). Farmers sowed seeds at the bottom of manually carved depressions in the soil. See page 51 for more details on the cajete system.

The high specificity of where and how cajete maize was sown helped stabilize crop yields in years of climatic extremes[2]. Respondents who grew cajete maize considered it to be highly resistant to the heat of the dry season and of the summer droughts (*caniculas*).[3] "Even without rain, [cajete maize] survives" (*aunque no tiene agua vive*).[4] The early sowing of cajete maize led to earlier harvests compared to seasonal maize and was more reliable due to avoiding frost damage.[5] According to respondents, cajete maize out-produced seasonal maize.[6] "The more that the plant grows, the more yield is obtained. The cob grows larger and the plants grow taller than seasonal maize, from sowing it earlier."[7] Even for those who considered the grain yields between cajete and seasonal maize comparable, cajete maize went further in feeding families due to its larger kernel size (*rinde más por su tamaño*).[8]

Additionally, farmers from highland cold lands recognized that cajete maize strengthened soils[9] and provided important animal forage. Unlike seasonal maize whose entire stover was used as forage, farmers made use of cajete maize for their animals by cutting young stalks[10] and secondary stalks (*hijuelitos*).[11] Additionally, the cajete maize stover (*zacate*) was harvested and stored for the dry season, and the leaves were used as forage.[12] Like seasonal maize, useful forage species, such as wild oats, grew in the understory of cajete maize.

A reduction in those who planted cajete maize was reported in temperate lands of both Zaragoza and Huautla.[13] A respondent from Zaragoza recounted that sixty years ago his grandparents grew cajete maize, but it was not feasible because the soil was no longer thick (*gruesa*) and rains arrived too late in the season.[14] In Huautla, a respondent confirmed that they abandoned cajete maize 20 years ago due to changing rainfall patterns.[15] "Before, seasonal rains started earlier. In the generation of our parents, it rained on time (*a tiempo*) and followed the *cabañuelas*. In November and December it rained enough to prepare soils for cajete."[16] Another respondent from Huautla abandoned cajete maize because of the upfront costs, which translated to greater losses than seasonal maize if crops failed: "The cajete is expensive. You have to call for people to help and give them cigarettes, food, and *tepache* (a fermented beverage). When there is no harvest, it doesn't seem worth it."[17]

Those respondents who had never sown cajete maize primarily cited soil quality and moisture as the major constraints. In Zaragoza, a farmers' soils were too dry for cajete maize.[18] Similarly in Huautla, three farmers said that their soils could not retain enough moisture,[19] and furthermore rains had changed to disfavor cajete maize.[20]

[1] MCI, MCJ [2] MCC, MCG [3] ZCB, MCA, MCB, MCD, MCE, MCF, MCG [4] MCA [5] MCC, MCF [6] ZCB, MTD [7] ZCA [8] MCA [9] ZCB [10] ZCC [11] MCH [12] MCH [13] ZCA, ZTD, ZTB, MGC, MGD, MTD [14] ZTB [15] MGD [16] MCH [17] MGC [18] ZTE [19] MTA, MTB, MTE [20] MTA, MGC

Cajete maize also suffered some damage from hail and animals. Since cajete maize was more vulnerable to early-season hail damage.[1] More significant damage was suffered in both communities from free-ranging animals (*libre pastoreo*), particularly goats and sheep.[2] Furthermore, dogs and wild animals ate the young ears of corn since they were the first to reach maturity.[3]

> We stopped sowing cajete 20 years ago, because ours was the first maize of the season and we suffered serious losses from raccoons and foxes, 70 – 80 cobs every night. Cajete is very certain, but the losses were high for us because we were the only ones planting it. We tried running around our fields at night to scare the animals away, but it didn't help.[4]

Despite these obstacles to producing cajete maize, respondents expressed an interest in reviving the practice: "We lost the cajete seed, but two years ago we started sowing our seasonal seed as cajete. We are taking the initiative to keep from losing of our customs and traditions."[5] This narrative came as a surprise. It suggested that this farmer either was sowing landraces of seasonal maize (*cónico* or *bolita*) using the technique usually reserved for cajete maize, or he had for the past 20 years continued to sow his cajete maize landraces (*chalqueño*) in the style of seasonal maize. In either case, it represented a wider range of flexibility between farmers' practices and landrace genetics than I had originally assumed.

Animals

Another important reason for the interviews was to understand changes in animal husbandry, as it was an activity directly affected by the outmigration of youth. Since the Colonial period, animal husbandry in the Mixteca Alta has made a lasting impact on the semi-arid landscape as rangelands were overgrazed and the highly variable climatic conditions washed away the most fertile soils. The following accounts describe the various functions of domesticated animals in traditional farming systems of the Mixteca Alta, with particular focus on how animal husbandry interacted with seasonal and cajete cropping systems.

Animal husbandry was reported to provide labor, food, manure, and income. Typically, cattle were used for the plow (*yunta*), horses for transport, and donkeys for portage.[6] All respondents in both communities used cattle and horses to plow their fields. Farmers in Huautla had not widely adopted tractors into their soil management whereas in Zaragoza farmers used tractors to disc their fields (*barbechar*) followed by cattle (*yunta*) for all subsequent soil tillage. The only exception in Zaragoza were those farmers with steep fields or those who still grew cajete maize: "I don't work with machines, always with the *yunta*."[7]

Farmers viewed animal husbandry as useful, because if they didn't keep animals, they would depend on others to cultivate their fields.[8] Cattle and donkeys were traditionally gifted to newlyweds.[9] In one rare case, a respondent tilled his fields using a horse-drawn metal

[1] ZCC [2] MCC [3] MCC [4] ZCA [5] ZCA [6] MGD [7] ZCB [8] ZTC, MCH [9] MCC

plow rather than the more typical Egyptian plow.[1] This farmer also kept horses specifically for riding, which was not very common.

Farmers valued animals for the contribution of their manures to soil fertility.[2] Traditionally, sheep and goats were corralled at night, while cattle, horses, and donkeys were attached to stakes within fields.[3] During the day, sheep and goats were herded by families on communal lands. Cattle and horses were left by some in communal forests to pasture.[4]

Animals provided meat, eggs, and income to families. Thirty percent of respondents from Zaragoza and 20% of respondents from Huautla found it important to raise animals for meat and eggs. For 20% of respondents in Zaragoza and a much larger 68% of respondents in Huautla, animals were an income source in times of need. They had animals to sell in the eventuality that they needed to purchase food, treat medical conditions, purchase clothing, or pay for agricultural labor. "Animals are for when we get injured or experience a drought. We have bread all the time."[5] Respondents sold animals at irregular intervals during the year.

Despite these benefits, animals posed challenges to their communities. Some families stopped tending animals because of their destructive impact on communal forests,[6] as well as for the time commitment required to care for them.[7] "We don't have many animals anymore. Twenty years ago we had larger herds, but it was destructive. We are now reforesting."[8] Several families had insufficient water, forests (*monte*), or pasture to support larger animal herds.[9] Moreover, two respondents from Huautla estimated that animal husbandry occupied approximately eight hours of work for one individual per day.[10] Older couples who were interviewed had given up animal husbandry because there was no one to look after the herds.[11]

Crop rotations

Families rotated crops and animal corrals through their small parcels of land that were often distributed across their territory. Rotations emerged from traditional farming systems in many parts of the world as a way to sustain a diversity and quantity of crops sufficient to meet a family's yearly consumption on small, dispersed plots of land with different soil fertility or pest issues. Rotations are also a linchpin of sustainable agriculture at larger commercial scales. I describe below the ways that the farmers interviewed managed rotations of crops and animal corrals.

Distinct crop rotations were reported based on agricultural environments. Seventy percent of respondents in Zaragoza and Huautla practiced crop rotations within temperate land. In Zaragoza, 70% of respondents planted a *milpa* polyculture – seasonal maize with beans, peas, fava and squash – in the spring of the first year followed by wheat at the end of the rainy season of the second year and beans at the start of the rainy season of the third year.[12] One respondent included fallows with green manures in their rotation.[13] Another described

[1] MTD [2] ZCA, ZCC, MGC [3] MCB, MGA, MGB, MGD [4] MGA, MGD [5] ZCC [6] ZTB [7] ZTB, MCA, MCB, MCD, MTA, MTB [8] ZTB [9] MCF, MCJ, MTC [10] MCA, MCB [11] MCD, MTA, MTB [12] ZCB, ZCC, ZTA, ZTB, ZTC, ZTD, ZTF [13] ZTA

that if the sowing of blue seasonal maize were to fail, they would replant with white seasonal maize.[1] Beans and wheat wasted the field (*gasta el campo*), whereas maize, squash, fava, and beans grown together healed the soil.[2]

While a similar rotation between *milpa*, legumes, and wheat was reported by 73% of Huautla respondents who cultivated dry land (*tierra seca*),[3] many farmers varied rainfed crop sequences in accordance with local soil and micro-climatic conditions. Crop sequences varied within seasons due to crop failure according to 29% of respondents. If the *milpa* polyculture sown in June failed to emerge, beans or peas were sown in July, and likewise wheat would be sown in September.[4] For some, seasonal maize was followed by beans in the same year if the crop failed, followed by wheat at the end of the rainy season of the subsequent year.[5] Other farmers rotated between seasonal maize and wheat every year, depending on patterns of precipitation and the field conditions, without fallows.[6] One respondent planted seasonal maize in the first year followed by two years of bush beans – replaced by wheat if the rains were late – followed by one year of seasonal maize.[7] Several rotations incorporated other legumes (peas, lentils, and fava), as well as grains (barley and oats).[8]

While not typical of the farmers interviewed, a small number of respondents in Huautla reported no crop rotation for seasonal crops[9] and irrigated fields.[10] Farmers reported planting bush beans every year in the temperate land (*tierra templada*)[11] and in the warm land (*tierra cálida*)[12] without any crop rotation or fallow.[13] Another farmer intensively grew seasonal maize on his small irrigated parcels using sheep corrals to maintain the soil's fertility.[14] In another rare case, a respondent with access to irrigated fields would produce 6 months of vegetables during the dry season for sale in the weekly farmers market.[15]

Zaragoza and Huautla respondents who produced cajete maize practiced crop rotations distinct from those for seasonal maize. In cold microclimates with humid soils, 23% of respondents that planted cajete maize did not practice crop rotations or fallows.[16] Sixty-nine percent of respondents who grew cajete maize practiced different combinations of crop rotations and fallows. Of these, 22% rotated cajete maize with wheat or barley.[17] One of these respondents would not rotate if it were to rain in January,[18] while another farmer added a one-year fallow after this two-year rotation.[19] A third farmer would rotate from cajete maize to seasonal maize depending on October and November rainfall;[20] if the soils were moist from late rains, they would able to cultivate the soil for cajete maize.

Thirty-three percent of those who practiced rotations with cajete maize incorporated both seasonal maize and wheat into their rotations.[21] After the harvest of cajete maize in November of the first year, the stover was cut and removed from the fields (*cortar el zacate y rastrear el rastrojo*).[22] Dry-farmed wheat (*venturero*) was planted without the first plowing (*sin barbecho*). In year two, a polyculture *milpa* was sown in June that included seasonal maize, beans, squash, favas, and pole beans followed by either dry-farmed wheat, a fallow, or beans in the third year, depending on rainfall patterns.[23] One of these farmers

[1] ZTD [2] ZTB [3] MCD [4] MCB, MTB, MTC, MGB [5] MTB, MGC, MCE [6] MCB, MCF, MCD [7] MCA [8] MCG, MCI, MCD [9] MCA, MCB, MGD [10] MTE [11] MGD [12] MCB [13] MGD [14] MCA [15] MTE [16] ZCB, MCD, MCF [17] MCA, MCG [18] MCA [19] MCG [20] MCB [21] MCC, MCE, MCI [22] MCC [23] MCC

also incorporated barley, oats, and lentils into his rotations with cajete maize, beans, and wheat.[1]

Corral management

In Zaragoza and Huautla, sheep and goats were herded during the day and corralled at night. Corrals played an important role in maintaining soil fertility since they accumulated large amounts of high quality manure that provided nutrients to the soil for upwards of 15 years.[2] Sixty-one percent of respondents who managed corrals would rotate them.[3] Respondents followed yearly,[4] biannual,[5] and three month rotations.[6] Another respondent rotated his corrals every 2 – 3 years.[7]

Some respondents managed their corrals according to the dry and rainy season. One respondent located his corral on sandy soils during the rainy season and on clayey soils during the dry season.[8] This was most likely to provide adequate drainage during the rainy season from the corrals for the benefit of his animals. Also, since many clayey soils in the region would crack during the dry season, animal manures became incorporated deeper through the soil profile. In another case, respondents rotated their corrals every three months during the rainy season.[9] Thirty-nine percent of respondents with corrals did not rotate them. Instead, they swept the manure to neighboring fields.[10]

The accumulation of manure in corrals often presented too high in nitrogen content – heat (*caliente*) – for most crops in the first year.[11] Fields were subsequently fallowed,[12] planted to squash and chilacayota squash (*Curcurbita ficifolia*),[13] or planted to vegetables.[14] In contrast to corrals for sheep and goats, donkeys and horses were often kept on stakes and ropes that were moved periodically through fallow agricultural fields, while oxen free pastured in the mountains when not at work.[15]

Fertilizers

Modern agricultural technologies in Zaragoza and Huautla were adopted to differing degrees. Farmers in Zaragoza first acquired synthetic fertilizers from merchants in the 1980's,[16] as well as from assistance programs, such as PROCAMPO in the late 1990's.[17]

Fifty percent of respondents in Zaragoza described the negative impacts of synthetic fertilizers.[18] As one respondent said, "with chemical fertilizers, the soil is lost."[19] Farmers preferred locally available soil amendments to synthetic fertilizers because of erratic rainfall patterns,[20] detrimental impacts of synthetic fertilizers on soil health,[21] and the long-lasting soil fertility provided by manures.[22] The other 50% of respondents who used synthetic fertilizers reported that they had increased the size of plants[23] and improved yields.[24] However they applied fertilizers moderately in small handfuls (*puños*) when weeding (*labrar*) or

[1] MCI [2] ZCA [3] ZCB, ZTC, MCB, MCE, MCG, MCH, MGB, MGD, MTE, MCA, MGC [4] MCB, MGB [5] ZTC, MCA, MGC [6] MCF, MCG, MCH, MGA [7] MGB [8] ZTC [9] MCA [10] ZCC, ZTA, MCC, MCI, MTD, MCA, MGC [11] MGC [12] MCB [13] ZCB, MCE, MGD, MGC [14] MTE [15] MGB [16] ZCC, ZGA, ZTB, ZTF [17] ZCB, ZTE, ZTD [18] ZCA, ZCC, ZTB, ZCC, ZGA [19] ZGA [20] ZCC [21] ZGA [22] ZCA [23] ZTE [24] ZCB

mounding (*encajonar*) their crops and in combination with other soil fertility management strategies.[1]

Similarly in Huautla, synthetic fertilizers were first introduced in the 1980's through a government program for agricultural credit called *Banco Rural*.[2] Farmers received support from an extensionist (*técnico*), new wheat and bean varieties, and small loans to purchase agricultural inputs that were to be paid off at the end of the season. However, the program only lasted for three years because farmers defaulted on their loans. "It affected us a lot. We paid an interest, and people dropped out because they couldn't pay it back, so it ended."[3] Others remembered first adopting fertilizers through the assistance programs: SEDESOL's PROCAMPO in 1998;[4] and the non-profit *Programa de Intercambio, Dialógo y Asesoría en Agricultura Sostenible y Seguridad Alimentaria en América Latina y el Caribe* (PIDAASSA)'s program called *Maíz y Frijol*.[5]

In comparison to Zaragoza, more respondents in Huautla (84%) reported not adopting synthetic fertilizers.[6] Reasons for this included poor performance in dry years,[7] detrimental effects on soil quality,[8] cost,[9] and poorer grain quality.[10] Farmers noted that plants only responded well to synthetic fertilizers in good rainfall years, which recently have been infrequent.[11]

Synthetic fertilizers changed,[12] ruined,[13] or burned soils.[14] Immediate increases in yields decreased long-term productivity.[15] The prohibitive costs of fertilizers were reported to have risen to $850 pesos per 50 Kg of urea and $900 pesos per 50 Kg of superphosphate.[16] Moreover, the grain grown with synthetic fertilizer reportedly was lighter and suffered greater post-harvest insect damage than the heavier grains nourished on locally available soil amendments.[17]

However, one Huautla farmer did speak favorably of fertilizers that enabled his family to meet or exceed their own production needs. "Our production has improved. We do not buy maize. It is not like before when in a year we did not produce enough to eat."[18]

Pesticides

Zaragoza farmers introduced herbicides and pesticides in bean production along with fertilizers as early as the 1980's.[19] Others only recently adopted pesticides starting in the late 1990's[20] and even just since 2005.[21] PROCAMPO provided 1 liter of pesticides per farmer for treating beans, which were applied by 50% of respondents in Zaragoza.[22] These farmers all sowed seasonal crops in temperate lands where flea beetles were a serious problem. Nevertheless, a small percentage of farmers in Zaragoza were strongly opposed to pesticides. "Chemicals make us crazy," said one respondent.[23] "We do not use pesticides; they smell bad."[24]

[1] ZTE, ZTF [2] MGB, MTC, MTD [3] MTD [4] MCE, MTA [5] MCG, MGC [6] MCD, MTB, MCA, MCB, MCC, MCD, MCF, MCG, MCH, MCI, MCJ, MGA, MTA, MGC, MTC, MTE [7] MCG, MGC [8] MCD, MCC, MCI, MTE [9] MCD, MTB, MCA, MCJ, MTA, MTC [10] MTC [11] MCG, MGC [12] MCC [13] MCD [14] MCI [15] MCD [16] MCD, MTA, MTB, MTC [17] MTC [18] MTD [19] ZGA, ZTA [20] ZTE [21] ZTF [22] ZGA, ZTA, ZTB, ZTE, ZTF [23] ZTB [24] ZTD

In Huautla, pesticides arrived in the 1980's through the same government rural credit program of *Banco Rural*.[1] A few farmers began using pesticides since 2005 to control spontaneous plants.[2] However, 71% of respondents in Huautla never used pesticide (n = 17). Farmers expressed that the potential health risks of applying pesticides still outweighed the savings in time weeding beans,[3] which one farmers estimated at 4 – 5 days of hand weeding accomplished in 1 day using herbicides.[4]

Tractors

Tractors were first used in Zaragoza in 2000 through government programs.[5] However, the frequent use of tractors in Zaragoza did not begin until 2004 when a group of farmers purchased a tractor from the neighboring community of Tres Lagunas.[6] Only 22% of respondents in Zaragoza did not report using tractors, due in part to the way that discing inverted soil layers (n = 9).[7]

Even those who used tractors recognized disadvantages to the technology for their soils. They found that the discs destroyed the aggregate structure.[8] Whereas the Egyptian plow cultivated to 30 cm, tractors cultivated to a much deeper 80 cm, which brought the poor soil (*cascajo*) to the surface.[9] This in turn increased their dependence on synthetic fertilizers to maintain acceptable yields.[10] Still, primary advantages that respondents cited were saving on labor[11] and more thoroughly working the soil.[12]

In Huautla, a tractor was purchased by the municipality in the 1990's that farmers could rent.[13] Nevertheless, 81% of respondents in Zaragoza did not use tractors (n = 16) due to the steep slope of their fields,[14] the loss of soil moisture provoked by tractor cultivation,[15] and the associated costs of renting tractors.[16] One farmer told of being unable to locate residual soil moisture for sowing cajete maize after he used a tractor to cultivate his field.[17] For this reason, tractors were not used in cajete maize regions of either Zaragoza or Huautla. Those who did use tractors reported doing so on rare occasions for seasonal crops when there was not enough time to cultivate with animals,[18] or in the exceptional case of one farmer who managed two large fields of 4 hectares combined that would take too long to plow otherwise.[19]

Family self-sufficiency

Across both communities, families reported a median annual consumption of 911 Kg of maize, 287 Kg of beans, and 370 Kg of wheat to meet basic family needs. Consumption of maize was greater in Zaragoza (1,432 Kg/year) than in Huautla (780 Kg/year), while wheat followed the opposite trend (Table 2.10). This corresponded to the relative importance of wheat in Huautla, where the production of maize had been challenged by unfavorable

[1] MGB, MTB, MTC, MTD [2] MGC [3] MCI, MTE [4] MCI [5] ZGA, ZTA [6] ZTB, ZTC, ZTD, ZTE [7] ZCB, ZTE [8] ZGA [9] ZTC, ZTF [10] ZGA [11] ZTA, ZTD [12] ZTB, ZTC [13] MCD, MCA, MCI, MGD, MTD [14] MCC, MCG [15] MCD, MCJ [16] MTE [17] MCG [18] MCA [19] MGD

climatic conditions. It was also common to mix maize and wheat in the *masa* for tortillas to produce a greater volume (*porque rinde más*).[1]

Table 2.10: Family consumption of basic grains in Zaragoza and Huautla (Kg/year).

