Farming in the Southwest: The Potential for Climate Transformation

By

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FARMING IN THE SOUTHWEST: THE POTENTIAL FOR CLIMATE TRANSFORMATION

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At the University of Wisconsin-Madison

Abstract

This study examines the potential for and presence of deliberate transformation of agricultural systems in the U.S. Southwest as farmers face increased challenges as a result of climate change. It focuses specifically on the decisions of farmers in four counties in southern and eastern New Mexico, locations where recent drought provides a useful proxy of conditions expected with future climate change. In contrast to much of the literature on the adaptation of agriculture to climate change, this study seeks to understand the ways in which social, economic, political, as well as climate parameters shape the ways that farmers make decisions when faced with on-going changes in the system in which they work. In tracing farmer narratives of the influences of their agricultural networks on their decision-making, this study finds that there are substantial barriers to transformation in the political economy of agriculture in the U.S. Southwest. Barriers include economic and institutional arrangements that tend to limit the options of farmers who do not have the land resources to achieve economies of scale. Barriers also include farmer narratives that emphasize the limitations built into the economic and institutional context while playing

down farmer agency. Farmer narratives often replay conservative rhetoric about government support for farms and labor in a way that inhibits the ability of farmers to advocate for policies that would better support their farm systems. Nonetheless, the study also finds that farmers whose networks and narratives are shaped in substantial ways by noncapitalist goals, goals centered in matters of care for both the human and non-human organisms that make up the larger agricultural system, are able to undertake transformation on their farms. That transformation also sometimes extends in limited but significant ways to a broader local community.

The results of this research are presented in seven chapters. The first chapter provides a theoretical framing of deliberate transformation as understood through the three spheres approach to transformation. That chapter also introduces the reader to the background and motivations for the project, the positionality of the researcher, and gives an overview of the research project's objectives and methods. The second chapter lays out the geographic and historical context in which incremental or transformative agricultural change is occurring in New Mexico. That context provides an important framing for how existing agricultural systems gained their current shape. That context also provides a platform for understanding what kinds of agricultural systems might be viable in a future New Mexico. Chapter 3 traces statewide and countywide change in farms over the same period as that covered by a series of farm interviews that form the basis for chapters 5 and 6. It thus provides a basis for understanding the more specific changes on individual farms, but also highlights the ways in which barriers in the political economic system have been driving farmers toward incremental changes that are contributing to a decrease in total land farmed in New Mexico. Chapter 4 offers a vision of what goals for a transformed agriculture could be, as well as an analysis of the literature on current barriers to that transformation. That chapter highlights most strongly the political and economic barriers to agricultural transformation. The analysis of farmer interviews in chapter 5 turns to the barriers that farmers identified that have shaped their decision-making on their own farms. In that chapter, I underline the ways in which both the political economic system itself and farmer narratives about the system raise barriers to transformative change. In chapter 6, I analyze farmer interviews to recognize and classify the network influences and associated narratives that help farmers overcome broader political economic barriers and engage in transformative change. Chapter 7 summarizes the main arguments of the dissertation, identifies its theoretical contributions, suggests why New Mexico should be seen as having an agricultural future, and offers recommendations for moving toward the transformation of New Mexican agricultural systems.

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Language Note

The standard contemporary New Mexican spelling for the hot peppers used extensively in New Mexican cooking is “chile.” That spelling will be used throughout the dissertation any time that the crop or the food is described. “Chile” is used in New Mexico to indicate the plant, the fruit, and food products made from the fruit including chile sauces and canned or frozen, sliced chile. The Anglo pronunciation is the same as for the meat and bean stew called chili. The Spanish pronunciation is the same as for the country of Chile.

Chapter 1. Introduction

Agricultural systems are vulnerable to climate change. Climate change impacts on agriculture have so far been mostly negative, except in high latitude regions. Changed temperature and moisture regimes, crop sensitivities to extreme daytime temperatures, and the ability of pests to thrive under new temperature regimes all create new vulnerabilities for agriculture (J. R. Porter et al. 2014). Given these vulnerabilities, climate mitigation alone is inadequate to ensure sufficient agricultural productivity; adaptation is necessary (Howden et al. 2007; Dowd et al. 2014; J.R. Porter et al. 2014). Moreover, in some regions incremental change may be insufficient and more fundamental changes of agricultural systems' structure or function will be necessary (Park et al. 2012; Rickards and Howden 2012). These more fundamental changes have been termed transformational adaptation (ibid.).

In the U.S. Southwest, temperatures are rising to levels warmer than any seen in the area in at least 600 years, heat waves have increased, and stream flows from sources like snowmelt have declined (Hoerling et al. 2013). Both drought and high temperatures raise challenges to current agricultural systems. Additional challenges to water availability are being raised by water demands of urban areas (Frisvold et al. 2013), depletion of aquifers like the Ogallala (Terrell, Johnson, and Segarra 2002; Rawling and Timmons 2017), and disputes over who has the right to use water sources such as the Rio Grande (Paskus 2013, 2018b). Agriculture also faces economic and social challenges, some of which are exacerbated by weather volatility, including crop prices. Shifting border conditions change labor availability (Devadoss and Luckstead 2011; Villarreal 2014), new technologies change seed and machine prices (Bonny 2014; Hawkins and

Buckmaster 2015; Maisashvili et al. 2016), and competition with other countries makes it difficult to receive prices that cover production (Hawkes, Libbin, and Jones, Brandon A 2008; Bryan 2018). With the varied challenges that farmers face in the Southwest, a definition of transformational adaptation that acknowledges social and economic as well as climatic vulnerabilities is a better frame for potential solutions than a definition that focuses mostly on biophysical vulnerabilities.

This dissertation focuses on these multifaceted vulnerabilities and on transformational adaptation that works systematically to address such vulnerabilities. I examine the ways in farmers in New Mexico face barriers to transformation (Moser and Ekstrom 2010) and how some are nonetheless able to make profound and positive changes to their farming systems. I approach transformational change through a lens that builds on a political ecological tradition, acknowledging that vulnerability and potential change result from a range of biophysical, social, and economic challenges and reactions to them.

Deliberate transformation to climate change (O'Brien 2012) focuses on preparing for long-term change in advance of the necessity for the change (Rickards and Howden 2012). Moreover, conceptions of deliberate transformation that emerge from traditions like political ecology, with their focus on economic and social vulnerabilities, provide room to address the multifaceted vulnerabilities faced by farmers as they deal with climate change. For Pelling (2011) a transformation lens would see vulnerability "as an outcome of wider social causes" rather than "proximate causes" like inadequate irrigation infrastructure (p. 97).

To better incorporate the variety of "social causes" that shape vulnerability, O′Brien and Sygna (2013) conceive of three spheres of transformation (based on (Sharma 2007)). The spheres are nested, with the practical sphere in the center, surrounded by the political sphere and then by the personal sphere. The practical sphere is where most of our adaptation interventions have so far tended to take place. O′Brien and Sygna (2013) include here "changes in management practices, the introduction of new technologies. . .. changes in strategies, practices, and behaviors" (p. 5). Next, the political sphere is the sphere of "systems and structures" (O′Brien and Sygna 2013, p. 6). It is where the institutions, markets and laws that shape our options are constructed and reworked. Finally, the personal sphere is where "the transformation of individual and collective beliefs, values and worldviews occur" (O′Brien and Sygna 2013, p. 6). The three spheres are useful for understanding different means through which transformation occurs. It is important to note, however, that they all are "embedded and interacting" (O'Brien and Sygna, p. 4). The practical is part of the political and both are part of the personal. The visual representation is not meant to separate them, but to show their deep relatededness. The personal sphere encompasses both of the others, which means that transformation in the personal sphere simultaneously shapes transformation in the political and practical spheres that are part of it. The personal is not just political; the personal permeates all

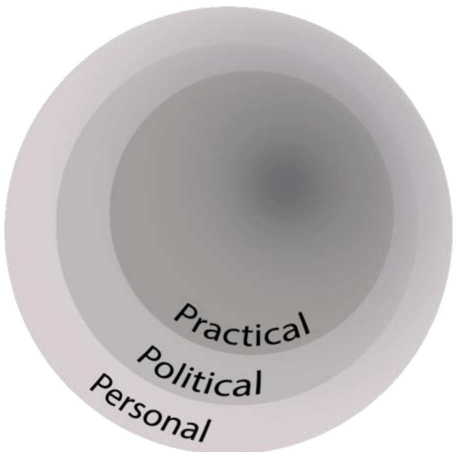

Figure 1: Representation of the three spheres of transformation. Based on O'Brien and Sygna (2013). The personal sphere corresponds to goals, values, beliefs, and worldviews; the political to systems and institutions; and the practical to "technical and behavioral interventions" (p. 155).

transformation. In identifying them separately in analysis, then, I am identifying the source of transformative influence, but recognizing that source as intricately intertwined with the other two spheres in both its origins and its effects.

What could transformations in the practical, political, and personal spheres look like in agriculture? A transformation in the personal sphere might involve a farmer coming to believe that minimizing her carbon footprint and her water use will lead to better outcomes on her farm and allow her to identify herself as a "good farmer." It might also involve a set of lawmakers coming to believe that preparing agriculture for a more volatile climatic and economic future might require a more diverse landscape, in which perennials and polyculture play as large a role as annual monocultures. Such beliefs could, in turn, shape the political sphere by leading the farmer to advocate for new laws about on-farm emissions or lead the lawmakers to pass a farm bill that would better support polycultures. Those outcomes would, in their turn, create new sets of options on farms, changing behaviors (i.e. practical sphere transformation) even for those farmers who have retained beliefs that their only economically sensible options are annual, monocultural crops. New incentives might, for instance, allow farmers to change their calculations about what is economically feasible on the farm.

So, the three spheres are nested because they interact with one another, with political shaping the practical, and vice versa. They are nested in their particular order because of their leverage to produce change (O′Brien and Sygna 2013). The authors modeled the relative leverage of each sphere partly after Meadows (2009). Meadows (2009) analyzed systems, and determined that particular points of intervention in a system were far more effective than others for effecting change. For example, a very ineffective (but easier) point of intervention is in "numbers" or "constants" under which she includes "parameters such as subsidies, taxes, [and] standards" (p. 147). In O'Brien and Sygna's conception (2013), numbers would fall in the practical sphere of transformation because they are oriented at technocratic management of citizen's behaviors rather than changing the broader political system[1]. A higher point of intervention comes in "balancing feedback loops" in which, for example, price can offer feedback that helps to maintain appropriate market conditions (Meadows 2009, pp. 153-54). These might fall in the political sphere, according to O′Brien and Sygna (2013). The highest points of leverage on the system are in setting its goals and paradigms, with the highest leverage of all coming from "transcending paradigms" (Meadows 2009, pp. 161-165). For O′Brien and Sygna (2013), these would fall in the personal sphere of transformation, along with values, beliefs and worldviews. Meadows (2009) points out that even though the highest leverage points have the greatest potential to produce change in a system, they are also difficult to access: "The higher the leverage point, the more the system will resist changing it—that's why societies often rub out truly enlightened beings" (Meadows 2009, p. 165). The highest leverage points also inherently enter uncharted territory, requiring that those attempting change "thro[w] [them]selve[s] into the humility of not-knowing" (Meadows 2009, p. 165). It can be difficult to enter into that spirit of willing uncertainty when one's farm or family depend upon the decisions made each year. Nonetheless, research in business and education (Rooke and Torbert 2005) art

[1] In relying on Meadows (2009) systems approach, a note of caution may be in order, given political ecology's history of critiquing systems theory, such as Watts (1983) critique of natural hazards research.

and geography (Hawkins et al. 2015) are demonstrating that changed mindsets can produce useful concrete outcomes. In chapter 6, this dissertation contributes an understanding of how such changed mindsets can happen for farmers and how they may affect farming outcomes.

The three spheres of transformation approach allows for analytical traction in understanding the source of transformation and which sources of transformation can be most powerful for enacting significant and widespread change to systems. So, for example, it allows the researcher to recognize that changes occuring through the practical sphere of transformation may have limited and specific impacts that do not produce broader change to the system. In agriculture, such limited and specific impacts may come from sources like changes in crop prices or the shifting of permissible numbers in regulation (e.g. how much of a pesticide may be used at a given time). These are changes that occur within the political sphere, but they are not fundamental changes *to* the political sphere. In other words, relations of power and regulatory influence remain the same, but the effects of change are felt in (often relatively minor) behavioral change on-farm. Such minor change may lead farmers incrementally toward maladaptation, as explored in chapter 5.

Transformation within the political sphere would be change that in some way reshaped power relations. For farmers, this might mean, for example, new lobbying bodies that more effectively make sense of the needs of small- and medium-sized growers, collated their information, and worked to reshape policy to better meet the identified needs. For the researcher, the distinction between the political and the practical is important for clarifying the difference between behavioral change that affects the on-the-ground decision-maker in (often) minor and specific ways (practical sphere transformation), and a reconfiguration of power relations in which (e.g.) farmers might work collectively to change the conditions of the broader system (political sphere transformation). When, as is often the case in agriculture, the political sphere is most often reshaped by powerful actors with extensive financial resources, like large agri-corporations and the massive political lobbies that support the largest commodity growers, the political sphere becomes a source not of agricultural transformation, but of limitation for farmers who are *not* those large commodity growers. In other words, using the first two spheres of transformation allows the researcher to distinguish between the kinds of system change that can encourage (although not require) farmers to lock themselves into maladaptive futures—the behavioral and technical change that does not fully account for broader change to come—and a change to the power structures of agriculture. Changes to the power structure may be in the larger institutional system, but they can also occur on-farm. When a farmer cedes some decision-making power to employees, for example, this can represent a transformation in the political sphere.

The most powerful transformation, according to the three spheres model, comes from transformation in the personal sphere. This is also the way in which the model provides the greatest analytical traction. By understanding change through the lens of the three spheres, the researcher can seek to identify shifts in worldviews, values, and beliefs that support transformation to the broader system. It is through transformation in ways of thinking that the greatest system change can occur. So, for example, when farmers come to think of themselves as direct shapers of the political process, they may become more involved in ensuring that transformation occurs in the political sphere that better and more direclty supports their needs. When agricultural policy makers come to believe in a different vision for the future of agriculture, the policy that, in turn, shapes daily agricultural decision-making may be fundamentally rewritten. If the agricultural community more broadly comes to see its role as providing high environmental quality, cohesion in rural communities, and healthful food, transformation across both the political (the Farm Bill, of the USDA) and the practical (resulting on-farm practices, kinds of research carried out). There are several avenues of research that have engaged with how particular farmer mindsets result in particular on-farm decisions, but it is through understanding how broader farmer worldviews transform that we can best begin to identify how broader systems transformation can best be enacted. The three spheres approach encourages the researcher to focus attention, therefore, on the psychological change occurring in the on-the-ground decision-maker. Attention in agricultural research often focuses most on the practical sphere's technical change (seed genetics, pesticide improvements) and the political sphere's institutional effects, but less attention is paid to the way in which the worldview of the on-the-ground decision-maker may be powerful enough to enact on-farm change even despite what may be occuring in agricultural institutions.