	Zaragoza			Huautla		
	Maize	Beans	Wheat	Maize	Beans	Wheat
n	10	9	10	16	14	16
Minimum	500	50	52	130	50	130
1st Quartile	775	149	232	352	137	258
Median	1,432	200	410	780	255	370
Mean	1,984	194	437	847	348	674
3rd Quartile	1,962	261	710	1,050	352	984
Maximum	7,800	330	782	2,738	1,250	1,825

Production

This section describes the agricultural activities associated the major grains produced in Zaragoza and Huautla: cajete maize, seasonal maize, beans, and wheat. An analysis of crop yields follows (page 55), as well as an analysis of the timing (page 55) and labor requirements (page 58) for agricultural activities.

Respondents in Zaragoza reported that cajete maize was sown 8 – 15 days after rows were plowed (*surquear*).[2] The latest sowing date for cajete was March 13,[3] though some farmers plowed rows as early as January 26 and sowed their fields February 4 – 5.[4] Food, drink, and $200 pesos per day were typical fare provided to workers (*mozos*).[5] It was rare that they did guetza since so few planted cajete maize.[6]

Workers were also hired for weeding (*labrar*) and for the harvest.[7] Weeding occurred one month after sowing.[8] For both cajete and seasonal maize, weeding (*labrar*) involved passing the Egyptian plow between rows. This step required a high level of skill with the plow to avoid the young maize plants. The *labranza* was followed by the labor-intensive step of removing overturned clods of soil from the young maize plants and simultaneously pulling weeds that had been dislodged by the plow (*destapar*).

Soil cultivation (*barbechar*) for seasonal maize in Zaragoza for some occurred between December 20 and January 15[9] while they were also cultivated after May 20.[10] Slopes cultivated by plow (*yunta*) for all seasonal crops (seasonal maize, beans, and wheat) took approximately 4 times as long to cultivate than tractors on flatlands,[11] while the charge for tractor cultivation was $500 pesos per hectare.[12] Interestingly, despite a female respondent's hesitation about using tractors for cultivation, it ultimately was her husband's decision.[13]

[1] ZTD [2] ZCA, ZCB [3] ZCA [4] ZCC [5] ZCA [6] ZCB [7] ZCA [8] ZCB [9] ZGA [10] ZCC [11] ZTB, ZTC [12] ZTB [13] ZTE

Sowing seasonal maize occurred from May 15 – June 20,[1] depending on the weather.[2] Still others considered May 20 to be their earliest sowing date.[3] The earlier the sowing, the better the chances of a good harvest.[4] Often seasonal maize was intercropped in clumps of seed called *matas* that included maize, beans, squash, etc.[5] When sowing, one person plowed furrows while 1 – 2 others cover the seeds with soil using their feet (*tapar a pie*). One farmer paid workers $450 pesos each to help with sowing seasonal maize.[6]

After sowing, seasonal maize was weeded (*labrar*) 20 days[7] to 1 month later,[8] often with the help of workers to uncover plants (*destapar*).[9] Mounding (*encajonar*) occurred approximately 1.5 months from sowing,[10] or 8 – 15 days after weeding (*labrar*).[11] Those farmers that used urea fertilizers applied it either at the weeding (*labrar*)[12] or mounding (*encajonar*) stages.[13] Harvest occurred from December 20 – January 15,[14] with some hiring from 4 – 7 workers.[15] Since seasonal maize was often sown in polyculture, farmers harvested multiple times starting with beans, followed by ears of maize, stover, and lastly chilacayota squash.

In Zaragoza, soil cultivation and sowing dates for beans varied greatly. Some cultivated their fields from February to March 15,[16] while others reported April 20 as the first cultivation date.[17] Still others cultivated from June 20 – July 8.[18] Tractor cultivation was rented at approximately $750 pesos.[19] Farmers sowed beans from July 12 onward,[20] until July 20, from July 20,[21] from July 12 to August 8,[22] starting July 15,[23] or from July 15 to August 15.[24] One respondent incorporated weeds that grew during the rainy season into the soil of fields using his Egyptian plow until he decided to sow them.[25] Beans were broadcast sown[26] or sown in rows.[27] Generally a donkey pulled a tree branch by a rope across the field to cover the bean seeds (*arrastrar la rama*).[28]

Bean fields were weeded by hand anytime after August to November.[29] Approximately 2 – 3 workers assisted families with weeding.[30] Some farmers in Zaragoza also fumigated their bean crops for insect pests and weeds. Beans were harvested (literally pulled from the ground, *arrancar*) at the end of December.[31] Some farmers recruited 6 – 7 workers to assist with the harvest.[32] To separate the beans from their pods, tethered donkeys would walk in circles over the dried plant biomass.[33]

Wheat fields were cultivated from February to March 15[34]. Different varieties of wheat were sown during the growing season: *largo* in June, *pavón* and *argentino* in July, and *barrigón* in August.[35] Some farmers did not grow all these varieties, and would only sow wheat from August 20 to September 20.[36]

Wheat was harvested with the help of approximately 2,[37] 5,[38] or even 7 workers.[39] In addition to approximately $70 pesos per day per worker, farmers provided them with food and drink.[40] The wheat was left to dry for 15 days before threshing (*trillar*), which involved walking tethered donkeys[41] or horses[42] in circles on the dried plant biomass. Farmers turned

[1] ZCA, ZTE [2] ZGA [3] ZCB [4] ZTE [5] ZTB [6] ZTD [7] ZCA, ZTD, ZTF [8] ZCC, ZGA, ZTE [9] ZCC [10] ZGA [11] ZTD, ZTE [12] ZTD [13] ZGA [14] ZGA [15] ZTB, ZGA [16] ZGA [17] ZCC [18] ZCB [19] ZTD [20] ZCA [21] ZGA [22] ZTE [23] ZTD [24] ZTA [25] ZTF [26] ZCA [27] ZGA [28] ZTE [29] ZCB, ZTD [30] ZTB [31] ZCA [32] ZGA [33] ZCA, ZGA [34] ZGA [35] ZGA [36] ZTE [37] ZCB [38] ZGA, ZTC [39] ZTE [40] ZTE [41] ZGA [42] ZTA

the biomass with pitchforks as the animals passed. Once threshing was completed, one person would wind winnow (*arrear*) the wheat from the chaff.[1]

In Huautla, fields that would be planted with cajete maize were cultivated throughout the dry season. The first dates for soil tillage (*barbechar*) were determined by the prior year's harvest,[2] but generally occurred from October – December.[3] In some years, there was not enough rain to cultivate soils properly for cajete maize, in which case some respondents opted to not sow it.[4] This was not only due to the ease of tilling the soil, but also the requirement of cajete maize for residual soil moisture until the rainy season began. Soil cultivation for cajete maize involved tilling the soil in three directions over two months prior to furrowing: *barbechar* ⇄, *recruzar* ⤡, and *recortar* ⤢.[5] The latter two tillages occurred from November – December.[6] Their purpose was to disrupt the capillary action of soils, thus conserving residual soil moisture after the rainy season. One respondent who received assistance from neighbors for soil cultivation paid them $300 pesos per day along with food for a period of 8 workdays.[7] Fields were left to rest (*descansar* or *asentar la tierra*)[8] 8 – 15 days after furrowing (*rayar*) so that farmers could judge the soil moisture with their digging tools (*pico y coa*).[9] Some farmers furrowed on specific dates, such as on March 20 in the case of one respondent.[10] Cajete maize was sown from March 10 – April 20,[11] while others had much more narrowly defined dates that they would sow (April 6 – 8).[12] Each family provided *tepache* and food to the neighbors who helped with the sowing (*cajeteo*).[13]

Weeding cajete maize was not as essential as with seasonal maize, since cajete better out-competes weeds that really began to grow with the rainy season. However, some farmers weeded with the Egyptian plow (*labrar* or *el primer arado*)[14] and uncovered plants (*destapar* or *arrancar la hierba*) with the first regular rains of the season (*cuando vienen más seguido*).[15] Others weeded 2 months after sowing when plants had reached approximately 20 – 30 cm.[16] A respondent without his own plow or livestock (*yunta*) paid his neighbors to weed the fields for $300 pesos per day over 8 days.[17] It was even less common that farmers mounded (*encajonar*) cajete maize. Still, mounding was carried out 2 weeks from weeding (*labrar*), when plants had reached approximately 50 cm – 1.2 m.[18] In some cases, harvests generally were obtained prior to seasonal maize, although also as late as mid-December.[19] Harvests would occur gradually for some,[20] while others who planted cajete maize year-in and year-out would make every effort to harvest and cut the stover in a timely manner. See page 46 on rotations of cajete maize.

Soils for seasonal maize were cultivated with the first rains.[21] Farmers in Huautla most typically used the plow to till their fields (*barbechar*) as early as January or February[22] through June, depending on soil moisture levels.[23] Fields were then furrowed (*rayar* or *surquear*) and sown to seasonal maize at the start of the first consistent rains of June.[24] Alternatively, soils were tilled, furrowed, and sown in the same day.[25] The same system of intercropped *matas* using the *tapar a pie* method was practiced in Huautla. Seasonal maize

[1] ZTD [2] MCD [3] MCH, MCJ [4] MCJ [5] MCE, MCF, MCJ [6] MCH [7] MCF [8] MCC, MCJ [9] MCC, MCD, MCG, MCH, MCJ [10] MCE [11] MCD [12] MCE [13] MCC [14] MCF [15] MCJ, MCF, MCG, MCH [16] MCI, MCJ [17] MCF [18] MCI, MCJ [19] MCD [20] MCG [21] MCC [22] MCI [23] MGC [24] MGB [25] MCD, MCE

was sown with the earliest summer rains in June.[1] Typically, July 16 was the last sowing date for seasonal maize.[2] If farmers were unable to sow seasonal maize before these sow dates, they refocused their production efforts on beans and wheat.

Some farmers offered monetary compensation, food, and drink to community members who helped them sow and mound seasonal maize,[3] though much more typically farmers in Huautla assisted one another based on non-monetary forms of exchange (*guetza*). Weeding and uncovering (*labrar* and *destapar*) occurred approximately 25 – 30 days after sowing seasonal maize.[4] Mounding (*encajonar*) 15 – 20 days after weeding[5] was conducted in good years when farmers wished to increase their yields.[6] In poor years the additional effort of mounding seasonal maize was not merited.[7]

Like in Zaragoza, Huautla farmers cultivated their fields to control weeds until beans were sown,[8] depending on how the rains came.[9] Some farmers tilled (*barbechar*) their fields for beans at the same time as for seasonal maize from May 20 – July.[10] Beans were sown, typically by broadcast seeding,[11] at different times. Some planted beans 4 – 8 days after cultivating the soil[12] while others sowed beans June 24 – July 30,[13] July 1 – August 15,[14] July 15 – 30,[15] or July 15 – August 15.[16]

Bean fields were weeded from one month after sowing[17] until the beans started to flower, depending on the amount of weed pressure in any given field.[18] Weeding was done by hand,[19] though a small number fumigated for weeds with *Reflex* (Fomesafen) when at approximately 20 cm.[20] For harvesting beans, they pulled (*arrancar*), beat or threshed (*asoltar* or *varear*), and winnowed (*aventar*), before the grain was stored (*guardar*).[21]

Tilling for wheat occurred 8 – 15 days prior to sowing,[22] or simultaneously with tilling for seasonal maize.[23] Some farmers paid $300 pesos, food, and drink for assistance with soil cultivation.[24] Like in Zaragoza, soils were tilled to control weeds during the season until wheat was sown.[25] The most common wheat in Huautla was adventuring wheat (*venturero*),[26] while only some still sowed seasonal wheat (*temporal*). Farmers decided to sow seasonal wheat based on May rainfall levels and dry-farmed wheat based on June and July rainfall.[27] Seasonal wheat was sown starting May 20 through June.[28] Adventuring variety *pelón* was sown in August while more precocious varieties (*mas violentos*) were sown after October.[29] Most typically, wheat was broadcast sown (*tapar al voleo*) between August 15 – December 15 with the rains.[30] Some farmers planted twice: the first time 8 days after cultivation in August or September, and the second time in November or December.[31] If there was not enough rain, farmers would skip the second planting.[32]

Weeding was not required in adventuring wheat since frosts kill weeds after September 20.[33] One respondent sowed his wheat in June and weeded by hand[34] though this was not commonly practiced. Seasonal wheat was harvested in January and February[35] while adventuring wheat was harvested in March and April. The early-sown *pelón* variety of ad-

[1] MGD, MTE [2] MCH, MGC, MGD, MTE [3] MCF [4] MCH, MTD [5] MTE [6] MCA, MCE [7] MTD [8] MCG [9] MCH [10] MGC [11] MCA [12] MCA, MCH, MCJ [13] MCH [14] MTE [15] MCH [16] MCE [17] MTB [18] MGD [19] MCE, MTE [20] MGB, MTD [21] MCA, MCE, MCG, MCI, MGC [22] MCC [23] MCD, MGC [24] MCF [25] MGD [26] MCB [27] MCH [28] MGC [29] MCJ [30] MCE, MGB [31] MCG [32] MCG [33] MCF [34] MGC [35] MTD

venturing wheat was harvested in April while more precocious varieties were harvested in March even though they were sown later.[1] Similar to Zaragoza, wheat was cut (*segar* or *cortar*), bundled (*manojear*), threshed (*trillar* or *despejar*), wind winnowed(*aventar*), and stored (*guardar*).[2] These steps were more rapidly accomplished for adventuring wheat than for seasonal wheat since they were threshed during the dry season when the wheat was most brittle.[3]

Yields

My analysis of grain yields focused on four crops that were consistently reported by farmers: cajete maize, seasonal maize, beans, and wheat. Yield data for less reported crops were also collected, though not analyzed in the figures. I first asked what the farmers considered to be good and poor yields. The median good crop yields in Zaragoza and El Rosario all fell between 500 – 1,000 Kg per hectare, while the median poor yields were close to zero (Figure 2.2).

While the majority of respondents in both Zaragoza and Huautla provided estimates of good and poor harvests, few respondents recalled past grain yields (Figure 2.2). The number of farmers who reported yield decreased going back in time for both communities. Additionally, farmers' memories reached at best as far back as 2004. This challenged making comparisons, however it was observed that farmers' yields are decreasing, with almost complete crop failures for all major crops in 2010. Wheat and beans in Zaragoza and cajete maize in Huautla performed well between 2004 – 2006 when other crops performed less well. However these data are not by any means conclusive, since the yields were reported by a limited number of farmers and far exceeded the median estimated good yield by a much larger number of farmers.

Outlying data was evidenced in the comparison in yield between cropping systems (Figure 2.3). No obvious pattern emerges between cropping systems in either community, except that overall productivity was on the decline in recent years.

Farming activities

I asked respondents to describe their farming activities associated with the production of each crop for which they reported yields (page 55). I recorded farmers' responses on a large sheet of paper that depicted the months of the year on the x-axis and the crop on the y-axis. Farmers described the number of hours, people, and animals required to accomplish each activity. I also noted additional qualitative information that emerged from our conversation. When analyzing the data, farming activities were grouped together into more general categories to facilitate comparisons between crops. See page 51 for more detailed categories.

While farmers reported a diversity of crops grown, cajete maize, seasonal maize, beans, peas, and wheat were the most consistently reported. Farmers who reported dry-farmed wheat (*venturero*) were combined with those who simply reported wheat. Likewise, those

[1] MCJ [2] MCB, MCC, MCD, MCG, MCH, MCI [3] MGC

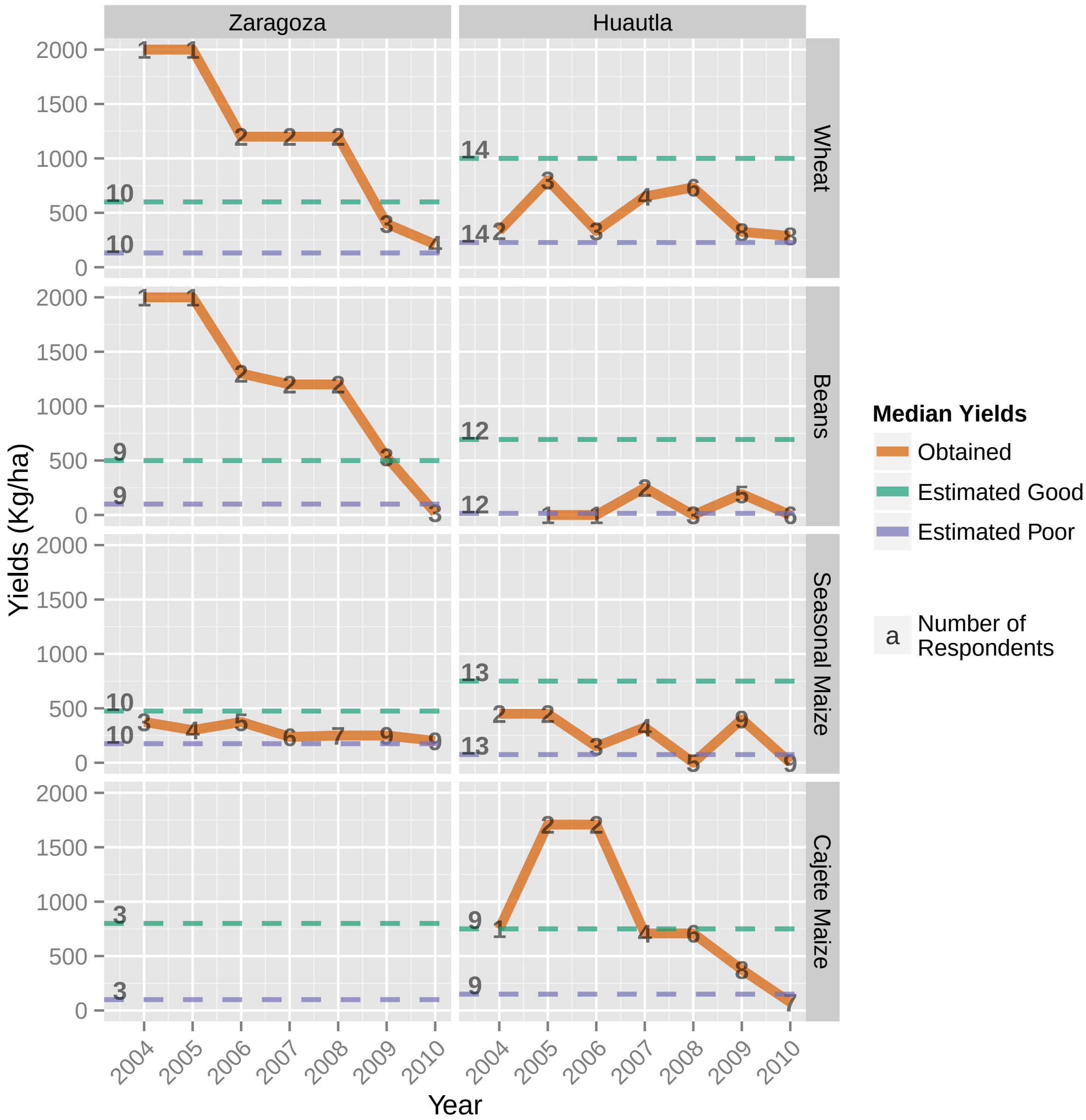

Figure 2.2: Median yields reported by Zaragoza and Huautla farmers from 2004 – 2010 for wheat, beans, seasonal maize, and cajete maize. Median estimates by farmers of good and poor yields are represented as dashed marks. The number of respondents for each element is labeled.

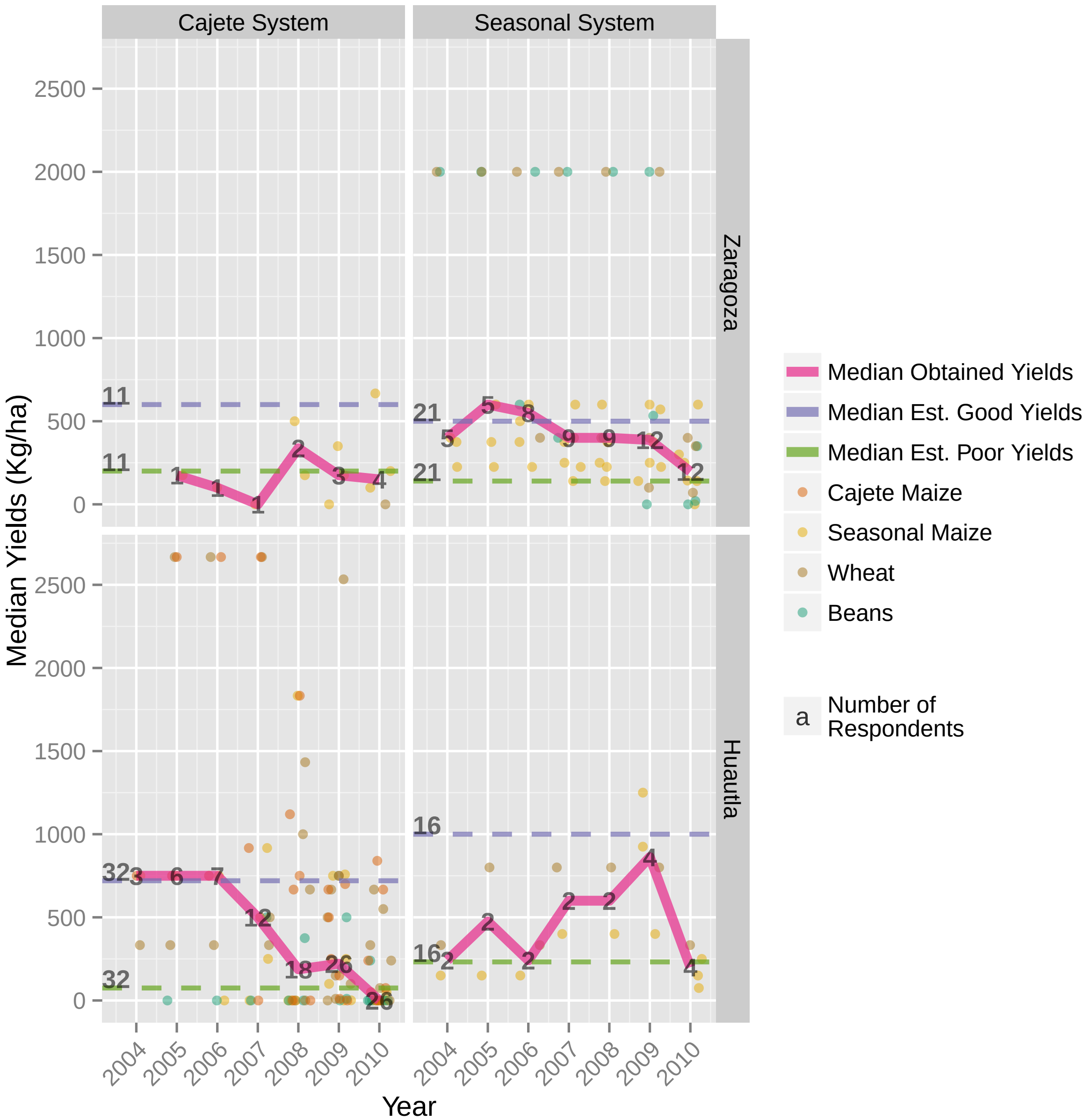

Figure 2.3: Median yields reported by Zaragoza and Huautla farmers from 2004 – 2010 growing seasons for all primary grain crops combined. Median estimations by farmers of good and poor yields for all crops are represented as dashed marks, and actual yield estimates that were used to calculate the median are depicted as colored circles.

who reported dry-farmed peas were combined with those who reported peas. A spectrum of planting dates existed for these crops that went beyond the level of detail recorded in this study. Also, some crops with limited production – barley, fresh corn (*elotero*), irrigated maize, lentils, oats, and seasonable vegetables – were excluded from analysis.

Cajete maize was the distinguishing feature of farmers' crop assemblages. In both communities, farmers that grew cajete maize often also cultivated seasonal maize, beans, peas, and wheat (Figures 2.4 and 2.5). The timing of farming activities for seasonal maize, beans, peas and wheat was approximately the same between farmers in the *Cajete System* and *Seasonal System* categories. Densities of farming activities for the agroecosystems that included cajete maize and those that did not showed a reduced concentration of labor activities during the months of June – July, and an increased concentration in the dry season months of September – April (Figure 2.6). This difference in the distribution of farming activities was influenced by cajete maize on the overall density.

Huautla farmers who grew cajete cultivated their fields for seasonal maize earlier than those farmers who were only dedicated to seasonal crops (Figure 2.5): November – January for cajete maize. Similarly, farmers in Zaragoza who produced cajete maize cultivated their fields during the same months though there was less of a temporal gap between cajete and seasonal maize for soil cultivation (Figure 2.4). This may be due to the earlier onset of the rainy season in Zaragoza compared to Huautla; Farmers in Zaragoza sowed seasonal maize in mid-May to early-June whereas farmers in Huautla planted maize in mid-June to mid-July.

Farming activities for cajete maize consistently occurred earlier than seasonal maize (Figure 2.7). For cajete maize, farming activities were also spread across a greater number of months than seasonal maize. Farming activities for cajete maize were concentrated in February and March, whereas agricultural activities for seasonal maize were concentrated in June (Figure 2.8). The greater evenness of farming activities for cajete maize during its cropping cycle when compared to seasonal maize was most clearly depicted in Huautla. While the median months for soil cultivation in Zaragoza and Huautla were the same, the ranges were much greater in Huautla than in Zaragoza. This difference in range may be explained by the use of tractor cultivation in Zaragoza that allowed farmers to cultivate soils in much shorter periods of time.

Labor

This section summarizes the labor associated with farming activities reported on page 55. Farmers described the number of days required for each crop's farming activity, as well as the number of people, animals, and tractors required. For the purposes of comparison, a normalized metric of days of labor per hectare was calculated from the hectares per crop produced by each farmer, and the associated human, animal, tractor, and total labor inputs per activity.

I received highly variable responses for estimates of labor. Data from one farmer were excluded prior to analysis due to exceptionally high responses overall, such as 480 human work hours and 960 animal work hours per hectare for preparing soils for cajete maize,

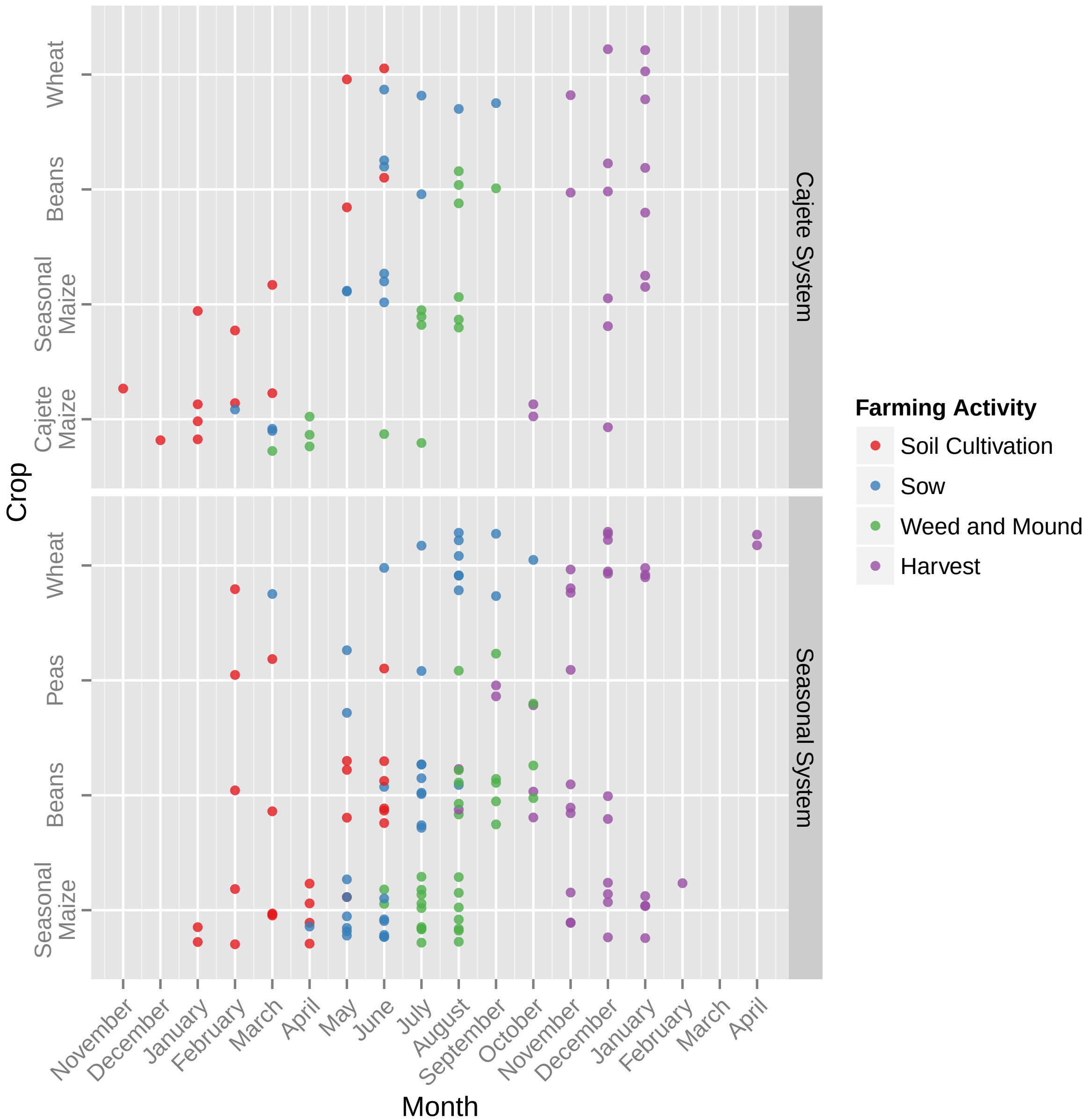

Figure 2.4: A scatterplot of farming activities reported in Zaragoza for the major grain crops of seasonal maize, cajete maize, wheat, beans and peas. Coloring depicts groups of farming activities practiced by farmers.

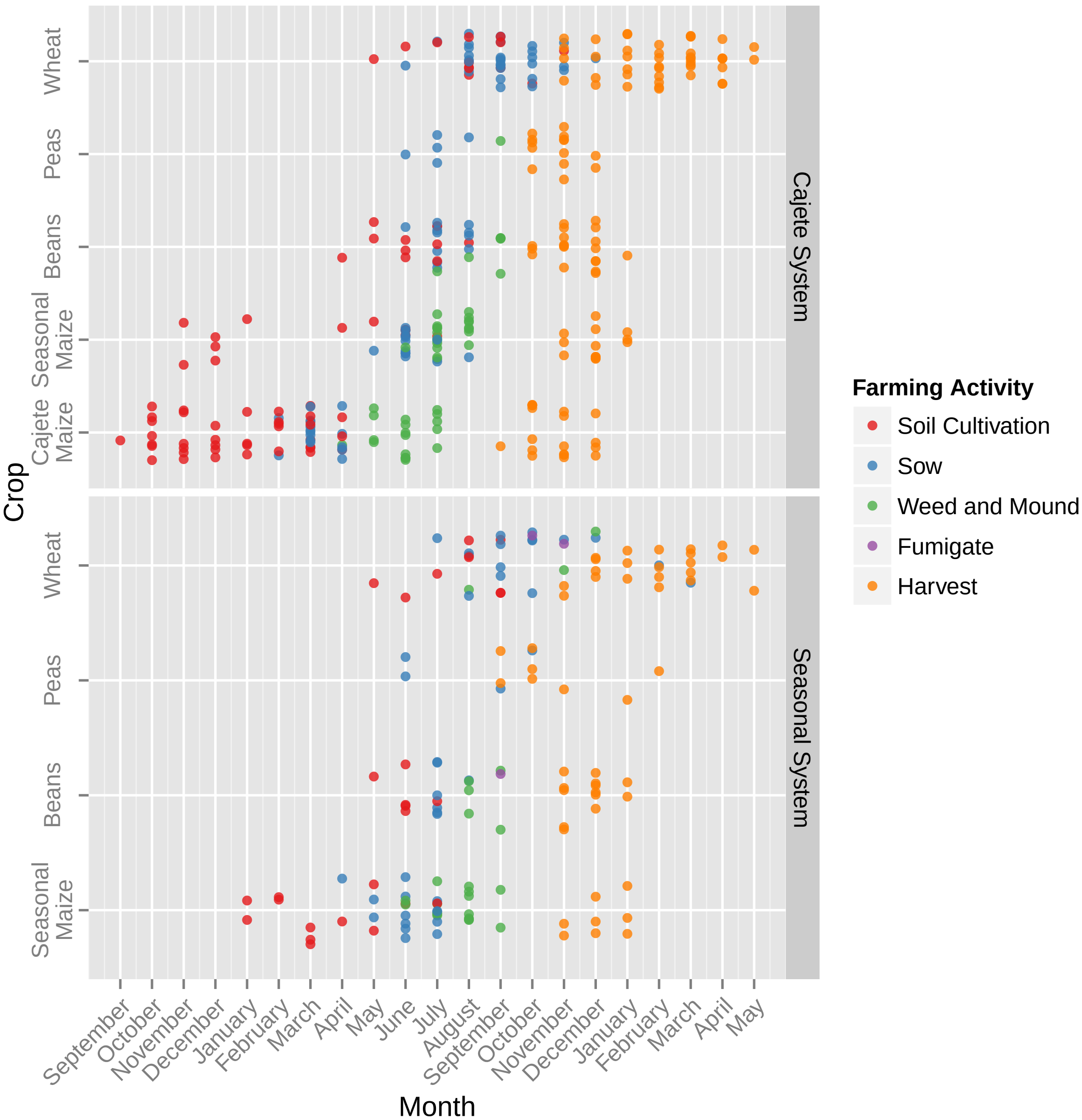

Figure 2.5: A scatterplot of farming activities reported in Huautla for the major grain crops of seasonal maize, cajete maize, wheat, beans and peas. Coloring depicts groups of farming activities practiced by farmers.

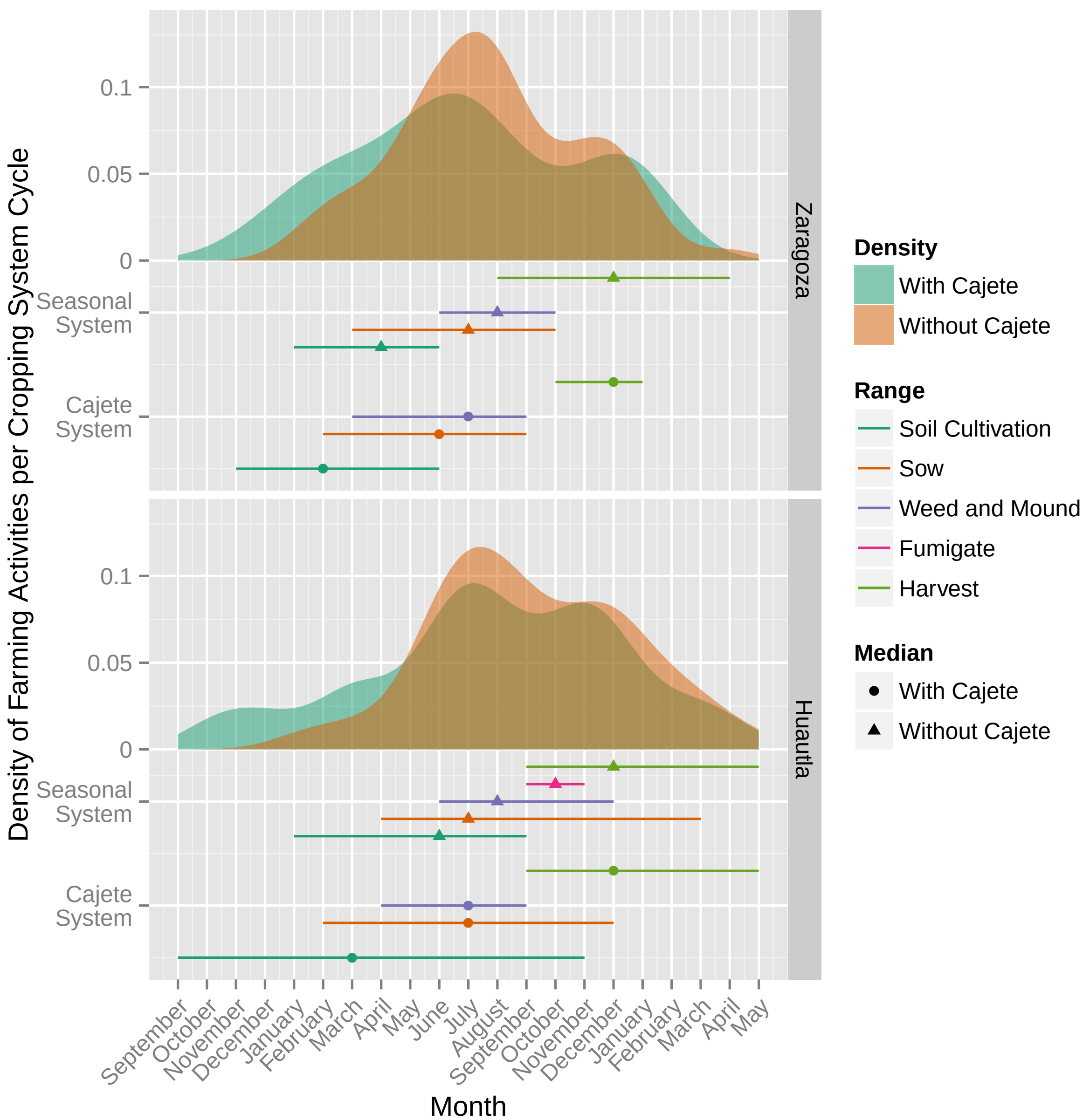

Figure 2.6: Density plots of agricultural activities for crop assemblages by farmers who grew cajete (cajete maize, seasonal maize, wheat, beans, and peas) and those who did not (seasonal maize, wheat, beans, and peas) in the communities of Zaragoza and Huautla. The shaded areas for cajete and seasonal maize are both equal to a value of 1. For each agricultural activity, horizontal lines represent the range of months reported, while points represent the median months reported.

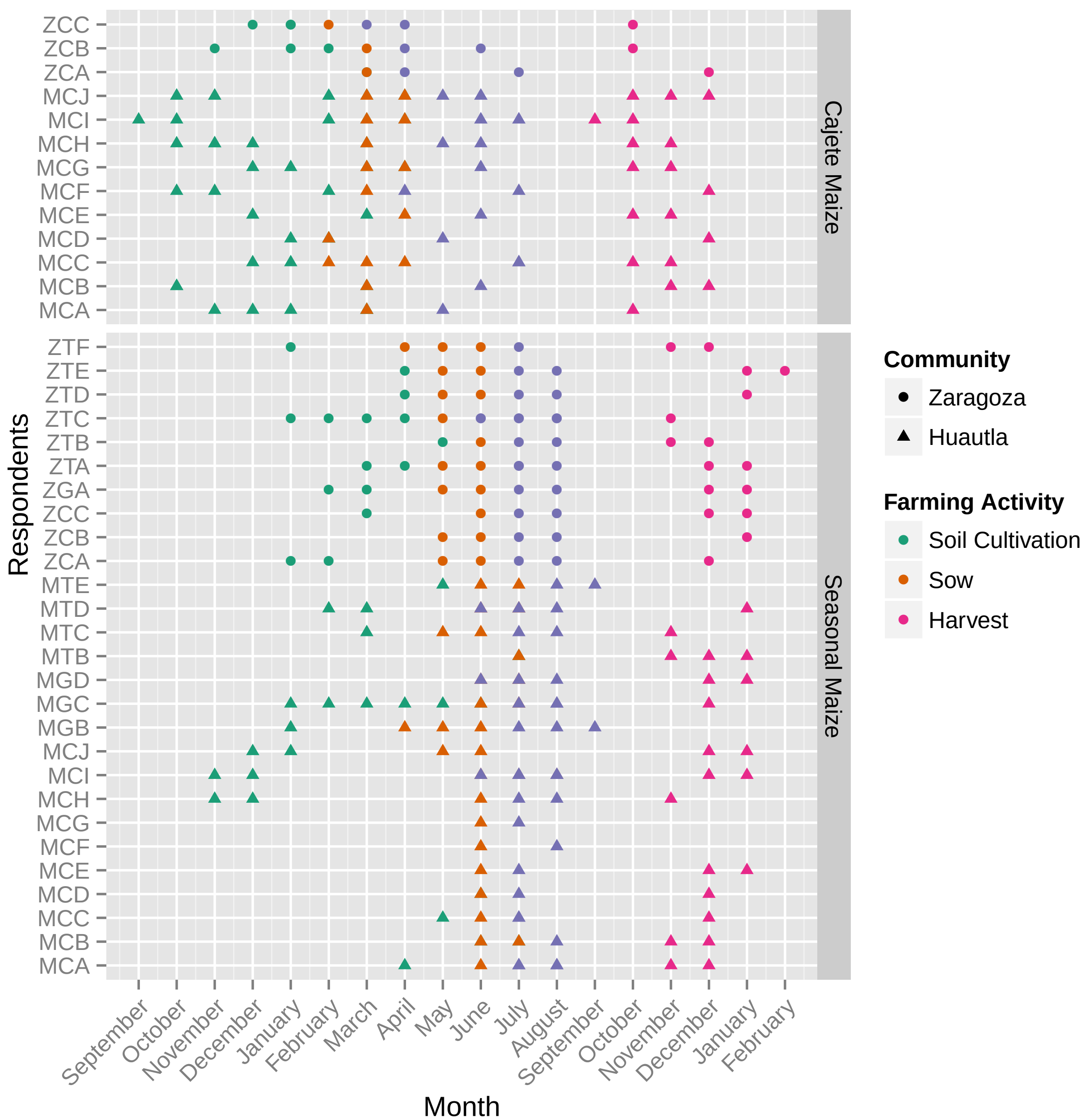

Figure 2.7: A scatterplot that depicts the months of farming activities associated with the production of cajete maize and seasonal maize reported by respondents in the communities of Zaragoza and Huautla.