Key Arguments

Indeed, that is one element of the overarching argument that I make. The central argument of this dissertation is that the capacity for transformational change already exists, often latent, in the agricultural system, and that initial moves toward transformation can occur on individual farms when farmers' personal spheres of transformation (values, beliefs, worldview) become strongly oriented toward change. Such changes are facilitated when farmers value strongly enough certain forms of change such that they can overcome some of the political sphere barriers to change or even recreate elements of the poltical sphere to better suit the changes they desire. That overarching argument is built through five related arguments:

> 1) the four counties I studied have examples in their ecology and their agricultural (pre)history that suggest potential directions for future agricultural transformation; 2) change has occurred in New Mexican agriculture in recent years, although much of it has been reactive and incremental rather than transformational; 3) climate change in agriculture is a wicked problem[2] and, consequently, a solution is best shaped by stakeholders working together, but key starting points for goals of a transformed agriculture are available in existing research on agricultural ecology, farm labor, and farmer and rural well-being; 4) barriers in the political sphere, as well as farmers' interpretations of the political sphere, stand in the way of the rapid spread of transformation through the agricultural system, and therefore transformation at the level of the individual farm will better resound through the agricultural system as a whole if political barriers are adressed at the same time as beliefs are shifted among those in the

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[2] Wicked problems are problems of our social systems. Information about wicked problems is "confusing," stakeholders have "conflicting values," and in trying to solve such problems we often solve only a small part (Churchman 1967, pp. 1-2). Churchman defined such solutions as "morally wrong" because they attempt to deceive us into believing they are solving the problem as a whole. He suggested that we (problem solvers) have a moral obligation to "enter into a deep mutual understanding of the untamed aspects of the problem" with those concerned in the problem (Churchman 1967, p. 2). Rittel and Webber (1973) add, that approaches to wicked problems should involve an "argumentative process in the course of which an image of the problem and of the solution emerges gradually among participants" (p. 162).

system; 5) transformation has occurred on individual New Mexican farms where beliefs and worldviews support an agricultural paradigm in which economic considerations do not alone determine the choices made in regard to crops, methods, machines, labor, and participation in agricultural networks.

Background and Motivations

Why climate change?

This project began with an interest in climate change. With a belief that the Global North, as principal actor in the making of climate change, must play the central role in solutions. And with a belief that both marginalization and agency are elements of the decision-making process of every farmer. Every farmer can make change to the agricultural system, but for many the barriers to change may seem insuperable. The barriers may seem to lock farmers in to particular sets of economic and ecological choices.

For my master's project, I worked with farmers in Niger who were experiencing extremes exacerbated by climate change. I had begun that project wanting to highlight the marginalization of the most vulnerable. Talking to farmers there, however, deepened my realization that every farmer has some degree of agency to make different decisions, and differing levels of vulnerability that constrain those decisions. Armed with the conviction that it was up to actors in the United States to make real progress with climate change solutions, I chose to focus on farmers in an American region with similar environmental challenges to those of Niger. The decisions of American farmers are important not just to the future of agriculture in the U.S. but are also important in climate change mitigation globally. I wanted to understand to what extent the agency of these farmers matters, and how strongly they were constrained by the economic, political, and social environment in which they make their day-to-day and longer-term decisions.

So, why climate change, in particular? There are so many factors that affect farmers, and we know a lot about what American farmers do and why. We even know a fair amount about their thoughts on climate change and its role in agriculture. But a key question remains: how will farmers prepare for the new challenges brought on by climate change?

This is no small question for the Southwest, nor indeed for most of the United States. For New Mexico, in particular, the period of my study has included a number of weather events that resemble those we expect to become more frequent and extreme as global average temperature continues to rise. In 2011 and 2012, drought slashed wheat harvests and the quality of cattle pasture on New Mexico's High Plains. Farmers in Roosevelt and Curry Counties who used irrigation sometimes found that added water did not provide adequate protection for plants experiencing hot, sandy storms. In the Elephant Butte Irrigation District on New Mexico's southern Rio Grande, irrigation water allocations over the past 12 years have never been greater than 2/3 of what is considered a full allocation of three acre-feet. Between 2011 and 2015, allocations were all less than one acre-foot, with an average of 7.3 acre-inches, and allotments in 2011 and 2013 of four and 3.4 acre-inches, respectively. The slightly increased precipitation of 2017 brought allocations up to two acre-feet, but they have fallen again to eight acre-inches in 2018.

While such events are intertwined with other human changes on the landscape, the weather stressors undeniably make agriculture more of struggle. As Southwestern temperatures warm, in tandem with global temperatures, farming is becoming increasingly challenging. The systems people have chosen in this arid landscape are becoming increasingly untenable.

So, weather is having increasing importance in farm decision-making. As a proxy of the future expected with further climate change, these events therefore give us insight into the ways in which farmers are prepared to act. What do they choose to do when weather provides more extreme challenges? How are they limited by the shifting forces of change in agriculture? And can they transform their systems to minimize vulnerabilities to climate change for both themselves and those in the most vulnerable regions around the world? These are the questions I sought to answer in this project. I found that answers to such questions lay, in part, in the narratives farmers tell about their systems and the constraints that they experience. That highlights one important lesson I have drawn from my time researching transformation: we need to learn to tell new stories, including stories of positive futures, if we are to build a more effective future. By now, we know well that facts alone are not convincing many to respond to climate change. Stories, however, have the power to redraw our understandings of the past and the future (Carleton 2017; Veland et al. 2018).

Why climate change in New Mexican agriculture?

In tracing the history of New Mexican agriculture over the past decade or two, one of my key sources of information has been the annually-produced New Mexico Agricultural Statistics bulletin from the New Mexico Department of Agriculture (NMDA). Among all the numbers and terse sketches of crop yields for the year, I was able to trace a number of stories. Stories of politics, markets, farmer choice. One overarching story of recent New Mexican agricultural history can be traced through the cover photos of the publication chosen by the NMDA. One recent photo for example, is a highly edited photo by a farmer and photographer who is a frequent user of social media like Instagram. His use of such platforms has grown out of his awareness of consumer concern—and ignorance—of what happens on farms. On social media, he posts images and information about what his happening on his farm to increase consumer familiarity and comfort with farm practices like the use of pesticides. The photo reflects the concerns of many contemporary farmers that the broader public does not understand what they do and blames them for food-borne illness and pesticide concerns.

Other photos reflect the distinctive agricultural heritage of New Mexico, focusing on crops like chiles (a.ka. hot peppers to those from outside the region), the Three Sisters, or, the recent star of New Mexican agriculture, the pecan. As the years pass, the shifting agricultural landscape becomes clear. Sheep disappear as milk and milk cows more often take center stage, reflecting how New Mexico's historically strong focus on sheep herding has diminished while dairying has taken on increasing importance. Abundant horticultural crops like onions and flowers, pictured in idyllic-looking farmers markets or on Instagram-worthy tables are increasingly replaced with the new cash-earners like pecans.

Most interesting for this study, however, is the photo from 2011. The image highlights the bright yellow foliage of autumnal cottonwoods against the backdrop of a dry canyon wall. It takes a moment to realize that there is, in fact, a crop in the photo. In the foreground is a rough-looking hayfield with a few, small "square" bales of the kind New Mexicans consider to be horse feed. In other words, these are not the huge, half-ton bales of alfalfa from which some farmers have made much of their income in good years. This is an image of a sideline crop, looking like it is making use of few extra acres near the river that are a bit hilly and hard to crop. The image seems most to celebrate the end of the season and fall color, but not the harvest. The photo stands out because it was in 2011 that the on-going drought began to have significant impacts on farm production across the state. In two eastern counties, Curry and Roosevelt, for example, this is the year that production statistics for a number of crops begin to simply disappear from the record for multiple years.

It is this history, of a region with a richly varied agricultural heritage that is much diminished by severe drought, that has continued to draw me in to the story of New Mexican agriculture. I was initially drawn to research the region because of the extensive stories of difficulty and scarcity that emerged during my preliminary fieldwork in 2012, at the height of the drought. I felt that the region would offer useful examples of the impact of severe climate-related events—and it has. But it is precisely because of the great variety and tradition of agriculture in the state that the losses of the drought appear so stark. As the state prepares for a future with increasingly severe droughts, farmers have a rich set of options on which to draw. But the recent history of the state has largely involved moving away from the rich diversity that represents its agricultural history and prehistory. It will be instructive to see whether farmers choose a return to diversity or a continued move toward industrial simplification.

Positionality

In conducting this research, I was reminded of my positionality as researcher in nearly every interview. I am a woman. I look young. My accent does not clearly place me in either

Wisconsin (where interviewees knew I was a student) or New Mexico. Many of my informants were older men, and would talk freely with me, jumping in to tell long stories of farm history, local history, and agricultural challenges. Often, my male informants, especially the older men, would jump from one topic to the next with little or no prompting from me. My female informants, and one or two younger men, would wait for me to ask questions, check that they were offering information that was useful to me, and engaged more in dialogue than monologue. As a researcher, I found that my reaction to such differences was much different than I was used to—I found the monologues offered me information I might not have considered asking about. Thus, my status as a young-appearing woman allowed me to sit in the role of the good listener with my informants assuming that everything they said might be of interest (as indeed it usually was).

The other important way in which my positionality mattered was that, in many cases, the topics that came up were highly political. We talked about government support of farming, about Medicaid, about disability support, about border policy. I had often referred to myself as a Montanan. I had often made known my knowledge of agricultural details as they came up (RTK guidance for tractors, *terroir* in grapes, the physiological stages of corn), and these seemed to make farmers even more willing to open up to me about all things agricultural. Importantly, I also dressed the part, wearing my button-up plaid shirts and jeans on interviews. Since I never mentioned my own political views, farmers felt comfortable telling me their own. As a result, I was better able to glean stories from them that explained the very real constraints under which they operate. I was also able to hear stories that they freely (and honestly) tinged with their political perspectives, and the subtle differences between two sets of narratives came across. Narratives of real barriers to change as compared to narratives that were clearly built on other conservative (e.g. talk radio) rhetoric became easy to identify, especially as I compared stories to the realities I could track down in news media and the academic literature. In never correcting or questioning farmers' narratives about their realities, I was able to hear stories that helped to explain our current political reality.

I would note, however, that my initial contact with farmers included a high turndown rate. Of four or five farmers contacted, usually only one would agree to speak with me. In the course of the research, I learned that American farmers, like many populations of natural resource managers elsewhere in the world, feel over-surveyed. More than one farmer expressed a feeling that he would not have spoken to me if such-and-such had not recommended I talk to them. They say that regular surveying by the United States Department of Agriculture (USDA), the New Mexico Department of Agriculture (NMDA), and others makes them tired of answering questions about their farms. More than one farmer who actually answered her phone also expressed outright distrust of me and of researchers more generally, sometimes stating that they did not want information about their farms publicly available, despite assurances that anonymity would be protected. Thus, the population of farmers in my study are among the most willing to talk to outsiders, and the most willing to allow others to know how their farms function. Thus, the stories in the study are those of a particular subset of farmers, varied though they are. Those farmers are probably more likely to be willing to engage with their communities outside of agriculture, and with those engaged in agricultural research. Consequently, I may have talked to some farmers who were more open to innovation and change, since farmers with more open, extended networks are more likely to be innovators (Dowd et al. 2014).

Stories, then, played an important role throughout the research. Farmers shared with me the narratives that shape their lives on the farm, and I was able to begin to understand how new narratives may contribute to shaping our agricultural future.

A Note on the Structure of the Dissertation

Some of the chapters (4, 5, 6) are intended as manuscripts for ultimate publication. Consequently, there is some repetition, particularly for parts of methods and important maps.

Research Project and Objectives

Farmers in New Mexico have experienced weather variability throughout New Mexican history, but the severity of drought in the early 21st century made for a case in which the reactions of farmers to conditions like those expected to worsen in the future with climate change could be examined. Given the multiple social and economic challenges farmers were also experiencing—from changing labor availability from Mexico to volatile prices in the wake of the financial crisis and world production shifts—I wanted to understand whether any farmers were choosing deliberate transformation (O'Brien 2012) for their farm systems. Since deliberate transformation involves reason and motive, I wanted to get an understanding directly from farmers themselves. I also wanted to understand, however, how farmers' decisions fit into a larger agricultural context.

The main objective of this study is to understand under what circumstances deliberate transformation happens in agricultural systems that are challenged by the weather extremes that climate change is expected to exacerbate. Specifically, my study examines: 1) the historical record of agricultural change for examples it offers for future change, 2) the barriers to transformative change inherent in both systems and institutions (the political sphere) and in narratives about them (the personal sphere), and 3) the means through which some farmers achieve transformative adaptation on their farms despite barriers to transformative change.

The following questions mediate my research to address these research objectives:

(1) What were agricultural or other livelihood practices of past peoples in New Mexico? Are there any that make use of systems or crops that provide alternatives to current crops and systems in terms of working well with lower water availability, decreased fossil fuel inputs, or higher temperatures? How does the physical geographic and ecological context of each county guide what is feasible for future agricultural choices?

(2) How do agricultural institutions contribute to or limit the transformative adaptation farmers can undertake? How do other elements of farmers' networks provide incentives or disincentives to transformative change? To what degree do elements of farmers' networks encourage incremental adaptation? To what degree might incremental adaptation represent a barrier to future transformational change? What are the narratives that farmers tell about their networks that contribute to disincentivizing transformative adaptation?

(3) Are any farmers transforming their on-farm agricultural systems? What does deliberate transformation look like in a New Mexican context? What are the supports for deliberate transformation? What is the narrative-network context (Lejano, Ingram,

and Ingram 2013) that supports deliberate transformation? Are elements of farmer or farm transformation reproducible to scale up the transformation?

Methods

Methods for the empirical sections of the dissertation include analysis of USDA Agricultural Census data, of New Mexico Department of Agriculture (NMDA) data, and the conduct and analysis of interviews with farmers and other members of agriculture networks. I will cover each in turn.

USDA Agricultural Censuses at the county level are available from 1910 forward. Theoretically, the census is conducted every five years, although that has varied greatly over time. For example, censuses were conducted every ten years until 1925. Data for each county was gathered from the censuses between 1910 and 1987 in order to provide historical background on agricultural change for each county. Data gathered focused on changes in acreage over time in order to offer a gauge of what farmers were choosing to grow in a given period. For certain crops, especially tree crops, data on acreage was not available for censuses until late in the 20th century, so data on tree numbers was gathered instead. For consistency, tree numbers were gathered even when acreage was included. These data were used in narrative format as part of the history for each county.