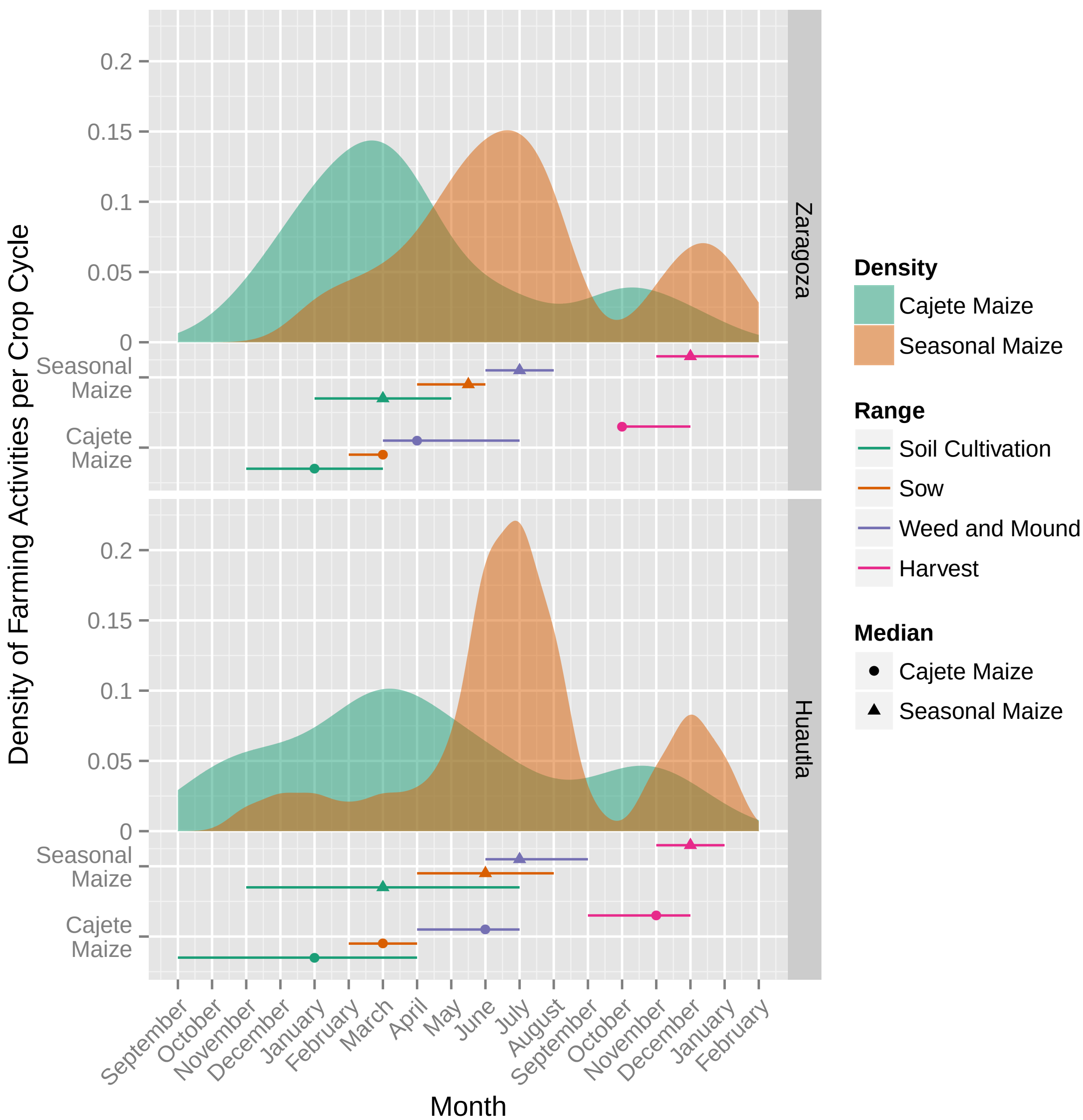

Figure 2.8: A density plot of farming activities over the cropping cycle for cajete and seasonal maize reported by farmers in Zaragoza and Huautla. The shaded areas for cajete and seasonal maize are both equal to a value of 1. For each agricultural activity, horizontal lines represent the range of months reported, while points represent the median months reported.

and 900 human work hours and 1,440 animal work hours per hectare for threshing wheat.[1] Another respondent's high values of 252 human hours and 210 animal hours per hectare for bean harvesting were also excluded.[2] Fumigation was not analyzed since only one respondent reported it. Still, the data was too highly variable to draw conclusions (Figure 2.9). A greater quantity of interviews combined with a more structured interview format might have produced more conclusive findings in this regard.

Shortages

Respondents were food secure to varying degrees. While all respondents in Zaragoza reported that they typically did not have to buy grain, the majority of them suffered a difficult year in 2010 that led them to purchase grains. This coincided with one of the highest rainfall years on record. Only one respondent said that it had been 10 years since they needed to purchase beans.[3] In Huautla, 26% of respondents had enough grain for tortillas in both good and bad years.[4] "There is always something to eat, even if it is only a salsa with nopalitos."[5] One household attributed their higher grain yields for the past 20 years to synthetic fertilizer.[6]

The more typical experience described by 90% of respondents in Zaragoza and 53% of respondents in Huautla was one of self-sufficiency in grain during good years and shortages of grain during poor years. However, the frequency and duration of grain shortages differed between respondents, partly due to the crops grown by different families. "When cajete maize is ready, seasonal maize is still growing"[7] and "we already have food to eat early in the season."[8] All respondents in Zaragoza had rarely experienced shortages, whereas in Huautla, grain shortages were a common occurrence.

Of these respondents, 5% experienced shortages in the month of September,[9] 32% experienced shortages for 2 months during the year between August and November,[10] 16% experienced 3 month shortages between June and September,[11] and 47% experienced over 7 months of shortages as early as January.[12] In the case of one family, June to August were the most difficult months.[13] This was the period of the year when they experienced shortages of both grain and water. Later in the year, while there may still be grain shortages until the harvest, they at the least harvested wild plants (*quelites*), young squash *calabacita*, and water from September – October.

In Huautla, 21% of respondents never had enough grain, even in good years.[14] In good years, the months without tortillas for one family was from May through September while in bad years they purchased grain year-round.[15] For another respondent, August to September were the "months of hunger" (*meses de hambre*),[16] since by October and November there were already green plants to eat. Every year these families purchased grain from neighbors or from the *Compañía Nacional de Subsistencias Populares* (CONASUPO), a subsidized food dispensary.

[1] MCE [2] MTD [3] ZGA [4] MCC, MCE, MGC, MTC, MTD [5] MCE [6] MTD [7] ZTD [8] ZCB [9] ZTB [10] ZCA, ZCC, ZTC, ZTE, MTA, MTE [11] ZCB, MCG, MGA [12] ZTD, MCA, ZTA, ZTF, MCF, MCB, MCI, MTB, MGD [13] MGA [14] MCD, MCH, MCJ, MGB [15] MCD [16] MGB

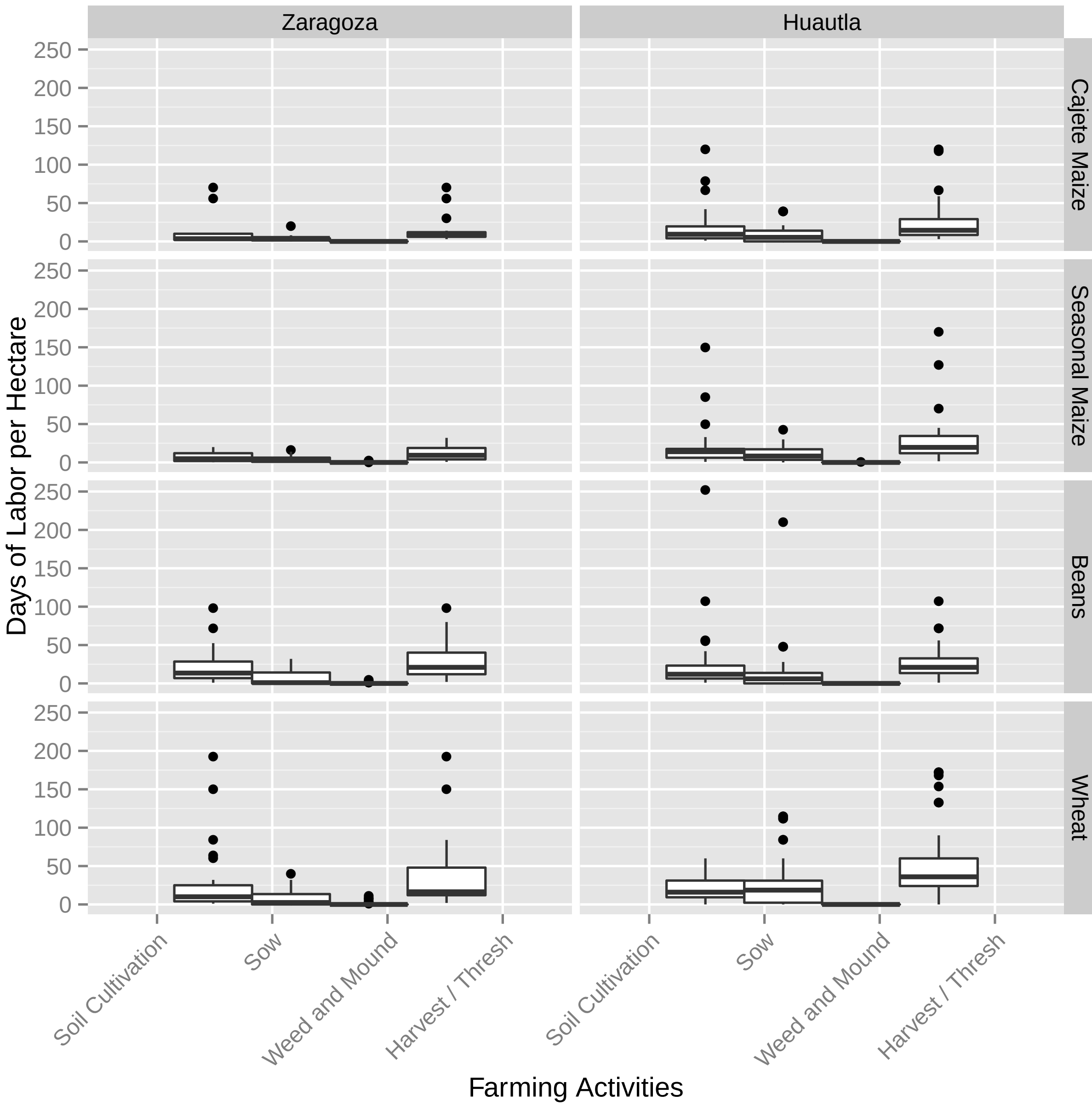

Figure 2.9: Boxplots of days of labor per hectare for the major grains produced Zaragoza and Huautla. A high degree of variability in the data with many potential outliers calls for better methods for documenting labor inputs.

Seed exchanges

I also asked farmers to describe their ability to sell grain in good and bad years. Respondents reported selling grains rarely, or at most 50 Kg of grain in a year.[1] The more common experience was to only produce grains the household (45% of respondents).[2] "One has to work for food" (*uno tiene que trabajar para la comida*).[3] Fifty percent of farmers interviewed in Zaragoza exchanged or sold grains within their communities.[4] In Zaragoza, maize was sold to families in *maquilas* (approximately 5 Kg) to an estimated total of 200 Kg in good years.[5] Wheat was sold in liters every 2 – 3 days to an estimated total of 100 Kg.[6] Other crops sold or exchanged in the communities included beans and peas.[7]

Sixteen percent of respondents in Huautla exchanged grain for labor between families,[8] contributed grain for social events,[9] and sold grain within the community.[10] The exchange of grain for labor was described as indirect; families gave grain to each other in times of need and also helped each other when there was work in the fields. Likewise, donations of grain to community events held no economic return to the families. Only one respondent reported selling grain every year within the community to fellow *paisanos*.[11] In 2010, they received 140 pesos per maquila of beans (1 maquila is approximately 5 Kg), $25 pesos per maquila of maize, and $35 pesos per maquila of wheat.[12] This respondent also sold vegetables and fruit such as mandarines, peaches, green beans, fresh corn, summer squash, avocado, and lemons.

Only twenty-one percent of respondents in Huautla sold or exchanged their grains outside the community.[13] One respondent from Huautla sold dry beans and vegetables occasionally in the Asunción Nochixtlán farmers' market,[14] while another sold his grain to an intermediary from Puebla who purchased beans and maize.[15] Others exchanged sacks of grain with absent landowners for use of their fields (*a medias*.[16])

Other exchanges

Respondents listed multiple alternatives for generating income to compensate for bad years, including artisanry, agricultural products, and livestock. In Zaragoza, no dominant alternative artisanry was reported. However, some respondents carved wooden religious statues[17] and were members of musical bands.[18] An elder used to weave rugs, however he and his spouse were unable to continue due to pain in their hands.[19] In contrast, all respondents in Huautla participated in the artisan industry of basket and sombrero weaving. While respondents did not dramatically increase weaving in bad years, the industry provided a stable income that supported families in years of poor harvest. Households wove a median of 19 *sombreros* per week, which would earn a total of $66 pesos through the intermediary at Huautla weekly farmers' market. Additionally, some families would weave baskets (*tenates*)[20] and would harvest palm from forests to sell or exchange to weavers in their community.[21] Local sources of natural palm fibers became brittle between the months of March

[1] ZCB, ZTA, MCB, MCI [2] ZCC, ZTB, ZTD, MCA, MCE, MCF, MCG, MCJ, MGA, MGB, MGC, MTD, MTE [3] MCJ [4] ZCA, ZGA, ZTC, ZTE, ZTF [5] ZCA, ZTC, ZTE [6] ZGA, ZTC [7] ZTE, ZTF [8] MCD [9] MTA [10] MTC [11] MTC [12] MTC [13] MCC, MCH, MGD, MTB [14] MCH [15] MGD [16] MTB [17] ZCA, ZTF [18] ZTF [19] ZGA [20] MCE, MCG, MTC [21] MGA

to May, at which time households would either weave with synthetic fibers[1] or reduce their output.[2]

Other sources of income during bad years included the sale of livestock and agricultural products. Cattle, turkeys, sheep, goats were the primary animals sold.[3] In Huautla, one sheep earned between $400 and $600 pesos, depending on the time of year when sold.[4] Respondents in Huautla reported selling between 1 and 16 head of sheep and goats per year, depending on necessity.[5] Government-subsidized greenhouse projects enabled some members of both Zaragoza and Huautla to sell tomatoes.[6] Others sold straw (*zacate*),[7] exchanged fruits and vegetables for basic goods with dispensaries (*tiendas*),[8] or sold vegetables in the farmers' markets.[9]

Grain markets

A commonly cited consequence of trade liberalization policies that Mexico adopted beginning in the 1990's has been the influx of foreign maize that destroyed national markets for farmers in Mexico. Perez Rodriguez and Anderson (2013) argue that low market values created by trade policies, such as the North American Free Trade Agreement (NAFTA), have undercut the ability of communities to generate an income from agriculture. To understand whether farmers perceived the effects of such political actions on their market access, respondents were asked, if they were to imagine a better market for their agricultural goods, would it change how they farmed?

The price of basic grains appeared to be influenced by local availability. In 2002 when a respondent from Zaragoza harvested 14 sacks of beans, the market value was 3 pesos per Kg, while in 2011, when local production was depressed, beans were worth 18 pesos per Kg.[10] When the price went up, there was a shortage of local production.[11] Moreover, respondents witnessed an inflation in the value of goods without an increase in what they received for their grains.[12]

In fact, farmers interviewed in Zaragoza and Huautla felt disadvantaged compared to larger-scale farmers in neighboring communities, such as in Santa Maria Jaltepec in the case of Zaragoza[13] and in the Mexican state of Puebla in the case of Huautla.[14] They also experienced that CONASUPO was underselling them already. The actual price would be much higher, and already farmers sold their goods in the community for more than the equivalent grains – though of lower quality – from CONASUPO.[15] Although this narrative was true to local perception by farmers, it should be noted that a cascade effect starting from national policy had most likely created the appearance of competition between neighboring communities or regions for suppressed market prices.

Forty percent of respondents from Zaragoza and 37% of respondents from Huautla expressed that a better market value would lead them to sell some grain. Of these, 25% from Zaragoza and 43% from Huautla would modify their farming practices. Some would plant

[1] MCA [2] MTB [3] ZCC, ZCB, MCH, MCI, MGA, MGB [4] MCI, MGA [5] MCI, MGA, MGB [6] ZTB, MCH [7] ZTD [8] ZTF [9] MTE [10] ZTE [11] ZTE, MGD. MTD [12] MGD [13] ZCA [14] MGD [15] MTC

more maize[1] or beans.[2] One respondent described, that he would only pay more attention to the production of beans.[3] The family used their corral for the goats, which was moved every 3 months, to maintain the fertility of their soils. The most important or high-value crops were grown in the most fertile soils where they would yield best (*donde hay mas abono para que haya mas*).[4]

Others imagined that a better market would encourage the youth to dedicate themselves to farming since in the past farmers had sown a *chile canario*, which had sold well.[5] The other 75% of respondents from Zaragoza and 57% of respondents from Zaragoza indicated that they would sell more grain, but not necessarily change the way in which they farm.[6] "Yes it would benefit us to sell grain in good years and we could buy those things that we do not produce."[7]

In contrast, 30% of respondents from Zaragoza and 52% of respondents from Huautla felt that an improved market would not lead them to sell more agricultural products or change how they farmed. These respondents expressed that they had just enough for their own needs and did not produce the quantity needed to bring grains to market.[8] As some expressed, "we would like to sell 2 – 3 sacks, but we only harvest enough for my children."[9] "We barely sell at all. The price in the market doesn't interest us. Better to save what we have for our own consumption."[10] Likewise, some of these farmers expressed that the problem for them was not the market value of goods, but the uncertainty as to whether there would be a harvest.[11] "We are guided more by the rains" (*son las lluvias que nos guían*).[12]

Losing seed

Another approach to understanding the vulnerability of families was by how frequently they had experienced complete losses of seed. In Zaragoza, 20% of respondents lost their seed (n = 10). This was a much lower percentage compared to the 88% of respondents in Huautla (n = 19, Table 2.11).

When seeds were lost, respondents procured new stock from a variety of local to regional sources. Fifty percent of respondents (n = 14) in both communities sought seed from relatives and neighbors.[13] Sometimes these exchanges took monetary form, as for one respondent who purchased beans from a neighbor in 2010 for 100 pesos per Kg.[14] While respondents preferred local seed, 43% of respondents reported procuring seed from neighboring towns due to shortages within their own community at different historical moments.[15] "We cannot obtain the seed in the community" (*Ya no se consigue la semilla en la comunidad*).[16]

Farmers recalled many years ago walking approximately 25 Km to Río Blanco[17] or 35 Km to San Juan Bautista Coixtlahuaca.[18] More recently, one respondent recalled purchasing landraces of white maize from the Asunción Nochixtlán market.[19] Twenty-one percent of respondents had purchased seed from commercial sources. In some cases, farmers planted

[1] ZTC [2] MGA [3] MGD [4] MGD [5] MCC [6] ZCC, ZGA, ZTB, MCE, MCJ, MTD, MTE [7] MTE
[8] ZTA, ZTD, ZTF, MCB, MCD, MCF, MCG, MCI, MGB, MGC [9] ZTD [10] ZTF [11] MCA, MTA, MTB
[12] MCA [13] ZTD, MCB, MCD, MGA, MGD, MTA, MTB [14] MTA [15] MCH, MCI, MCJ, MGB, MCB
[16] MCJ [17] MCB [18] MGB [19] MTB

Table 2.11: Causes for the loss of seed as reported in Huautla and Zaragoza.

Year	Description	Community[1]
2010	Excessive rains; first time ever to lose seed	Zaragoza
1991	Post-harvest insect pest infestation	
2011	A very bad year. They did not harvest beans or maize, only wheat	Huautla
2010	Four years of drought followed by a year of heavy rains, frost and rot (*chasluisa*[2]) in 2010 resulted in losses of maize, beans, and wheat in 2010[3], with one farmer lost the seed his father had passed down to him[4]	
2007	No description provided	
2004	They lost everything	
2000	They lost all their harvest (*se secó todo*)	
1987	A worm (*gusano*) rained down and destroyed pasture, wheat, and corn. This same year they had problems with white grubs	
1986 – 1989	In the years between 1986 and 1989, the family suffered from poor harvests due to a drought and the husband's poor health	
1949	When he was 10 years old, he remembers eating nopales and quelites for three years because of a drought. It wasn't possible to find beans, wheat or maize anywhere	
1914	A bad year when people died from hunger	

[1] Respondents in order for each row: 1 – ZTD; 2 – ZGA; 3 – MGA, 4 – MCB, MCI, MCJ, MGD, MCF, MTB; 5 – MCE; 6 – MGC; 7 – MGB, MCH; 8 – MCA; 9 – MCC; 10 – MCG; 11 – MTA
[2] MTB, MCJ
[3] MCI
[4] MCJ

imported seed from the subsidized grain dispensary CONASUPO[1] or "improved" seed from government agricultural subsidy PROCAMPO.[2] Others (though the exception to the rule) purchased hybrid white maize and fresh corn (*elotero*) every year.[3]

Those who had never lost their seed described slowly recuperating seed stocks from small amounts of seed (3-4 L in one case).[4] Some had sown the same seed for generations[5] and viewed it as natural and resistant to the agricultural environments of the Mixteca Alta.[6] Eighteen percent of respondents in both Zaragoza and Huautla were yearly suppliers of seed and grain to others in their communities.[7]

[1] ZGA [2] MGD [3] MGD [4] MCG, ZCA, ZCC, ZTF [5] ZTA [6] ZCB [7] ZTC, MTD, MTC

2.3 Discussion

Interpreting vulnerability

Like García-Barrios and García-Barrios (1990), the communities that I studied appear to have experienced a series of changes in the past generation. These include the reduction of animal husbandry and the abandonment of cajete maize. Households were in fact the unit of productive capacity with limited communal production, exchange, or stores of grain. Families relied on economic activities often outside of their communities and government assistance programs for tractors, fertilizers, and imported grain during lean years. Reduced investment by farmers in soil conservation strategies have led to patterns of severe soil erosion.

Moreover, farmers interpreted climate through the impact on their animals, crops, and seed stores. Questions around the *canículas* proved to be a very useful mechanism for exploring the differential effects of intra-annual climatic variability on farming systems. Studying actual year-to-year climatic variability through yields was more challenging, since few respondents recalled their crop yields for more than 3 years in the past, if at all.

These interviews offer a glimps at both the vulnerabilities and strengths of small farmers to climatic variability. In the future, these interviews will allow for a more in-depth analysis of farming systems. Holt-Giménez (2002) describes the Wilches-Chaux model, which proposes that the risk of a disaster is influenced by the exposure of a population to the event in combination with the vulnerability of that population, where vulnerability is their incapacity to anticipate, absorb or adjust to the event. The threat of climatic events might also be understood by farmers' rankings of the frequency of good and poor years, farmer observations of changing climatic trends, and major social problems that affect their farming decisions.

Indicators of vulnerability to climatic events might include support networks from family members, months without grain, *per capita* grain yield, size of landholdings, social norms that regulate the use of community resources, the ability to integrate farming lifestyles while earning money, and government subsidies and development projects. This may prove to be a useful framework for interpreting the interviews, though more research on risk and vulnerability is needed prior to conducting such an analysis.

At this juncture, What can be said is that families in both communities were in many senses vulnerable to climatic variability. Rainfed agriculture by its very dependence on climate is more exposed than other forms of production, especially in such regions as the Mixteca Alta where little water retention or harvesting has been introduced for basic crops. Many families were not self-sufficient in grain production, going months with low stores of grain, and reporting crop yields in recent years well below their estimates of good years.

In addition, a crisis of labor has led to the abandonment of animal husbandry and other important strategies for self-sufficiency. From a historical perspective, García-Barrios and García-Barrios (1990) found that the focus of maize production had shifted from communal self-sufficiency to that of the family. The incorporation of small farmers into market economies may continue to erode local farmer knowledge that, while imperfect, did develop ingenious ways of managing natural resources and interpreting the environment.

Agroecosystems

Social norms and institutions play a critical role in articulating sustainable farming practices. Reciprocity between family members, neighbors, and across rural communities were found to be critical for maintaining social cohesion and local support networks. Farmers also expressed a deep connection with their land. To many, farming was to care for their inheritance. This was expressed as a motivation to participate in their communities despite challenging conditions. In addition wellbeing included more than matters of money, but intangible values surrounding food choices, healthy lifestyles, freedom in one's labor, and solidarity.

The abandonment of cajete maize clearly represents a complex set of stories from the erosion of social norms and institutions to environmental change. Authors describe cajete maize as a crop of moisture (*cultivo de humedad*; García Barrios, García Barrios, and Álvarez-Buylla 1991, 160-174; Rivas Guevara 2008, 142). These studies, as well as my own, document how farmers conditioned the agroecosystems where cajete was produced by shaping contour ditches, bunds, and terraces; by carefully managing soil moisture between seasons through the use of the plow; and by choosing adequate agricultural environments it would grow best. The knowledge of how to build terraces has survived, however few terraces were constructed by the current generation, but rather by their ascendants (*los antepasados* Perez Rodriguez and Anderson 2013). This would support the argument by García-Barrios and García-Barrios (1990) that the market integration of small farmers has left but the vestiges of ancient technological knowledge.

I found that cajete maize was still practiced in the more marginal regions for other seasonal crops, and at higher elevations. These regions were cooler temperate lands, thus reducing crops' water demand. The temperate regions that I studied had at one time been suitable for cajete maize some 20 years ago, though according to farmers, current socio-cultural norms, soil properties, and climatic conditions had changed such that cajete maize was no longer feasible.

Several changes in the biophysical environment were identified by farmers to make cajete maize less suited to temperate zones. If soils were not moist enough to cultivate in the fall, several farmers said that they would not sow cajete maize at all. Moreover, farmers described their soils as no longer thick and capable of sustaining cajete maize through the dry months. This may be the outcome of soil erosion from poor soil conservation, the reduction in animal manures and organic material to the soil, or a possible drying trend as temperatures rise. These explanations are all speculative, but do demonstrate how social and biophysical phenomena coincide to shape how people make use of their environment.

Farmers' language itself is important for making interpretations about relative sensitivities of crops to climatic conditions. Heat (*calor*) carried dual meanings to farmers. It referred to the dry period of the year, as well as dry spells in the rainy season. Thus, cajete maize was resistant to drought in farmers' minds because it was capable of growing for several months without rainfall. However, a delay in the onset of the rainy season until July did affect cajete maize in 2011, thus revealing that the cajete system has its own set of vulnerabilities to the impacts of climatic changes.

In contrast, seasonal maize was described by farmers as sensitive to heat because its sowing was determined by the start of the rainy season. If rainfall patterns did not align to sow seasonal maize by mid-July, farmers would focus their efforts on other crops instead. The vulnerability of the seasonal maize system was expressed in years when it was planted with the rainy season, but was followed by a dry large *canícula*, as occurred in 2009. In that particular year, cajete fared far better than seasonal maize (Ríos et al. 2011).

The variability in yield data did not allow for a quantitative comparison between cajete maize and seasonal maize. However qualitative descriptions of farmers placed cajete yields as equivalent or higher than seasonal maize due to several attributes: larger cob, larger grain, and more dense grain. Additionally, cajete maize was harvested earlier than seasonal maize, which reduced the months of hunger between approximately August and November for those who grew both crops. In contrast, seasonal maize was accompanied in the *milpa* by a diversity of food that was unmatched by the cajete system: beans and squash. Edible and medicinal wild plants however, grew in the understory of both systems.

Farmers who grew cajete maize did not report a noticeably higher level of overall production or self-sufficiency. This may be due to their limited access to temperate lands where beans and seasonal maize were more commonly produced by non-cajete farmers. The farmers who still grew cajete maize lived in regions with restrictive climates, and thus short of relocating their homes, were most dependent on producing there. Moreover, they may not have had the family labor sufficient to fully utilize the lands available to them.

In contrast, those farmers who lived in areas more conducive to seasonal crops were reluctant to adopt cajete both because they perceived that their soils were not appropriate for it, and it was too costly (i.e. high upfront investment, uncertain return). Therefore, cajete was most present in marginal environments for other crops, such as high elevations prone to frost. Cajete required farmers to cultivate fields during the dry season. This was distinct from such crops as wheat crops that grew during the winter, but did not require farmers from approximately December – March. I examine labor dynamics further starting on page 73.

Farmer adaptations to climatic variability took multiple forms. Farmers in the region were skilled at following the rains. Where crop failures and low yields were common, it was especially important to manage their fields according to the seasons. Sowing in accordance with the yearly climatic conditions has resulted in later sowing dates. This in turn, has stimulated the introduction of more precocious varieties of seasonal crops that matured adequately to avoid being affected by late-season frosts.

Wheat had become the grain of sustenance for Huautla families between 2005 – 2009 due to a series of poor maize harvests. I found that wheat varieties had changed the most, with many long season varieties falling out of favor. Also, minor grains, such as barley, favas, and lentils, provided additional planting times for farmers. Thus crop diversification, though always changing with the seasons and economic conditions, was an important strategy that farmers maintained. Moreover, crops were also valued for more than their grain. Forage and soil cover was just as important.

Animal husbandry, even at small scales, was an insurance against the *canículas*. Nevertheless, animals were still responsible for continuing environmental degradation in the Mixteca Alta. During multiple years of drought in Huautla from 2005 – 2009, goats and sheep overgrazed the landscape. When the region received torrential rains in 2010, there was very little vegetation to buffer its impact: superficial runoff was laden with soil from the fields, manures drifted downhill, and landslides affected drainages and the steepest of slopes. Several farmers who kept animals in Huautla described this dynamic, but few proposed solutions.

In summary, at this level of analysis there do not appear to be any simple truths in comparing the resistance or vulnerabilities of the cajete and seasonal systems to climatic variability. The unique attributes of the two systems have enabled families to withstand unpredictable climatic conditions. While cajete maize has clearly played an important role for some farmers, it remains equivocal whether promoting cajete maize would be an effective solution to the most pressing problems of sustaining rural livelihoods and family self-sufficiency in a very unforgiving climate. It was in fact one among many farmer strategies for coping with climatic variability.

Labor

The farmers I interviewed understood the ecology of their systems. Given the social and environmental constraints on them, they were faring remarkably well. Agriculture is a manifestation of practices embedded in unique social contexts of economy and culture. Reduced rural labor has suppressed agricultural productivity and resulted in environmental degradation of the Mixteca Alta.

Farmer management was influenced by multiple factors, including labor availability; income from non-agricultural work; climate (*son las lluvias que nos guían*); changing soil fertility as areas were degraded and restored; family demographics; political conflict; and compliance with the stipulations of government subsidies. Interestingly, abandoning cajete was not just a means to reduce the total amount of labor, but to concentrate the distribution of agricultural labor. This allowed families to engage in remunerated labor during the dry season.

I did observe a distinct temporal difference in labor between those farmers who grew cajete maize and those who did not. Growing cajete maize required a more year-round dedication to farming that many families no longer were able to afford. This alone provided a powerful explanation for why cajete maize had been so significantly reduced.

While changes in farm management were ostensibly be intended to save labor, they may in fact accomplish the exact opposite. In the case of cajete maize, labor was spread out throughout a longer growing season and across multiple families. Thus, the labor required per family was not distinct from the labor requirements of seasonal maize. True costs of cajete maize only appeared to increase when fewer people in the communities sowed it, outmigration disintegrated social cohesion, and monetary economies were imposed on indigenous communities.

Likewise, tractor cultivation, though more efficient in comparison to the *yunta* in actual time cultivating the soil, may in fact require more labor and time away from the community to accumulate the money for paying the costs of a driver, equipment, and fuel. The same may be argued of environmental degradation, where minimizing farming labor in the short-term has led to the immeasurable long-term costs of recuperating, where possible, severely eroded soils. Edinger (1996, 124-125) discusses similar patterns in the town of Mixtepec where the weaving of sandals from palm had cost farmers less than the time working in exchange for modern footwear. Both in terms of time and money, weaving one's own sandals was by far the more economical option, though culturally out of favor.

The parallels between terraces, cajete maize, and so-called labor saving farming innovations have their common origins in the history of the Mixteca Alta. It would seem that farmers have changed their farming practices and have left their lands due in part to climate, but also social, political, and economic disruption. Just as terraces have come and gone during different historical periods, one might speculate that cajete maize and other sustainable farming practices would also be adopted anew were social conditions in the region to change. However, once farmer knowledge and culture are lost, the costs of recovering them may be insurmountable.

Chapter 3

Farmer strategies

Climate change is expected to disproportionately impact tropical regions where the majority of small farmers and pastoralists reside (Easterling et al. 2007). Small farmers that manage diversified and small-scale farms, that rely on family labor, and that produce both subsistence and commercial goods are a predominant mode of production in many regions of the world (Marta Astier et al. 2012). One of the challenges for addressing twenty-first century climate change is scale. Climate models do not provide specific enough information for adaptation at small scales (Oreskes, Stainforth, and Smith 2010).

Effective adaptation to climate change requires location-specific understandings of climate variability (Gamble et al. 2010). This is especially true for small farmers, who often use local climate knowledge for decision-making. While climate may seem an unlikely candidate for management, small farmers are not limited to reacting to it (Wilken 1987a, 224). Small farmers have developed innovative farming strategies for withstanding challenging climatic conditions (Altieri and Nicholls 2013). The recovery of traditional management practices from creative and motivated local stakeholders may in fact represent important strategies to prepare for climate change (M Astier et al. 2011). Scientific and local knowledge must be bridged to contribute to the well-being of agricultural communities (Valdivia et al. 2010). Moreover, Roncoli 2006 recommends the use of ethnographic and participatory methods to move towards a climate vulnerability and adaptation paradigm led by farmers and institutions.

This dissertation discusses participatory research in the Mixteca Alta Region of Oaxaca, Mexico that facilitated a process whereby farmers evaluated the ability of their agroecosystems to withstand the vagaries of climate. The proposed methodology documented small farmers' past strategies for dealing with climatic variability, developed local indicators to assess the ability of agroecosystems to withstand climatic variability, and placed the locally-derived indicator framework in the hands of farmers for evaluating the current state of their agroecosystems. Additionally, we put the farmers' description of climate history in conversation with regional climate records. This latter step was not essential to identifying farmer adaptation strategies, but rather may validate farmers' experiences to scholars, community organizers, and policy makers.

3.1 Methodology

Researchers and CEDICAM collaborated for a period of three years, from 2009 to 2011, to conduct a total of eight day-long workshops with farmers in CEDICAM's farmer-to-farmer network. I lived and worked alongside small farmers in the Mixteca Alta for a total of 20 months while conducting ethnographic studies, interviews, and agronomic field experiments. These experiences inform the research presented in this dissertation.

Researchers and CEDICAM followed a co-investigation methodology similar to that described by Freire (1970, 125). Meetings between researchers and CEDICAM identified objectives and reflected on outcomes of farmer workshops (Figure 3.1). While farmer workshops primarily aimed to empower small farmers to conduct their own analysis in the vein of Freire (1970, 99), the workshops were also focus groups as described by Hennink (2007) and Wilkinson (1999), in that a series of qualitative research questions were embedded in the activities conducted by farmers. CEDICAM invited farmers in each community through their farmer-to-farmer training network. An average of 6 women and 7 men ranging from an estimated 18 to 70 years old attended each farmer workshop. However, participation varied greatly due to competing responsibilities in local governance positions and employment outside of their communities.

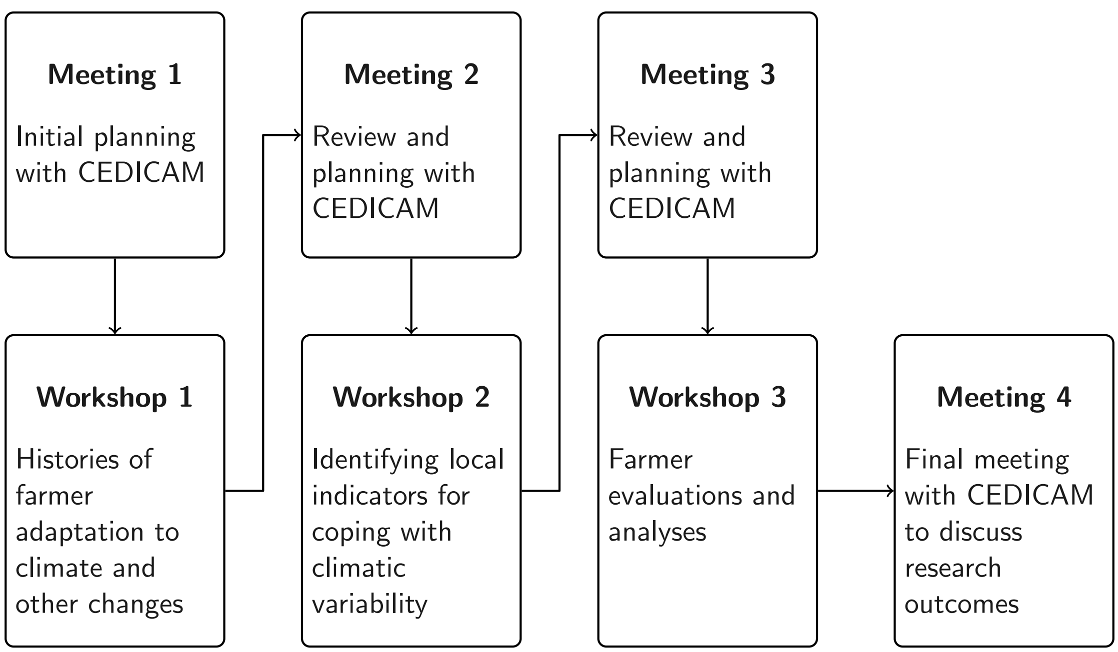

Figure 3.1: A diagram outlining the co-investigation process with the farmer-led Center for Integral Rural Development of the Mixteca Alta (CEDICAM) and researchers. The co-investigation process jointly defined objectives, refined methodologies, organized community members for workshops, and interpreted results. A constant emphasis was also placed on validating farmer perceptions throughout the research process.

Climate histories

In the first series of workshops, groups of farmers discussed their adaptations to past climate challenges, which was an important strategy since participating communities maintain oral history traditions. From a focus group perspective, discussions between farmers obtained a more unified recollection of past experiences (Morgan and Krueger 1993). Farmers' climate narratives provided a basis for an investigation of the historical climate.

Researchers facilitated the workshops by recording farmers' narratives on a large sheet of paper. Key historical events in each community served as baseline references of a stratified timeline. The impacts and farmer adaptations to extreme climatic events – namely severe droughts, storms, and frosts – were layered upon this baseline. Researchers relied on the farmers' interpretations of climatic extremes, since there are many possible interpretations of extreme events (Peralta-Hernandez, Balling, and Barba-Martinez 2009). We also asked farmers how they experienced and responded to long-term climate changes, and how their production systems changed over time, as did Geilfus (1998) and Ortiz-Ávila, Quiroz, and Camou (2007).

Climate record

For the climate, we examined a $1° \times 1°$ region encompassing the communities ($96.5 - 97.5°$W, $17 - 18°$N). We investigated monthly-averaged data from a Mexican National Meteorological Service meteorological station in Nochixtlán and from high-resolution gridded datasets based on station data: temperature and rainfall from the Climatic Research Unit time series dataset (CRU-TS) version 3.21 (Harris et al. 2013); and rainfall from the Global Precipitation Climatology Center full data reanalysis (GPCC) version 6 (Schneider et al. 2013). The automatic station data were available from 2005 onward; we only used temperature since several months of rainfall appeared to be missing.

We investigated the 50-year climate record in the study region focusing on long-term secular changes to compare with farmer perceptions of climate. As the gridded products are at a much larger spatial scale compared to the farming communities and have lower temporal resolution compared to most extreme events, we did not expect individual local extreme events to be present in the data. Our workshop methodology may have primed respondents to associate climate changes with non-climate historical events in the communities. However, we believe that this is unlikely to have affected the perceptions of a long-term signal. Since the workshop participants were from a wide age range, we examined both 50 year (1961 – 2010) and 25 year (1986 – 2010) trends. Trends were calculated using the Kendall-Theil robust slope to reduce the influence of outliers, and we evaluated significance using a two-tailed Mann–Kendall test with a cutoff of $\alpha = 0.05$ (Helsel and Hirsch 2002). We characterized ENSO events using the Multivariate ENSO Index (Wolter and Timlin 2011).

Local indicators

A second series of workshops asked farmers to describe the biophysical attributes of their production systems that enable or limit productivity given the climatic variability described in the previous workshop series. We refer to these biophysical attributes as indicators. The use of indicators in participatory research with farmers is well established in Latin America (M Astier et al. 2011; Pulido and Bocco 2003).