The New Mexico Department of Agriculture (NMDA) began producing the New Mexico Agricultural Statistics Bulletin in 1962, although the names have varied slightly from year to year. The bulletin is produced yearly from surveys conducted by both USDA and NMDA staff. I used data from these surveys to analyze change in the counties, for the most part since 1995. In a few cases where there was a story of change before 1995 that was relevant to current realities, I used the Bulletins to trace back into the 1980s. The time period of focus for analysis of the Bulletins was, therefore, a time period recalled by most farmers, and a time when most had been farming. That meant that the analysis from the Bulletins helped to provide background to farm histories provided by farmers.

Identification of informants began in preliminary research with finding staff of the Natural Resources Conservation Service (NRCS), Farm Service Agency (FSA)—both agencies of the USDA—and county extension. These staff were identified through internet searches of the USDA websites with information on each county. I began with the NRCS, FSA, and APHIS (Animal and Plant Health Inspection Service) offices at the state level in Albuquerque and received advice from staff there on counties that might have stories of drought impacts. Initial recommendations included Chaves County, where Roswell is, and did not include Luna County. Based partly on recommendations from state-level officials and partly on web searches, I identified USDA staff to interview in Curry, Roosevelt, and Doña Ana Counties. Ultimately, I talked to five USDA employees in Curry, Doña Ana, and Roosevelt Counties, as well as county extension in each of the counties. I dropped Chaves County after a visit there, finding that most drought impacts reported to me by NRCS staff were related to pasture rather than crops. My interest was in cropping choices, so Chaves County did not fit my criteria. I added Luna County largely because visits to the Las Cruces farmers market yielded some informants who worked in Luna County, and because the county was experiencing similar climatic impacts to Doña Ana County. Note that while USDA informants were useful for general information about counties,

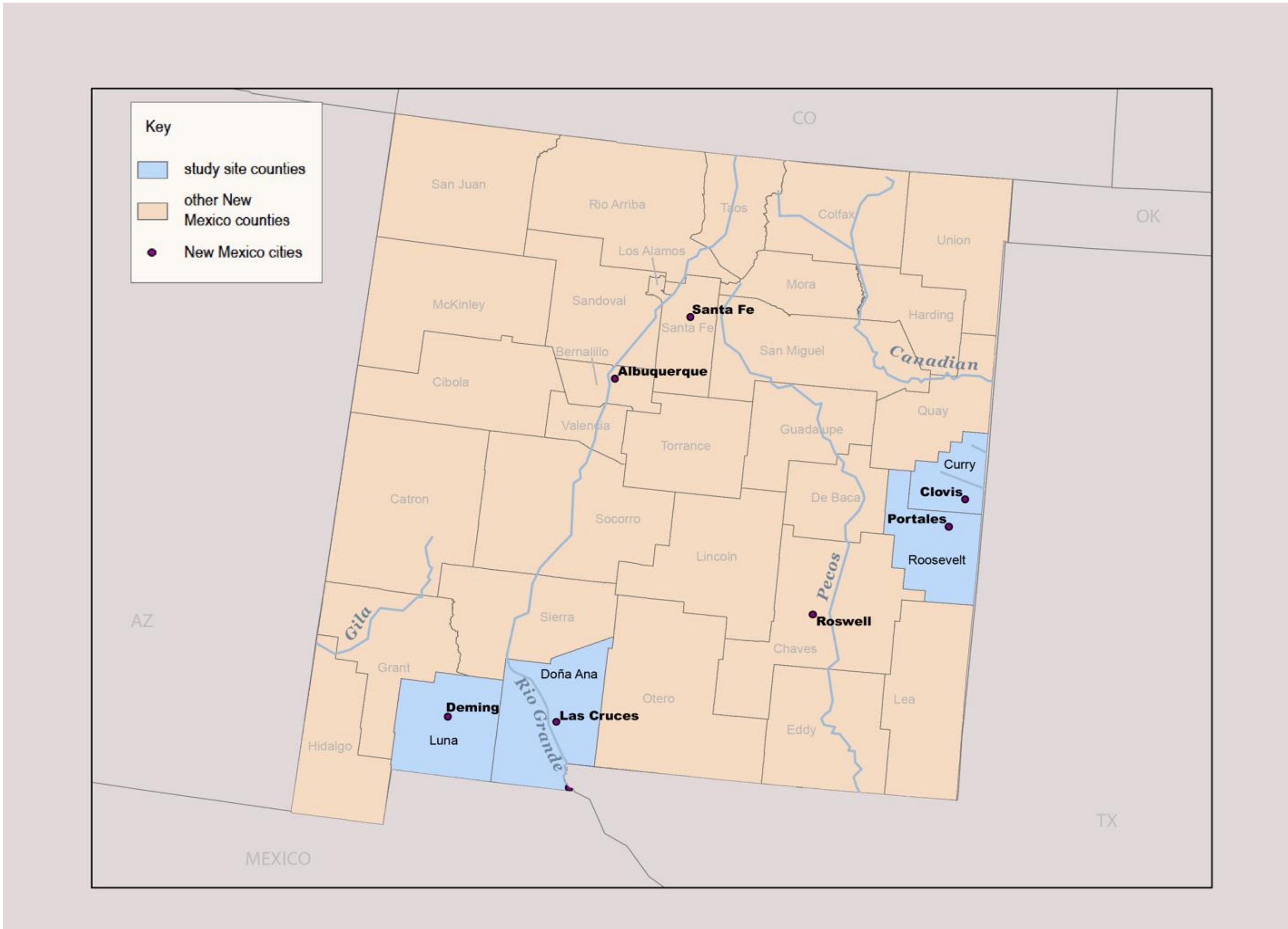

Figure 2: Study area counties in blue. County seats labeled next to magenta dots.

they are not permitted to give out any kind of farmer information, so they were not able to direct me to useful farmer informants.

Identification of informants continued through discussions with both research and extension professors at New Mexico State University (NMSU) (ten of thirteen of them in agricultural sciences or extension, the other three in geography) and Eastern New Mexico University (ENMU) (two in agricultural science at this much smaller institution). As indicated above, I also attended the Las Cruces Farmers and Crafts Market and made initial contact with small, direct-to-market growers there. Interviews with staff of the local food cooperative led to some useful suggestions of smaller growers, but none of them panned out. None of the professors associated with agriculture came through with any of their promised contacts, but I was finally able to connect with a conventional farmer in Doña Ana County through a professor in the NMSU Geography Department. After repeated requests, the county extension agent in Roosevelt County also provided me with several successful contacts. My initial farmer contacts thus came from three sources: the Las Cruces Farmers and Crafts Market, a NMSU Geography professor, and the Roosevelt County Extension Agent. Thus, it took more than 45 initial interviews to yield the three farmers who represented the starting points of my farmer contacts. All farmer contacts from there (with the exception of one farmer I met at the annual Chile Conference) were the result of recommendations from previous farmers. I found that about one in five of the contacts I gleaned from other farmers were willing to talk with me. In eastern New Mexico, I had trouble getting any farmers to pick up at all until I got a new phone number with a New Mexico area code. Even then, only about one in three farmers ever picked up the phone when I called, even if I was able to leave a message on a previous call. At least half of farmers, however, did not have voicemail set up or their voicemail was always full. In Doña Ana and Luna Counties, I experienced more than one phone call in which the caller hung up after I said my name, the contact who had recommended them, and the fact that I was researching agriculture in the county over the previous ten years. Several farmers let me get a bit further but said they did not want to talk to me when they learned I would be taking down details about their farm operation. Therefore, it was clear that some who refused to participate were those who did not want to risk their data being publicly available. Nonetheless, with persistence, the snowball method in Roosevelt County yielded both large conventional and small direct-to-market growers in both Roosevelt and Curry Counties. Snowballing from Doña Ana County informants resulted in both large and conventional growers and small, direct-to-market growers, but I met most small growers directly at the farmers market. The fact that there was a limited selection of farmers willing to talk to me may indicate that my sample is more heavily skewed toward growers with potentially transformative methods, as they may be the growers more willing to engage with outsiders, just as they are they growers more willing to engage with outside ideas. That does not suggest, however, by any means, that the farmers I talked to were those who were most "progressive" in their methods. There were many farmers who very much fit the mold of conventional farmer in methods and approaches. It may mean, however, that I encountered a higher ratio of farmers with transformative worldviews than would be found in a full county survey.

Table 1. Comparison between farms participating in the study and each county's farm sizes in the 2012 Census of Agriculture.

	Doña Ana County	**Luna County**	**Roosevelt County**	**Curry County**
Size of Study Farms (Acres)				
1-9	3	1		1
10-49	1		1	
50-179				
180-499	3		3	
500-999			1	1
1000+	4**	1	4	2
County Totals*				
County Average Farm Size*	302	2,896	1,984	1,468
County Median Farm Size*	5	195	440	480
Farms by Size* (acres)	1-9	1,466	27	36
10-49	403	23	82	56
50-179	150	44	137	45
180-499	66	26	102	76
500-999	40	17	102	125
1,000+	59	53	221	83

**From the 2012 Census of Agriculture*
***One of these farms has approximately half its acreage in Doña Ana County and half in Luna.*

I conducted 26 interviews with 30 farmers. Four pairs of farmers were interviewed; all pairs were members of the same family. Farmers ranged from growers for farmers markets with varying inclination toward organic-like practices, to high acreage (100s or over 1000 acres) organic growers, to conventional growers. Conventional growers themselves ranged from those with lower acreage farms (<500 acres) growing a range of entirely irrigated crops (as in Doña Ana and Luna Counties), a mix of irrigated and dryland crops (in Curry and Roosevelt Counties), or entirely dryland crops (in Curry and Roosevelt Counties). Those classified as conventional growers (all but two of the farms with more than 50 acres) for the most part use techniques typical of those growing commodity crops elsewhere in the country, including genetically modified seeds, industrially-produced petrochemical fertilizers, and a range of industrially-produced pest-control chemicals.

In-depth interviews included discussion of farm history as the farmer knew it (often back to establishment of the farm under parents or grandparents) and an in-depth history of decision-making over the 10 most recent years, or as far back as the farmer was able if less than 10 years. Decision-making histories included discussion of choices made from year to year as well as why those choices were made. Farmers were asked to describe how members of their networks were important to shaping decisions. Actors in farmers' networks included entities like input suppliers, buyers, bankers, neighbors, farm media, popular media, university agricultural research websites, creators of agricultural software, family, laborers and other organisms on the farm itself such as crops and animals. I asked farmers to explain which entities were important to their decisions and why. Also included in the discussion was how farmers had dealt with drought, other forms of water shortage, and severe weather events. Some farmers were able to directly trace details such as changes in crop percentages planted and income over time. Others recalled major decisions somewhat more generally once the discussion extended beyond three or four years into the past.

I conducted narrative-network analysis (Lejano, Ingram, and Ingram 2013) of farmer interviews. Goals of the analysis were to determine the barriers farmers experienced to transformational adaptation, the ways in which farmers were able to transform their systems, and the narratives that contributed to shaping both barriers and transformative capacity. Both barriers and transformative capacity were grouped into personal, political, and practical spheres to assess how influences from each sphere affected farmer beliefs, decisions and farm outcomes.

In the chapters to come, I first (Chapter 2) provide a picture of the ways in which the climatic, geographic, and historical background of the studied counties offers a framing of the agricultural possibilities in those counties. Current responses on the four counties are shaped not only by biophysical conditions, but by cultural and agricultural history. This context and history is important to understand the particular decisions made by farmers recently. In chapter 3, I then provide context for the recent changes made by farmers in the study by presenting current statewide and county-level agricultural change during the study period. In addition, chapter 3 begins to analyze how the three spheres of transformation may be a useful framework for understanding why farmers may or may not make adaptive or transformative decisions. In chapter 4, I provide a vision of the kinds of goals a transformative agriculture might set for itself, and lay out a theoretical understanding of the barriers that lie in the way of achieving those goals. Chapter 5 discusses the barriers to transformation experienced by farmers in the study, and lays out, in particular, the ways in which institutions in the political sphere combined with farmers' personal sphere conceptions of those institutions may limit transformative change. In Chapter 6 I analyze the few cases of transformative farmers in the study and find that they, among other qualities, have a propensity to see value in more elements of their networks than just those tied to capital and markets. With chapter 7, I conclude and offer some recommendations for change in the agricultural system.

Chapter 2: Background: The Climatic, Geographic, and Historical Settings

Introduction

For the New Mexican counties of Doña Ana, Luna, Curry, and Roosevelt, a combination of factors has made their agricultural present and future increasingly challenging. The physical geography, ecology, and history of the counties contribute to explaining how they have arrived at their present realities. The Chihuahuan Desert and the Great Plains both offer distinct challenges to human subsistence, and at various times in the area's past, drought has steepened the challenge to a degree that has forced human migration to friendlier zones of the Southwest, often places in higher elevations or in closer proximity to rivers.

In addition, though, the ecology and agricultural past of the counties offer some ideas for models of the agricultural future. The prehistoric peoples of these counties made heavy use not only of crops that originated in the Americas, like corn, beans, and squash, but also of locally occurring plants of the Chihuahuan Desert and Great Plains. Prickly pear cactus, yucca, walnuts, pigweed (*Chenopodium fremontii*), and a variety of other native plant species were once key food sources for the people living in the region, both farmers and hunter-gatherers. Making a living from the land for prehistoric farmers in southern New Mexico was not a question of growing vast fields of corn and beans, but of working with each plant in its specific ecological niche, some cultivated and some wild. Raising animals like turkeys was also important for some groups of early New Mexicans. For all peoples in prehistoric New Mexico, hunting was also an element of livelihoods. For the European immigrants who followed in the region, these native plants rarely played a part in their food stocks. Instead, immigrants planted a mix of domesticated crops, some brought from Europe and some encountered in the Americas. As they became more and more linked to wider regional, national, and international markets, the diversity of crops grown often declined, although not always permanently.

This chapter thus provides context for both the current and future challenges of the study areas as well as the potential to be found in the past. The chapter lays the groundwork for understanding the starting points, the potential, for agriculture in the four study counties. The starting points include climate and its continued change, which will affect water availability and temperatures that shape crop options in the future. Another starting point lies in the physical geography. The rich agricultural soils of places like the Mesilla Valley, the outlet of the Mimbres River Valley, and parts of the Great Plains provide fertile ground, but their use is constrained by elevation, rain shadows, and their sources of water. The ecology therefore provides another outline of the potential for agriculture in the study areas. Many of the plants in the region are plants well adapted to drought, but many of them are edible. Moreover, they grow in an arrangement of far greater ecological complexity than most of the agriculture in the region, and thus offer potential models for how to rethink agriculture to provide the increased ecosystem services in forms like shade and erosion reduction that will permit food crops to grow even with reduced water. Then, the history of the counties offers an idea of what has sustained people in the counties in the past, how institutions are important to shaping agriculture in the region, and how (non-climatic) agricultural transformations have occurred in the past.