The identification of local indicators followed a similar study of cacao agroforestry systems in Costa Rica and Nicaragua conducted by Miguel A. Altieri (2010). Field visits to three agroecosystems in each community stimulated a conversation between researchers and participating farmers about the most important indicators. It also became evident through these discussions that some of the indicators described conditions beyond the scale of one farmer's fields (*Landscape*), while others were related to conditions directly influenced by farmers' actions on the field-scale (*Farmer Management*) or to conditions of soil quality at the field scale that for some indicators were indirectly related to farmers' intervention in the system (*Soil Quality*).

Farmers described conditions for each indicator within a three-tiered ordinal scale of marginal, acceptable, and optimal that were respectively linked to red, yellow, and green colors. Describing conditions of indicators with stop-light colors has been developed in Latin America as a simple methodology for farmers to evaluate their agroecosystems (Miguel A. Altieri 2010; Cammaert et al. 2007). However, farmers participating in this case study did not intuitively associate indicator conditions with colors since many had limited interaction with stop lights in their day-to-day lives. For the agroecosystem assessment phase described below, researchers paired colors with facial iconography: sad for marginal, normal for acceptable, and happy for optimal. While facial iconography was effective at improving communication between researchers and farmers during the workshops, for the purpose of this dissertation I make reference to the scales of marginal, acceptable, and optimal.

Researchers and CEDICAM subsequently refined the indicators described by farmers into a set of 14 indicators (Table 3.1). Repetitive indicators across communities were combined, as were those indicators that distinguished between dry and wet years. For example, while wheat was described as more resistant to drought than to excess soil moisture, most varieties of maize were sensitive to both drought and excess soil moisture. Therefore, we described wheat as more resistant to climatic variability than maize.

Agroecosystem assessments

In the third series of workshops, three teams of farmers independently evaluated four production systems in Zaragoza and El Rosario using the set of 14 indicators. Researchers pooled the teams' agroecosystem evaluations within each community by assigning numerical scores of 0 for marginal, 1 for acceptable, and 2 for optimal. Farmers analyzed outcomes by drawing bar plots of the pooled scores for their community. Farmers were prompted to analyze the results of their evaluations as a group by the following questions:

Table 3.1: Evaluation forms used by farmers to evaluation agroecosystems in Zaragoza and Huautla.

Team:
Community:
Production System:

Category	Indicator	Marginal	Acceptable	Optimal
Landscape	Territorial Composition			
	Windbreaks			
	Field Location			
	Soil Conservation			
Farmer Management	Crop Rotation			
	Crop Varieties			
	Polyculture			
	Soil Amendments			
	Soil Cultivation			
Soil Quality	Spontaneous Plants			
	Soil Productivity			
	Soil Organic Matter			
	Soil Depth			
	Soil Texture			

- How to obtain more happy faces (i.e. the optimal condition) in the Landscape, Farmer Management, and Soil Quality categories?
- How to maintain the happy faces (i.e. optimal condition) that you already have in the Landscape, Farmer Management, and Soil Quality categories?

These questions differ slightly from previous implementations of this methodology, where farmers are asked "how to move from marginal towards optimal?" (Miguel A. Altieri 2010; Cammaert et al. 2007). The modified questions aimed to direct farmers' attention towards both improvements needed and characteristics to maintain in managing their agroecosystems.

3.2 Results

Climate histories

Farmer narratives and the regional climate

Climate histories dated back to the 1970's in Zaragoza, to 1969 in El Rosario, and to the 1930's for one individual in Coxcaltepec. Farmers reported that climate changes in recent decades – namely later rains and more drought – have made growing conditions less favorable for traditional forms of agriculture. Across the three communities, participants reported a shift towards a later onset of the rainy season. Zaragoza participants recalled the onset of rainfall before the 1990's between February and March while since approximately 1990 rainfall began from May to July (Figure 3.2). In El Rosario rainfall began from May to June during the 1970's, whereas they began between June and July starting in the 1990's (Figure 3.3). Farmers in Coxcaltepec observed a progressive shift beginning in the 1970's in the onset of rainfall from May towards July (Figure 3.4). These shifts were associated with historically important dates in the communities: the years electricity arrived in Zaragoza and Coxcaltepec and the year El Rosario's main road was built.

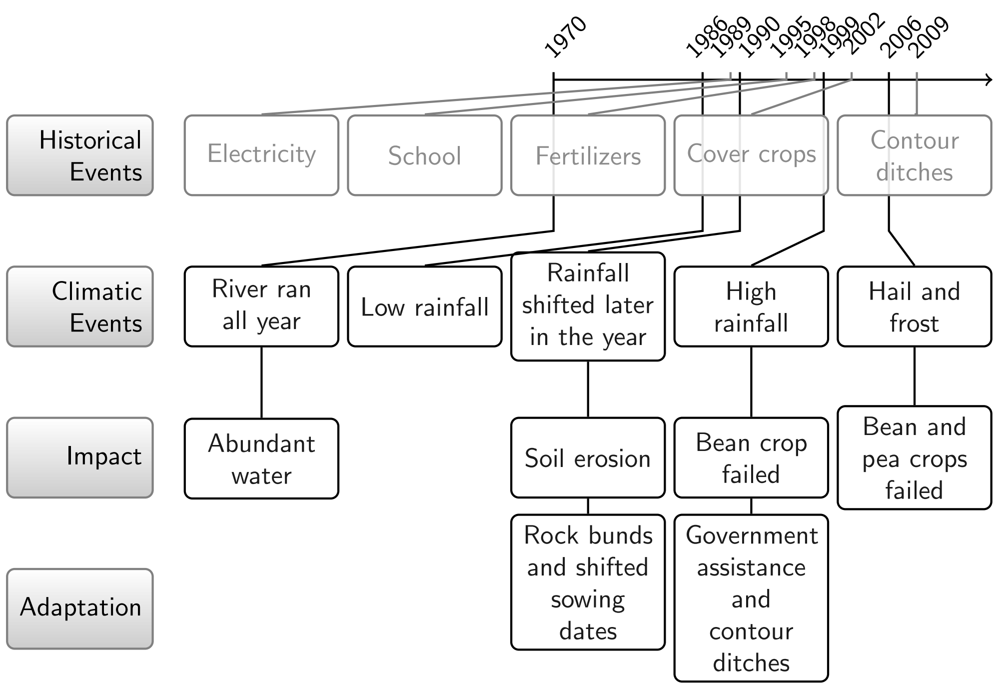

Figure 3.2: Stratified timeline summarizing farmer narratives of historical events in Zaragoza, significant climatic events, impacts on agroecosystems caused by the climate, and adaptation strategies used by farmers to deal with the situation.

Increased storm intensities were particularly noted in the last decade by the three communities. Extreme climatic events described by farmers in the three communities were remembered for their impacts on agroecosystems. Zaragoza experienced a near complete crop failure in 2006 due to frost, as well as suppressed yields in 2009 due to high rainfall in June followed by an unusually dry mid-summer drought. El Rosario farmers recalled a catastrophic drought in 1996 that killed crops, trees, and palms alike.

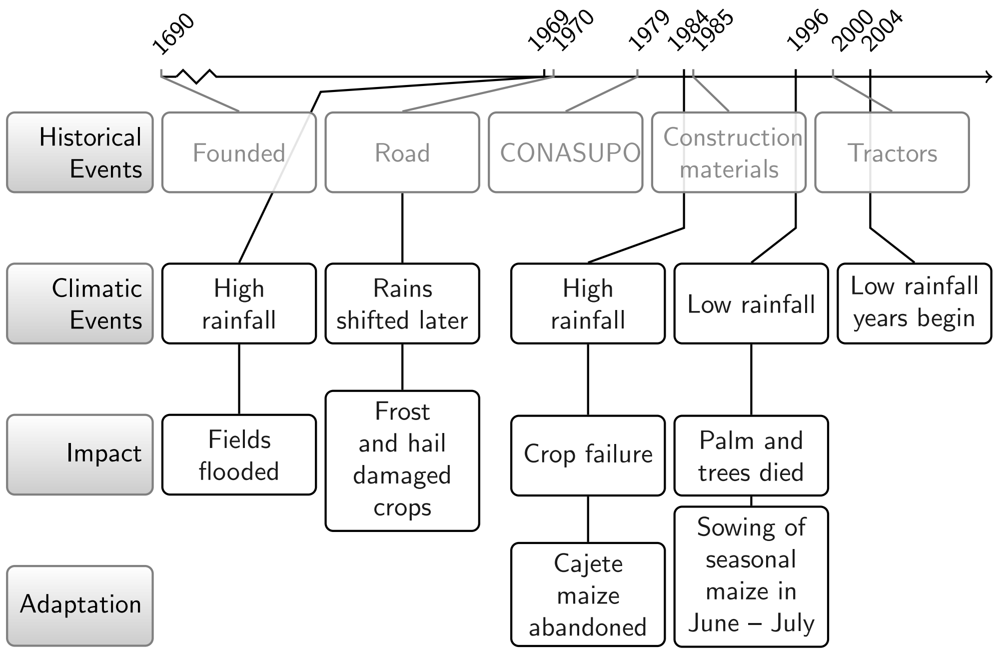

Figure 3.3: Stratified timeline summarizing farmer narratives of historical events in El Rosario, significant climatic events, impacts on agroecosystems caused by the climate, and adaptation strategies used by farmers to deal with the situation.

Farmer adaptation to climate

Farmers identified multiple instances of agroecosystem change that in some cases were associated with climate. Particular mention was made by farmers of detrimental climate changes during the beginning of the rainy season when many crops are sown (see *Climate* in Figure 3.5). Sowing dates for seasonal maize had shifted from May to June in Zaragoza since the 1990's, and from between May to June 16 to between June and July 14 in El Rosario. Coxcaltepec and El Rosario participants noted that later sowing dates place seasonal maize and beans at greater risk to frost damage in September and October.

In addition to shifting sowing dates, participants in El Rosario and Coxcaltepec largely abandoned cajete maize (see *Crops* in Figure 3.5). While at one time approximately half of arable lands were cultivated to cajete maize, today the practice is greatly reduced in the three communities. One reason cited by farmers was greater heat (*calor*), consisting of both extended dry seasons as well as more frequent droughts (*sequía*) during the rainy season. Similarly, Sánchez-Cortés and Lazos Chavero (2011) reported that changes in the agroecosystems of Zoque farmers in the Mexican State of Chiapas was provoked by less rain and increased temperature.

Farmer observations would suggest that they do not necessarily respond to specific cases of climatic extremes, but rather their long-term management strategies buffer agroecosystems from climatic shocks. During a series of dry years from 2004 to 2009, cajete maize and wheat

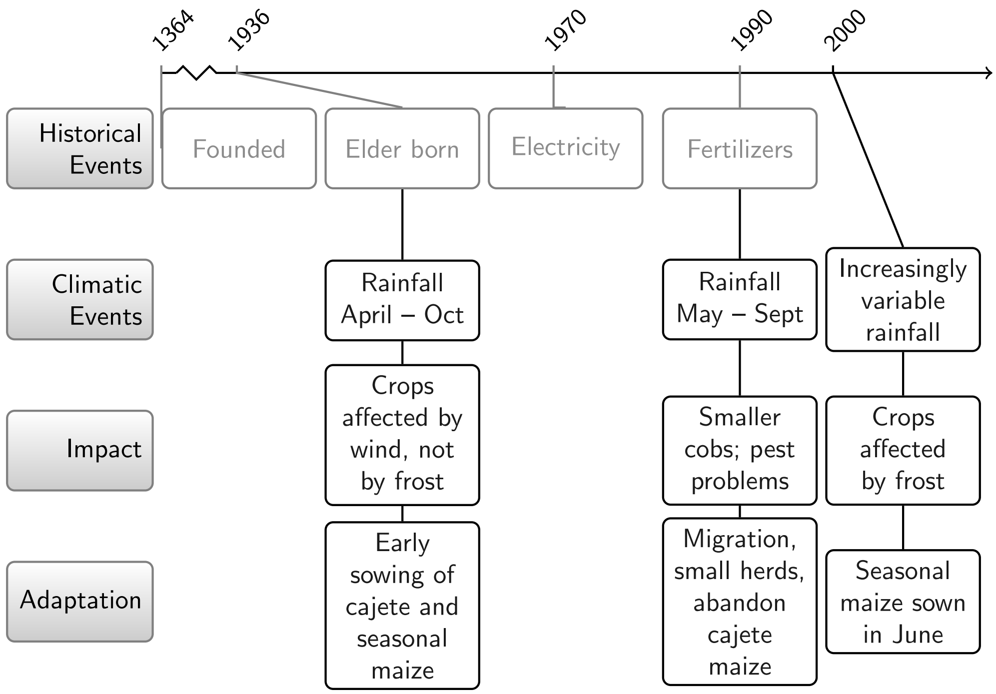

Figure 3.4: Stratified timeline summarizing farmer narratives of historical events in Coxcaltepec, significant climatic events, impacts on agroecosystems caused by the climate, and adaptation strategies used by farmers to deal with the situation.

were most resistant while seasonal maize and beans failed. Farmers attributed this to cajete maize suffering less damage from excessive rainfall and frost at the end of the rainy season since it is harvested earlier than seasonal maize.

Farmers in the three communities described how contour ditches improve water infiltration, recharge aquifers, retain water in dry years, and facilitate drainage of fields in wet years. Living barriers and windbreaks, as told by farmers, protect maize from windthrow. Farmers noted the role that CEDICAM plays in training communities to conserve soils using appropriate technologies, such as the Apparatus A (León Santos 2007, 14-21). Additionally, farmers noted the importance of governmental support for conservation practices, like the funding Zaragoza's municipality received from government sources to build contour ditches in 2009.

Non-climate drivers of change

The impacts of climate are interwoven with other drivers of change (Eakin 2000). Beyond climate, crises of labor and soil fertility also contributed to the shift from cajete maize to seasonal maize. Participants in the three communities noted a decrease in rural labor and an increase in labor-saving agricultural technologies (see *Management* in Figure 3.5). Farmers reported that the massive out-migration of youth from Coxcaltepec contributed

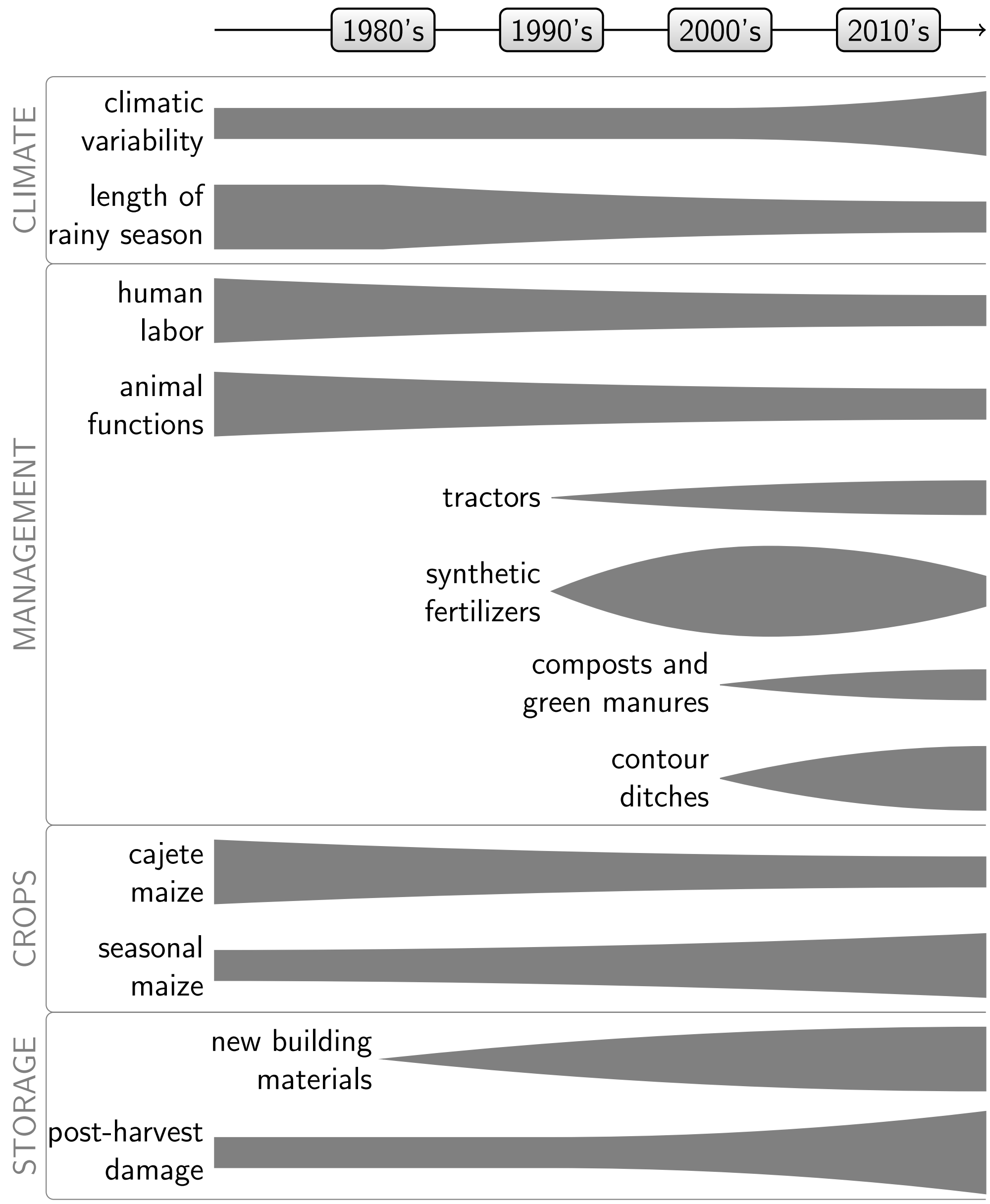

Figure 3.5: Changes in agroecosystems during approximately the past 50 years that were described by farmers in Zaragoza, Coxcaltepec, and El Rosario. The width of bands represents a qualitative presence of each element in the agroecosystems. The bands are grouped into themes to emphasize specific relationships between them.

to the abandonment of cajete maize in favor of labor-saving crops such as seasonal maize. Farmers associated reduced rural labor with declines in animal husbandry since the 1980's. The majority of oxen used for plowing fields were sold by Coxcaltepec farmers with the introduction of tractor technology in 2009. Consequently, farmers substituted traditional soil fertility management based on animal manures with purchased synthetic fertilizers in Zaragoza since 1998 and in Coxcaltepec since the 1990's.

Maize yields increased initially by the change in soil fertility management. However soils were negatively affected over time and productivity eventually declined. Zaragoza farmers began experimenting with green manures and composts in 2002 to reduce the costs of synthetic fertilizers and to improve soil quality. An initial reduction in yields was followed by increases in subsequent years. Research from Mixteca Alta (Edinger 1996; García-Barrios and García-Barrios 1990) and elsewhere in Mexico (Eakin 2006, 2000) support the observation by farmers that decisions for managing their agroecosystems are influenced by larger economic and technological forces.

Farmers recognized that the adoption of new technologies can bring unanticipated consequences. Farmers associated greater heat during the dry season with elevated post-harvest losses in Zaragoza and El Rosario due to the increased prevalence of grain weevils and moths (see *Storage* in Figure 3.5). According to farmers, post-harvest pest damage is exacerbated by state-subsidized construction materials of cement, cinder block, and corrugated metal introduced since the 1980's that elevate indoor temperatures compared to traditional building materials of adobe, palm, reeds, and oak. Temperature is an important environmental factor in the degree of post-harvest grain damage, which is why cooling techniques are well established in the classic approach of insect pest control (McFarlane 1988).

Climate record

Temperature

Figure 3.6 shows the annual and decadal mean CRU-TS temperature anomalies from 1961 – 1990 over the study region. The 25-year and 50-year trends both show statistically significant warming (0.16 and 0.18°C per decade). This is consistent with our finding of regional-scale warming over south–central Mexico (15 – 20°N, 95 – 100°W) in the Climatic Research Unit variance-adjusted land surface temperature record (CRUTEM4) version 4.2.0.0 (Jones et al. 2012), which is not shown. The influence of ENSO is also apparent on interannual timescales, with anomalously high temperatures associated with the strong El Niño events of 1982–1983 and 2009.