First covered is climate. Climate variability has shaped regional realities throughout human presence in the region. The range of variability likely to occur in the region, however, has not been experienced by European "newcomers." The worst of droughts during human inhabitation were in prehistory, around the 12th century A.D. Those paleo-droughts therefore provide some understanding of the future change that may be in store for the region. After the climate context is presented, I will turn to each county in turn to offer the specific geographic and historical context that have shaped agriculture there into what it is today. Within the geographic, ecological, and historical tales of these counties are clues for models of future climatic adaptation as well as important biophysical limits. This chapter thus provides important context for understanding what may be possible for the agricultural future of southern and eastern New Mexico. In chronological terms, the history in this chapter precedes that in chapter 3, which focuses on the specific agricultural changes that have occurred during the period talked about by farmers in the study, of approximately 1995 to the present. This chapter focuses on pre-history through the mid-1990s.

Climate and climate change in New Mexico

With its highly varied topography, in an area which includes the Basin-and-Range Province, the southern Rocky Mountains, and the far western Great Plains, climate and weather vary widely across New Mexico. Nonetheless, the summer monsoons tend to bring a peak of precipitation across nearly all of the state. Winter precipitation varies widely, but is generally significantly less than that available from the summer monsoons (Figure 1; (Garfin et al. 2013)). Average annual precipitation on the Great Plains to the northeast averages higher than in southern New Mexico's Chihuahuan Desert. Average annual precipitation in the eastern counties of Roosevelt and Curry is 17 inches in Portales and 18 inches in Clovis, with totals varying widely from year to year. In southern New Mexico, total annual precipitation averages under 10 inches in Doña Ana County and about 10 in Luna County, with similar broad interannual variation. Snow in the upper elevations of the mountains of northern New Mexico and southern Colorado has typically provided the spring streamflow that maintains flow in the Rio Grande (Garfin et al. 2013).

Temperature in the state is also highly variable, with average temperatures lowest at higher elevations (Garfin et al. 2013). Lows in southern New Mexico winters tend to be above freezing, but freezes often occur in December and January. Contemporary summer highs in the High Plains and southern New Mexico are often in the upper 90ºF to 100ºF range (Midwestern Regional Climate Center 2018). Such highs challenge or even prohibit a number of market garden crops like tomatoes, lettuce, and brassica crops.

In southern New Mexico, average annual low temperatures have risen substantially over the past 125 years (Figure 2), and they have also risen in eastern New Mexico (Fig. 2). Statewide, average temperatures have risen, resulting in more cooling degree days and fewer heating degree days across New Mexico (Figure 3). In southern New Mexico, the higher lows of the 2000s have coincided with a near disappearance of snowfall in Las Cruces during this century (Figure 4). In eastern New Mexico, precipitation overall has changed little, but its pattern has been redistributed, with fewer instances of very high rainfall totals during summer monsoon months (Figure 5). As in Las Cruces, snowfall in the Rio Grande Basin has fallen over the past few decades (Figures 5 & 6 (USDA Natural Resources Conservation Service 2018)). For both southern and eastern New Mexico, these trends have also included hotter summer temperatures. As summer temperatures rise, soil moisture during the growing season declines, meaning greater need for irrigation water for those farmers who irrigate. At the same time, with declining snowpack in the Rio Grande Basin, less water is available for irrigation from the Rio Grande (Garfin et al. 2013). This decline is reflected in broader trends across the western U.S. (Mote et al. 2018). The Rio Grande is the source of both surface water and groundwater for farms in counties all along it, including Doña Ana County, where it is the source for most of the water used for all purposes.

In addition to the effects of general warming trends, at least two forms of severe weather incidents have been causing increasing damage. Southwestern dust storms have increased during the 21st century as compared to the 1990s (Tong et al. 2017). Farmers report that dust storms cause damage to certain crops, especially when the crops are young. Farmers attribute chile deaths to the static electricity built up in dust storms. As that electricity also results in more sand traveling close to the ground (Kok and Renno 2008), the effects of the particles themselves may be equally important. In addition to sand storms, meteorologists and farmers report having to deal with more difficult hailstorms that they experienced in the past (Crowder 2017; V. Franzoy, personal communication, Dec. 6, 2016). In southern New Mexico and far west Texas (i.e. El Paso), numbers of insurance claims for hail have jumped substantially in recent years (Crowder 2017). Research on how anthropogenic climate change affects hailstorms suggests that in regions like the U.S. Southwest, hail size may be increasing as global temperatures warm, thus increasing the potential for damage (Brimelow, Burrows, and Hanesiak 2017).

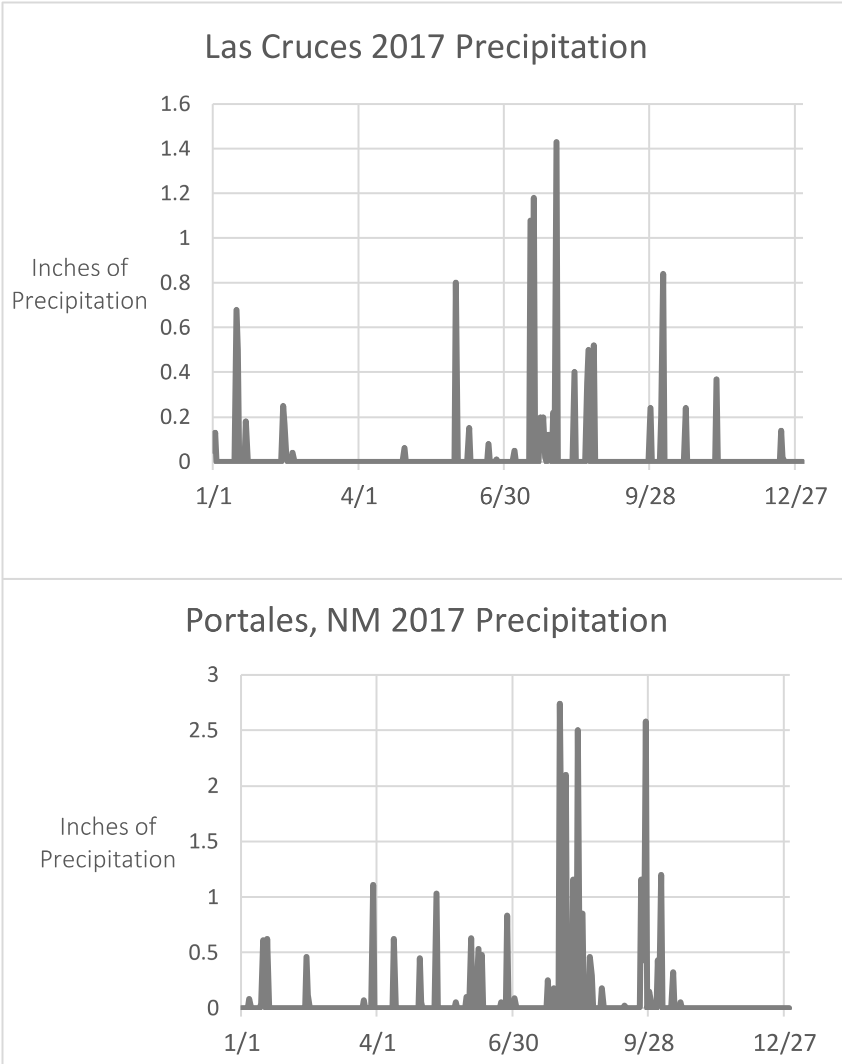

Figure 3: 2017 Precipitation for Las Cruces (southern New Mexico), and Portales (Great Plains/eastern New Mexico). Notice that peak precipitation for both is in late summer. Data from (Midwestern Regional Climate Center, 2018).