Rainfall intensity

For an estimate of rainfall intensity, we divided total annual rainfall by the count of days with rainfall from CRU-TS to obtain an average of the rainfall amount per rain day. Figure 3.7 shows this estimate of annual mean rainfall intensity. There are increasing trends over both

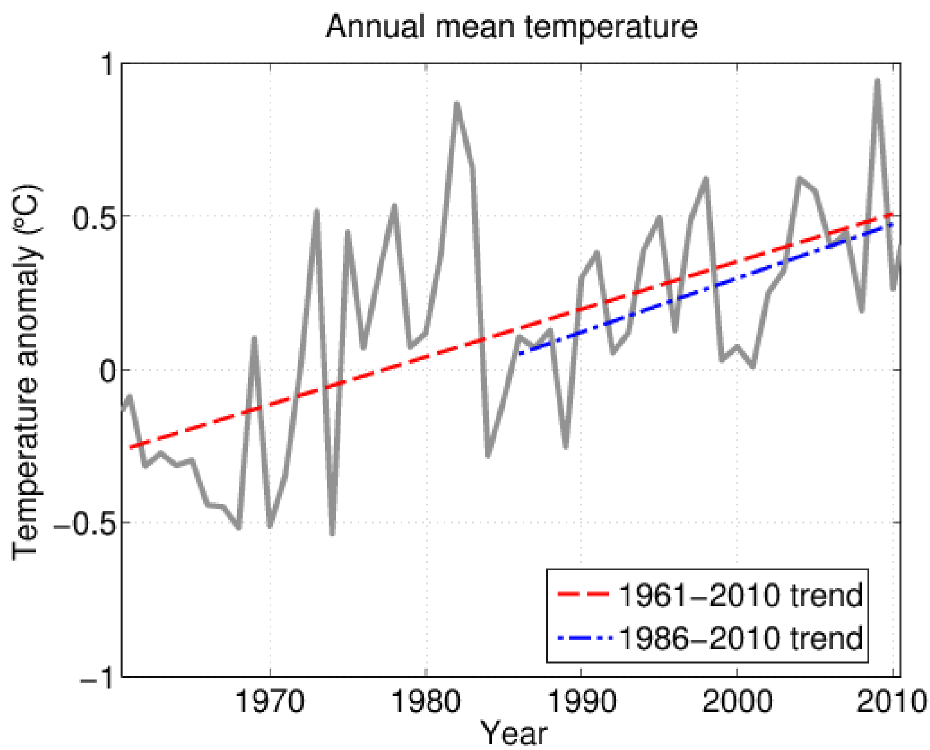

Figure 3.6: CRU-TS annual mean temperature anomalies (°C; solid grey) over 96.5−97.5°W, 17 − 18°N. The dashed lines show the 1961–2010 (red) and 1986–2010 (blue) trend lines. Anomalies are with respect to 1961–1990. Figure produced by Andrew R. Friedman with input from Paul Rogé.

1961–2010 and 1986–2010, though neither is statistically significant. The increase has been larger in recent years; the 1986–2010 trend is over three times as large as the 1961–2010 trend (0.03 cm/rain day and 0.10 cm/rain day per decade), and three of the four most intense years were in the 2001–2010 decade. There is also an association with the ENSO activity: the very intense rain years of 1983 and 2010 were each in the second year of a strong El Niño. 2010 also transitioned quickly into a strong La Niña (Ruiz Barradas 2011).

Rainfall seasonality

It is difficult to directly assess the length and timing of the rainfall season both because we did not examine daily rainfall data, and there is not a strict threshold for the onset of the local rainy season. For a sense of changes in rainfall seasonality, we examined the time series of early season rainfall (April–June), late season rainfall (July–September), and the difference between these two seasons, shown in Figure 3.8. The early and late rainfall seasons have different associations with ENSO. July–September had dramatic spikes in rainfall in 1983, 1998, and 2010, each the second year of a strong El Niño as mentioned above. 2010

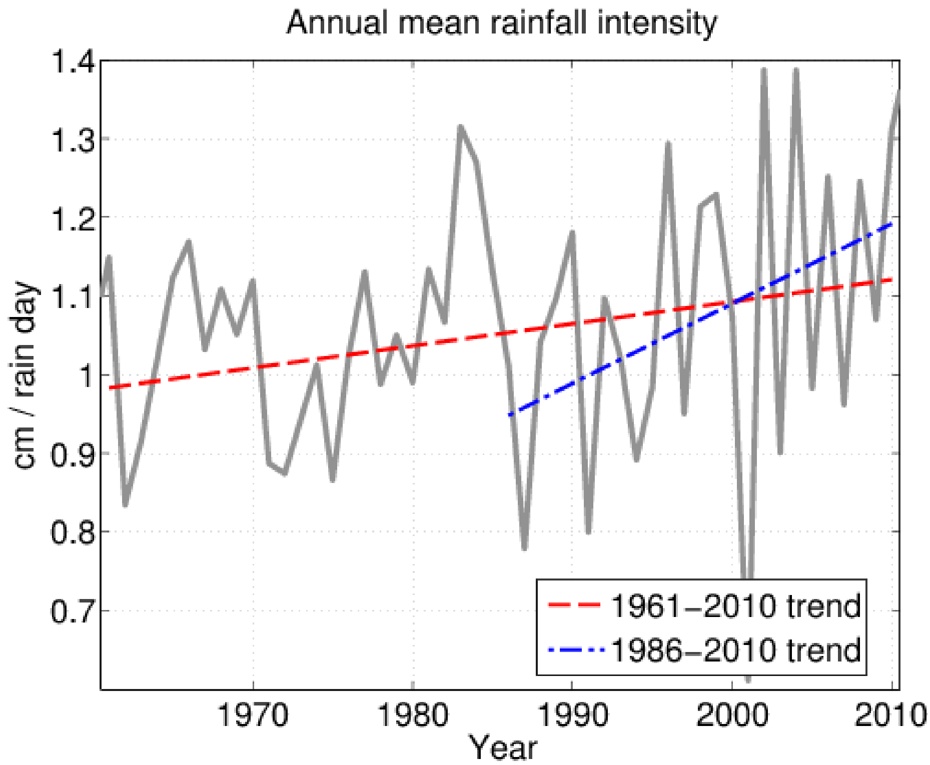

Figure 3.7: CRU-TS annual mean rainfall intensity (cm per rain day; solid grey) over 96.5 – 97.5°W, 17 – 18°N. The dashed lines show the 1961–2010 (red) and 1986–2010 (blue) trend lines. Figure produced by Andrew R. Friedman with input from Paul Rogé.

also transitioned into a strong La Niña. These years had low April–June rainfall, resulting in a very large seasonal difference. 1969 had a similar rainfall pattern, but does not appear to have been a strong El Niño.

The 1961–2010 and 1986–2010 trends are slightly positive for both April–June (0.39 and 0.78 cm per decade) and July–September (1.68 and 4.43 cm per decade). Since the July–September trend is larger, the difference also has a positive trend over both 1961–2010 (0.98 cm per decade) and 1986–2010 (2.43 cm per decade). None of the trends is statistically significant. Similar results were found in the GPCC dataset (not shown).

Though the data do not directly support a later spring rainfall onset, the increasing difference between the late and early season may account for the perception of a shift to later rainfall, as found in a recent study of farmer climate perceptions in the Caribbean (Gamble et al. 2010). Alternatively, the rains may indeed be arriving later on the order of days or weeks, which would not be recorded in the monthly data we analyzed. Another caveat is that we did not investigate changes in the variability of rainfall, which could relate to the frequency of droughts that was identified by some farmers.

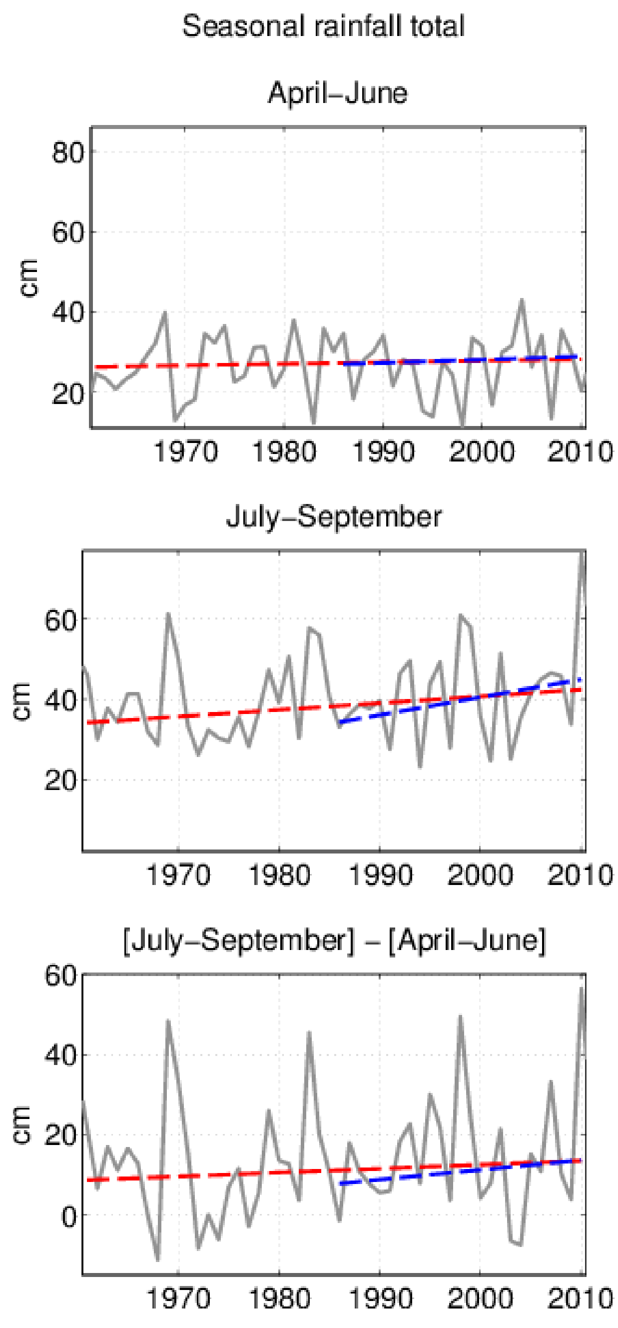

Figure 3.8: CRU-TS seasonal rainfall totals (cm; solid grey) over 96.5 – 97.5°W, 17 – 18°N for April–June (top), July–September (middle), and the seasonal difference (bottom). The dashed lines show the 1961–2010 (red) and 1986–2010 (blue) trend lines. Figure produced by Andrew R. Friedman with input from Paul Rogé.

Table 3.2: Indicators for dealing with climatic variability at the landscape scale that were identified by farmers during workshops in Zaragoza, Coxcaltepec, and El Rosario.

Indicator	**Marginal** ☹	**Acceptable** 😐	**Optimal** ☺
Territorial Composition	The majority of fields are producing the same crop and during the same cycle as the production system being evaluated	Surrounding the production system there are other production systems in fallow or with different crops, but no forests	Surrounding the production system there are forests and other production systems in fallow or producing different crops
Living Barriers	Without trees or windbreaks	Large trees that compete with crops, such as juniper, pine, and eucalyptus	Multiple purpose vegetation for firewood, wood, forage, and fruit
Field Location	Steep slope or in risk of frequent floods	Flat to intermediate slope with some risk of flooding	Flat to intermediate slope, below native forests and without risk of flooding
Soil Conservation	No border on the edges of the production system	Rock bunds on the edge of the production system	Contour ditches with some slope for drainage. Distance between ditches based on slope

Local indicators

The conditions of *Optimal*, *Acceptable*, and *Marginal* for the 14 indicators are described per category of *Landscape* (Table 3.2), *Farmer Management* (Table 3.3) and *Soil Quality* (Table 3.4). We highlight below several indicator conditions to demonstrate how they are grounded in farmers' local knowledge for dealing with climatic variability.

At the level of the community, Zaragoza farmers observed that vegetated borders and perennial vegetation with multiple uses mitigate exposure to extreme climatic events (see Living Barriers indicator, Table 3.2). Similarly, Coxcaltepec farmers' recognized that heterogeneous and forested landscapes provide ecosystem services, including protecting fields, bringing rain, retaining groundwater, accumulating soil organic matter, and controlling insect pests (see Territorial Composition indicator, 3.2). In addition, some tree species may compete with crops for resources or negatively affect crops if their leaves give heat (*calor*), such as juniper and pine, in contrast to the cool leaves of oak, manzanita, and madrone. El Rosario participants described how ditches along the upslope of contour ditches capture soil and water, and how a slight slope to contour ditches avoids flooding and breaching during heavy rainfall events (see Soil Conservation indicator, Table 3.2).

Indicators of farmer management at the field-scale included the importance of crop ge-

Table 3.3: Indicators for dealing with climatic variability directly influenced by farmer management that were identified by farmers during workshops in Zaragoza, Coxcaltepec, and El Rosario.

Indicator	**Marginal** ☹	**Acceptable** 😐	**Optimal** ☺
Crop Rotations	No rotation or fallow	Rotations without legumes	Yearly rotations that include legumes
Crop Varieties	Less precocious varieties of seasonal maize; beans	Precocious varieties of seasonal maize; less precocious varieties of wheat (var. *largo* and *rocome*); squash; fava	Precocious varieties of wheat (var. *pelón*); cajete maize, white sweet clover clover; Peas
Polyculture	Monoculture	Intermediate polyculture	Functional polyculture
Soil Amendments	No application of fertilizers, composts, or manures	Synthetic fertilizer or poor quality manures	High quality composts, green manures, and animal manures
Soil Cultivation	Tractor for cajete maize	Tractor for seasonal maize	Discing with tractors followed by hilling up with draft animals

netic and species diversity for stabilizing overall yields given the variation in crop performance from year to year (see Crop Varieties and Polyculture indicators, Table 3.3). While farmers described maize as generally more vulnerable to climatic extremes than wheat, cajete maize was described as more resistant than seasonal maize. The apparent contradiction between farmers' prior narratives of abandoning cajete maize and subsequent ranking of cajete maize as more resistant than seasonal maize will be discussed later in this dissertation. The indicator of Soil Amendments (Table 3.3) were derived from farmer testimonies that synthetic fertilizer only improves crop yields with favorable rainfall; in drought years, synthetic fertilizer is ineffective and may even burn crops. Coxcaltepec participants recommended substituting synthetic fertilizers with various locally-derived soil amendments, including animal manures, worm castings, forest humus, and human urine.

Soil quality was also described by farmers to affect the impact of climatic variability on agroecosystems. The three communities associated soil moisture retention with soil texture and depth. Although soil color was also mentioned as an indicator, it was difficult to use due to apparent contradictions of color classifications across communities. Generally, clayey soils were described as the most productive in drought years, but also difficult to work in wet years (see Soil Texture indicator, Table 3.4). In contrast, farmers described sandy soils as the easiest to work in wet years but also the least productive. Deep soils, measured by farmers as the depth that the Egyptian plow enters the soil, are considered by farmers to be the most productive soils in both wet and dry years (see Soil Depth indicator, Table 3.4).

Table 3.4: Indicators for dealing with climatic variability related to soil quality that were identified by farmers during workshops in Zaragoza, Coxcaltepec, and El Rosario.

Indicator	Marginal ☹	Acceptable 😐	Optimal ☺
Spontaneous Plants	Few spontaneous plants in the milpa	Intermediate number of spontaneous plants in the milpa	Excessive amount of spontaneous plants in the milpa
Soil Productivity	Poor soil that is unproductive unless amended	Fragile soil with poor harvests	Good soil that does not require many amendments
Soil Organic Matter	Soil with little organic matter that is difficult to cultivate, does not retain humidity, or that floods	Intermediate organic matter	Soil with high organic matter that is easy to cultivate, retains moisture, and is porous
Soil Depth	Rocky, shallow or thin soils that the plow does not enter and presence of gullies	Thin soil where the plow enters approximately 1/2 forearm (*codo*), or approximately 10 cm, and presence of rills	Deep soil where the plow enters approximately 1 forearm (*codo*) or 25 cm and without signs of erosion
Soil Texture	Clayey soil that is sticky or sandy soil that dries quickly	Gravelly soil that retains soil moisture	Loamy soils that do not flood

Agroecosystem assessments

Overall, farmers in Zaragoza and El Rosario ranked their agroecosystems in decreasing order as *Optimal* (175 counts), *Acceptable* (119 counts), and *Marginal* (42 counts) across both communities (Figure 3.9). However, the rankings differentiate most clearly between categories of indicators, as described below.

The assessments show that farmers consider their field-level management to be largely appropriate. In both communities, indicators in the category of *Farmer Management* gained the highest number of *Optimal* rankings (46 counts in Zaragoza and 34 counts in El Rosario) and the lowest number of *Acceptable* and *Marginal* rankings combined (14 counts in Zaragoza and 26 counts in El Rosario). *Soil Quality* received a close to equally divided ranking between *Optimal* (29 counts in Zaragoza and 32 counts in El Rosario) and the combined rankings of *Acceptable* and *Marginal* (31 in Zaragoza and 28 in El Rosario). In contrast, *Landscape* indicators received the higher numbers of *Acceptable* and *Marginal* rankings (27 in Zaragoza and 35 in El Rosario, combined) compared to Optimal rankings (21 in Zaragoza and 13 in El Rosario). Indicators of soil quality that are only partially influenced by direct farmer intervention had mixed rankings while those indicators that operated at the landscape scale

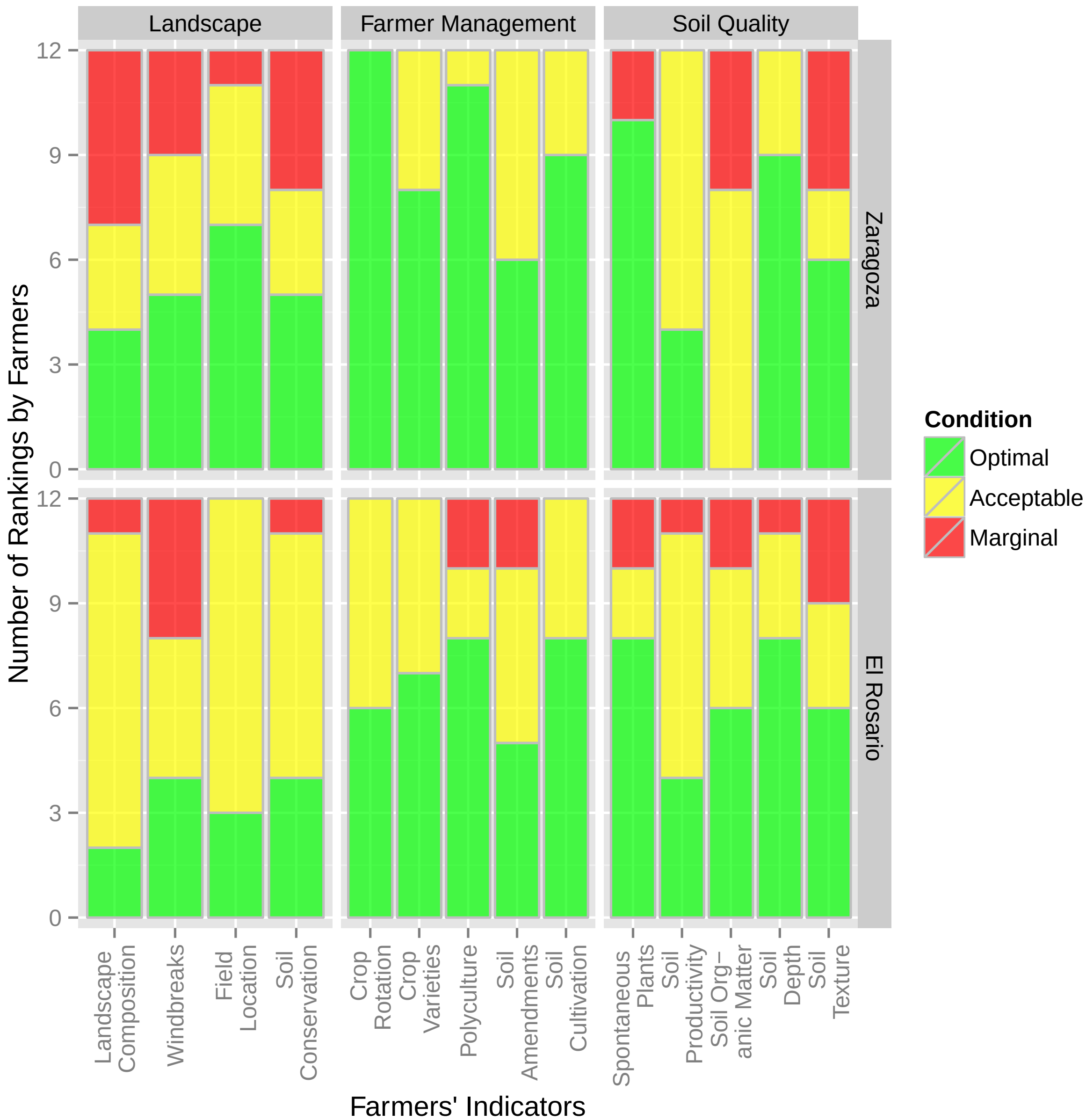

Figure 3.9: Mosaic plot of evaluations of four agroecosystems using 14 indicators that were conducted by three groups of farmers in each of the communities of Zaragoza and El Rosario. The y-axis represents the number of farmers' rankings along an ordinal scale of Marginal (red), Acceptable (yellow), and Optimal (green) for the agroecosystems in their community. The 14 indicators are grouped into those operating at the landscape scale, those directly influenced by farmers' management, and those describing soil quality.

were in the greatest need of improvement.

The lowest and highest scored indicators served as points of departure for answering the reflection questions posed to the farmers of how to maintain the optimal conditions of their agroecosystems while improving the marginal ones. Farmers ranked the most Acceptable and Marginal scores to *Soil Organic Matter* in Zaragoza (8 and 4 counts, respectively) and to Windbreaks in El Rosario (4 and 4 counts, respectively). The indicators with the most Optimal scores were *Crop Rotation* in Zaragoza (12 counts) and *Soil Cultivation* in El Rosario (8 counts).

Farmers' analysis of their evaluations identified multiple local strategies to better prepare for climatic variability. Strategies recommended by farmers for improving their agroecosystems given climatic variability involved establishing perennial vegetation and adopting more soil conservation strategies along field margins (e.g. agroforestry, terraces, contour ditches, and bunds; Table 3.5). In response to low scores for *Landscape* indicators, Zaragoza farmers proposed planting fruit trees and acacia at the edges of fields to diversify the production of food, forage, and fodder, as well as to stabilize soils. Moreover, El Rosario farmers recommended making better use of stone borders (*camellones*) for stabilizing soils, given local soil conditions.

Table 3.5: Strategies proposed by farmers in the Mixteca Alta region for dealing with climatic variability based on indicators operating at the landscape scale, relating directly to farmer management, and describing soil quality. Notably, farmers recognized the need for community education and organizing to successfully implement the landscape-scale recommendations, while highlighting various practices that conserve soils and increase soil organic matter.

Category	Strategies For Moving Towards Optimal
Landscape	Education of community members
	Plant trees for fruit, fodder, etc.
	Protect planted trees from domestic animals with fencing
	Improve livestock management
	Construct contour ditches and bunds
	Maintain windbreaks
Farmer Management	Apply animal manures and composts
	Relax weeding
	Cultivate soil with the oxen
	Respect the seasons
	Harvest water
Soil Quality	Plant fruit trees and acacia
	Sow green manures
	Apply animal manures and composts
	Avoid synthetic fertilizers

Farmers in Zaragoza and El Rosario discussed social constraints to establishing perennial vegetation that would need to be addressed were they to improve landscape-scale indicators. Farmers discussed the important services that animal husbandry provides to their agroecosystems, including manure, farm labor, and income. However, they also recognized that poorly managed herds provoke overgrazing and challenge the establishment of perennial vegetation. Fallow fields and field margins are common pool resources traditionally used by all members of the community to graze animals, which limits the establishment of perennial vegetation, especially at fields further from homesteads where families exercise less oversight. Farmers recommended educating community members about responsible animal husbandry and conservation that would allow for the establishment of perennial vegetation.

While Farmer Management and Soil Quality indicators generally ranked high, farmers discussed several field-scale strategies that primarily aimed to increase levels of soil organic matter (Table 3.5). El Rosario and Zaragoza farmers suggested that cutting weeds and allowing weeds to reseed would provide the benefits of a living mulch without compromising grain yields. Also, farmers suggested that traditional crop polycultures of maize and legumes could instead serve as a green manure if incorporated into the soil prior to harvesting grains, thus improving soil fertility and reducing soil erosion.

3.3 Discussion

This research described farmers' interpretations of climate and identified local strategies for dealing with climatic variability. The workshops highlighted the depth of farmers' knowledge for dealing with climatic variability. The basis of small farmer agroecosystem management in traditional ecological knowledge is well documented in Mesoamerica (Toledo, Boege, and Barrera-Bassols 2010; Pulido and Bocco 2003; Wilken 1987b). Participatory methods based on qualitative evaluations in combination with local farming knowledge of the Mixteca Alta produced a set of best agricultural practices for the region. While the detailed strategies outlined by farmers may be highly site specific, the participatory methodologies used with small farmers in this study can easily be adapted and applied in other regions of the world.

It is noteworthy that farmers' analysis of their situation mirror general policy recommendations for climate change adaptation and mitigation. Farmers' criteria for evaluating landscape features, agricultural practices, and soil attributes overlap with many of the indicators of agricultural resilience proposed by Cabell and Oelofse (2012), including ecological self regulation, connectedness, spatial and temporal heterogeneity, etc. Moreover, farmers' ideas for transforming their agroecosystems correspond to climate adaptation and mitigation strategies recommended by the Intergovernmental Panel on Climate Change (IPCC), notably: increasing reforestation, increasing soil carbon retention, composting, decreasing emissions from manure and petroleum-based fertilizers, and reducing fossil fuel dependency in agriculture (Smith et al. 2007).

Farmers in the Mixteca Alta described long-term modifications to their agroecosystems that represent important strategies for adjusting to changes in average climatic conditions.

Oral histories of farmers document significant changes in farming practices over the past generation. Farmers responded to changes in rainfall patterns by shifting sowing dates, sowing different crops, and selecting crop varieties that succeeded despite environmental disturbances. Farmers guide their cropping decisions based on rainfall patterns in a given year, which has led to progressively later sowing of rainfed crops and the selection of more precocious crop varieties.

In this region that experiences climatic variability, maximizing yields does not appear to matter as much to farmers as stabilizing fluctuations in yields over time. Such stabilizing practices identified from the workshops included soil management to increase soil organic matter, agricultural diversification, and landscape complexity. This perspective may offer space to broaden the lens of appropriate mitigation and adaptation strategies to a changing climate. It is particularly important to consider local strategies and multiple agroecosystem objectives for greater responsiveness to climate change and social need.

Dealing with challenges posed by climatic variability involves much more than a set of farming practices. The apparent contradiction of farmers abandoning cajete maize – one of the drought resistant crops identified by farmers – requires further investigation. Farmer narratives and climate records point to changes in agricultural environments of the Mixteca Alta that may favor seasonal maize over cajete maize despite cajete's resistance to drought events. Though cajete maize is more resistant to drought events, it requires cooler temperatures and moist soils during the dry season. I speculate that the warming and intensity trends have caused a drying of the mean state of soils, so that planting seasonal maize is more favorable. Just as important may be reductions in available rural labor for maintaining traditional practices associated with the production systems like cajete maize. Farmers expressed concerns that labor-saving technologies were negatively affecting their production systems, but considered that many labor-intensive traditional technologies are today impractical.

An unanticipated outcome of the workshops were calls by participating farmers in Zaragoza and El Rosario for greater community mobilization. Farmers recognized that improving landscape-scale indicators would require community-level education and collective action. Before evaluating their agroecosystems, farmers expressed sentiments typified by one participant in El Rosario: "the rains come differently every year. When there is no rain, there is nothing we can do." After conducting their assessments, farmers recognized how their management strategies influence their ability to cope with climatic variability. Again in El Rosario, a farmer asked the group "we know what we need to do now, but how will we make it happen?" The farmers agreed to organize working groups to take action. I interpret this as a process of moving from inevitability, to empowerment, and finally action. In fact, this may reflect the mobilization toward food sovereignty occurring through farmer networks across Latin America that in its collective sense has been described in the literature as a growing agroecological revolution (Altieri and Toledo 2011).

Chapter 4

Conclusion

For agroecology to be scaled up, it must be embedded in social action. The issues that farmers face, even when discussing matters of climate change, are firmly grounded in social dynamics. The first part of this research described the many challenges facing small farmers in the Mixteca Alta region, as well as the richness of farming knowledge that informs daily practice. It is only when this information connects with motivated and forward-thinking groups that real change is possible.

The second part of this research used a farmer-centered approach to find solutions to the challenge of climatic variability. First, this research took a historical approach to ground reflections of possible actions in a known past. This initial step allows farmers to consider what issues in their farming system mattered the most for overcoming the challenges of climate. It became clear that in fact farmers do have a high capacity to interpret outcomes of such evaluation processes. This methodology can be be scaled up through farmer networks and applied in different regions to motivate local preparation, adaptation, and mitigation strategies.

The active participation of the CEDICAM network in all aspects of this research validated local knowledge and prioritized farmer interventions. The example of pre-Conquest practices for regulating soil erosion have inspired modern efforts by CEDICAM to reduce soil loss and crop damage from extreme climatic events. This research project was but a moment in the ongoing research and experimentation that this group of farmers initiated thirty years ago. CEDICAM made this research possible, but more importantly they continue to promote the social conditions for agroecology to flourish in the Mixteca Alta.

At the last meeting held with the 10 leaders of CEDICAM on May 13, 2013, we discussed the outcomes of our collaborative research. I present our group reflections below.

Initial climate analysis would suggest that climate change is happening in the Mixteca Alta, particularly increases in temperature. The members of CEDICAM concurred that rains have arrived later and not sufficiently to sow. Moreover, frosts at the end of the growing season have occurred earlier, putting crops in harm's way.

These climatic changes have been felt in more ways than just poor harvests. Agricultural productivity has dropped, while food prices have risen. Pest damage to both plants and stored grains are increasing. Access to food and water has been reduced, both for livestock and human consumption. Also, animals have been getting sick. Some of the most serious problems that the communities face include forest fires and soil erosion, desertification, social delinquency, sickness, and the abandonment of the countryside, particularly by the youth.

CEDICAM recognized that they are taking many actions to address these problems. Both as members of their communities and CEDICAM, they are conserving their soils (contour ditches, windbreaks, bunds, etc.) to retain water in the moment of rainfall, reforestation to retain soils and soil moisture, and preparing organic composts to improve the quality of agricultural soils. The composts improve their agricultural productivity, and reduce pest damage once the grains have been stored. They promote the recuperation of the *milpa* system and the organic production of vegetables to improve the health of their families, as well as to generate income from agricultural activities.

This research informed CEDICAM's future actions and interventions. While they work with the conservation of seeds, they are interested in farmer-led research to identify more precocious crop varieties. It is important to consider that the frosts have become unpredictable. The evaluations that farmers conducted of their agroecosystems indicate that there is a need to better manage soil moisture and soil cover. They are interested in improving the management of soil moisture so that production systems become more adapted to the climate that farmers have encountered, as well as to other problems.

The network of families that are part of CEDICAM represent a long history of social change through training networks. The CEDICAM network serves to share experiences and to organize working groups. The value in sharing practical skills and knowledge, is that more farmers are trained to change their own lives and their communities. When CEDICAM starts working with a new community, they identify a local promoter. CEDICAM trains her and gives her some new techniques to trial. Once the promoter forms a working group, she shares her experiences with them. Those families then try out the new techniques to see if it works for them. Then, neighbors see what has worked for the group, and they also try them out. It is not just the CEDICAM group. New ideas are tried in parcels, similar to experiment stations, but at smaller scales, before they become more widely adopted.

This gives some insight into the important role that CEDICAM, as an institution and a network, plays in introducing a set of agroecological practices and farmer knowledge into a social arena. This energizes grassroots efforts to tackle problems as they emerge. This kind of mobilization in rural places would seem the best chance to cope, recover, and prepare for climatic changes. Agroecology as a discipline, is well positioned to understand the details of local places, contribute to organizing groups of people to take actions, and creating viable alternatives, especially when engaged with movements like CEDICAM.

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Appendix A

Interview Guides

A.1 Guiding Questions (in Spanish)

1. **Información Personal y Migración**

   a) Código de la persona entrevistada:
   b) Sistema Agrícola:
   c) Familia:
   d) ¿En qué meses se salen fuera de la comunidad y por cuánto tiempo?
   e) ¿Por qué se van?
   f) ¿Por qué se quedan?
   g) ¿Por qué se regresan y qué hacen cuándo regresan? ¿Siembran o cuidan de los bosques?
   h) ¿Cómo afecta que los hijos se vayan en las actividades agrícolas y el cuidado de los animales? ¿Cómo ha afectado a la comunidad?
   i) ¿Qué opina usted sobre migrar o sobre que se tenga que salir a buscar trabajo afuera de la comunidad?

2. **Ingresos Familiares**

   a) ¿Cuándo considera usted que un año es bueno o que es malo? Vamos a pensar ¿qué se produce y qué cosas tendría que comprar en un año bueno y un año malo?
   b) ¿Producen ustedes como familia sus propios alimentos? ¿Qué alimentos se producen y cuáles se recogen o recolectan en el campo? ¿Qué labores se requieren para producir estos alimentos?
   c) ¿Cuánto debería producir para cubrir las necesidades de su familia todo el año?
   d) ¿Cuáles son los meses en que falta alimento en los años buenos? ¿y cuáles en los años malos? ¿Hay siempre granos para hacer tortillas?

e) ¿Qué semillas se intercambian o venden en los años buenos y en los años malos?

f) ¿Qué otros productos intercambian o venden en los años buenos y en los años malos, por ejemplo animales, productos del bosque, artesanías, o carbón?

g) ¿Si consiguiera un mejor precio de venta para el maíz, frijol, o trigo, qué cambios haría usted en las labores de la preparación de la tierra, abonado, o siembra en sus predios? ¿Qué prácticas cambiaría?

h) ¿En qué tipo de empleo han trabajado los miembros de su familia, por ejemplo de albañil, taxista, servicio domestico, jornaleros, o peones? ¿Cuántos días están afuera en los años buenos y años malos?

i) ¿Cómo logran a combinar sus dos trabajos, el del campo y de afuera, en los años buenos y años malos?

j) ¿Cada cuánto tiempo le envían remesas en los años buenos y malos, por ejemplo a cada mes, tres meses, una/dos/tres veces, o solamente para emergencias?

k) ¿Ha tenido apoyo de la comunidad o del gobierno para la producción de los cultivos? Por ejemplo, han recibido apoyo de programas como *PROCAMPO*, *Alianza para el Campo*, *Kilo por Kilo*, *DICONSA*, etc? ¿Qué usted opina de estos programas?

3. **Gastos Familiares**

a) ¿Cómo se ocupa el dinero que usted gana y de remesas de la familia– para alimentos, la escuela, labores agrícolas, construcción, animales, proyectos o fiestas de la comunidad, o otra cosa? ¿En qué meses son los gastos?

b) ¿Qué alimentos compra en años buenos/malos?

c) ¿En qué meses se tiene que comprar? ¿Por qué?

d) ¿Qué hace cuándo sube el precio de los alimentos?

4. **Seguridad Alimentaria**

a) ¿Qué mazorcas de maíz selecciona usted para sembrar? ¿Cómo se guarda la semilla?

b) ¿Cuáles fueron los años en los cuales se perdió la cosecha y la semilla completamente?

c) ¿De donde se obtuvo la semilla para sembrar en esos años? Quién se le dio a usted? ¿Tuvo que comprar o tuvo que prestar o regalar semillas para sembrar?

d) ¿Qué tan importante es guardar sus propias semillas y animales?

5. **Agroambientes**

a) ¿Qué tipos de tierra existen en la comunidad, por ejemplo Tierra Caliente, Templada, Fría, etc.? ¿Donde se encuentran y cuáles son los cultivos y variedades que se producen?

b) ¿Cuál es la temperatura en estas zonas? ¿Hiela? ¿Graniza? ¿Hay sequía? ¿Se encharca? ¿Ventiscas?

c) ¿Qué tipos de suelos hay en cada una de estas zonas, por ejemplo cerrudos, sueltos, chicludos, etc? ¿Tienen nombres en Mixteco o Español?

d) ¿Qué tipo de vegetación se encuentra en cada zona?

e) Cuáles de estas zonas han perdida más suelo que otras?

f) ¿Cuáles son las zonas que se ocupa su familia para el temporal, cajete, o animales? ¿Cuántos predios o hectáreas se cultivan en cada una de las diferentes zonas del territorio?

g) ¿Qué tipo de tenencia existe en estos predios, por ejemplo pequeña propiedad, comunal, ejidal?

h) ¿Cuál es el nivel de productividad en años buenos y malos de estos predios en kilos o costales?

i) ¿En los cuáles se tiene que abonar? ¿Qué echan a los predios para mantener su productividad? ¿Cómo le maneja la fertilidad del suelo?

j) ¿Cuándo empezó a utilizar fertilizantes, plaguicidas, o tractores? ¿Por qué? ¿Mejoran o empeoran la producción?

k) ¿Cuántos animales tiene? ¿Se ocupa un corral para todos los animales o una parte?

6. **El Clima**

   a) ¿Qué son "las cabañuelas", "las caniculas grandes" y la "las caniculas chicas"? ¿Las usa?

7. **Acción Comunitaria**

   a) ¿Qué hacen estas organizaciones?

   b) ¿Ha percibido cambios en la tradición del tequio y/o en el tipo de ayuda que se prestan las familias?

8. **Visión para el Futuro**

   a) ¿Qué significa para usted la vida campesina de producir sus propios alimentos, cuidar de los animales, y convivir en una comunidad rural?

   b) ¿Cuáles son los problemas más importantes para su familia y para la comunidad? ¿Y cuáles son los de la agricultura y de los bosques?

c) ¿Cómo se podría mejorar la condición de su familia y de su comunidad?
d) ¿Cuáles son las oportunidades y las limitaciones para alcanzarlos?
e) ¿Qué futuro le espera para sus hijos?

A.2 Example Response Sheet to Additional Questions (in Spanish)

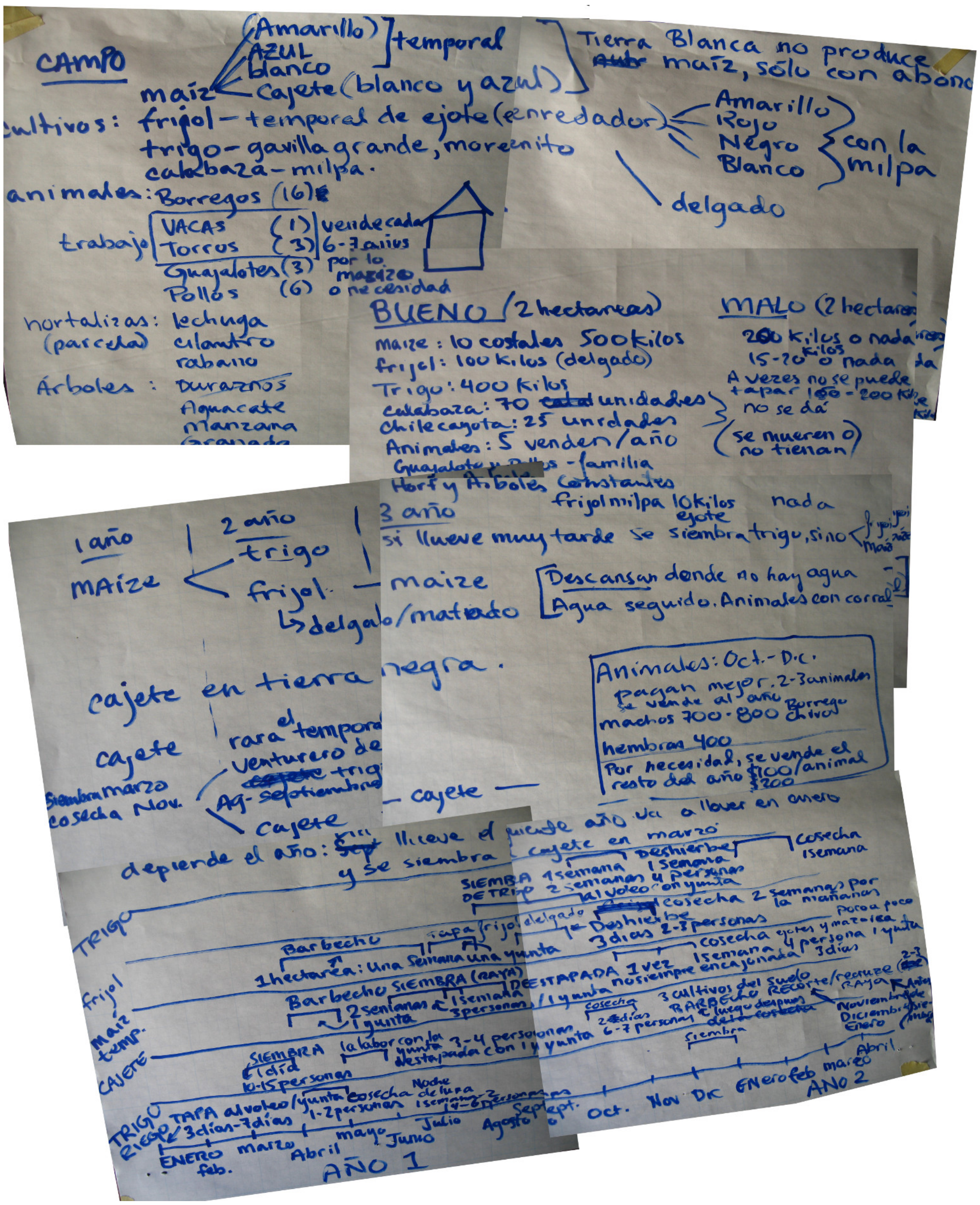

Figure A.1: Interviews involved a discussion on agroecosystems, cropping cycles, varieties of crops, and experiences with climate that went beyond the above listed questions and were recorded with a marker on a large sheet of paper.