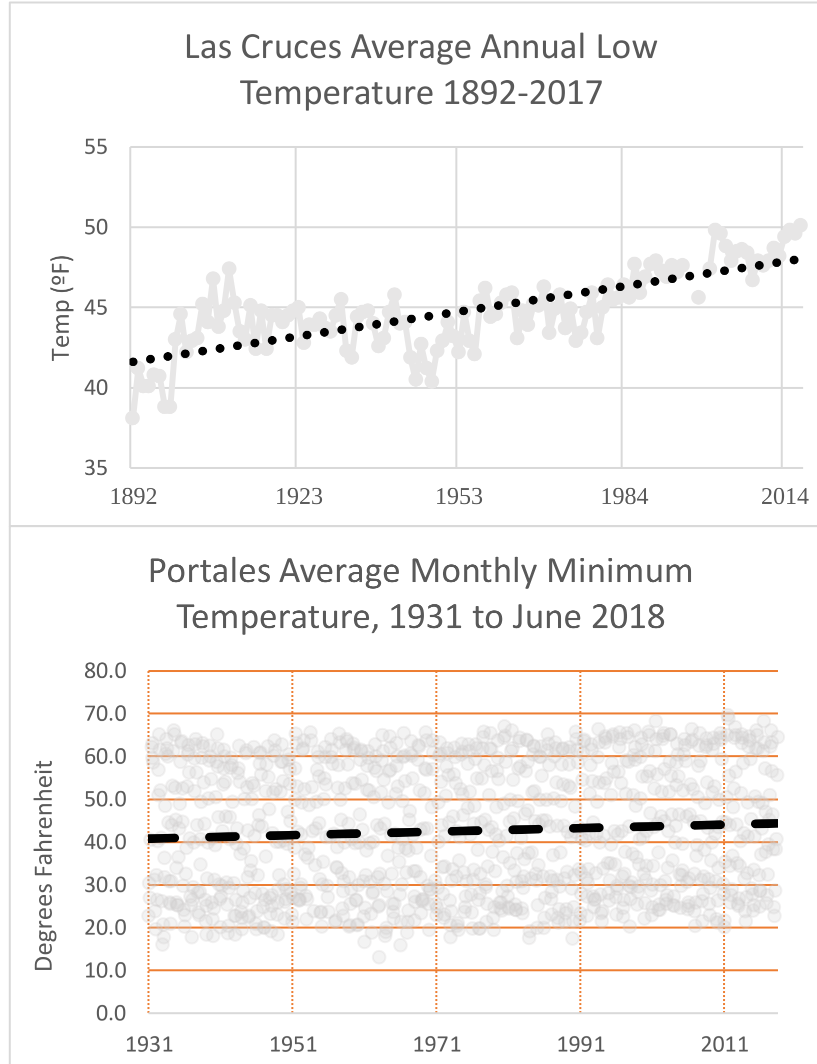

Figure 4: Average annual (Las Cruces) and monthly (Portales) minimum temperatures. Incomplete data in 1996, 1997, and 1999 removed from Las Cruces. Dotted/dashed lines are linear trendlines. Data from Midwestern Regional Climate Center 2018.

Drought has an important history in the region. Since 1901, drought in the first decade of the 21st century was second in areal extent to drought in the 1950s[3]. Prior historical drought has also been severe, with the Rio Grande having had severely low flows (as measured by tree ring data) for 10 out of 11 years from 1873 to 1883 (Fleck 2013). Although droughts in the historical record have not reached the areal extent of paleodroughts in the region, they have nonetheless had important impacts in New Mexico. Paleodroughts like those affecting Puebloan peoples in the 13th, 16th, and 17th centuries, and especially the megadrought of the 12th century were spread over a wider geographic area than have the droughts of the 21st century (Hoerling et al. 2013). The evidence of the impacts of paleodroughts in the region, especially in the 12th century, suggests that Ancestral Puebloans and others in the region experienced forced migration and severe hardship (Childs 2008). Even though recent droughts have not reached the extremity of paleodroughts, with higher demands for water with increasing population, and Rio Grande water heavily allocated across three states and two countries, the 21st century drought is providing extensive challenges for adaptation in the region. The degree to which groundwater is drawn upon is far greater than it was in the 1950s, and snowpack from the Rio Grande Basin is substantially decreased. Moreover, the evidence of the past suggests that previous warm periods were also periods of drought in the region (Hoerling et al. 2013). Projections for the 21st century

[3] The 1950s drought was severe throughout much of the Southwest and southern Great Plains, and some farmers still recall its impacts or stories told by previous generations. The 1930's drought, a contributor to the Dust Bowl, was not as severe in the Southwest except in 1934, although it was severe on the Great Plains as eastern parts of the Southwest through much of the Dust Bowl period (Garfin et al. 2013).

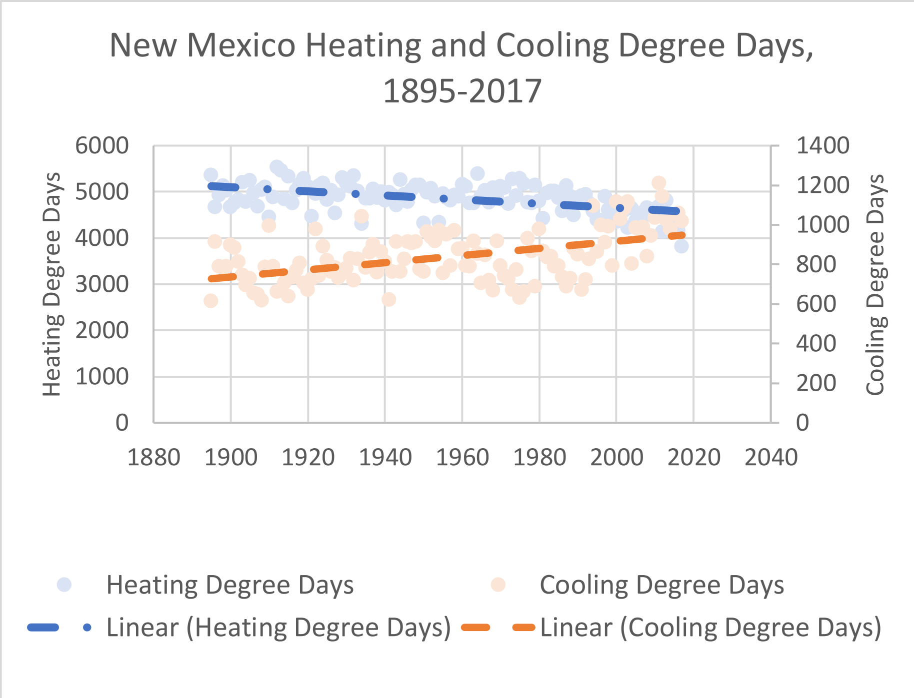

Figure 5: Heating degree days (number of days when average temperature is below 65°F and homes require heating) have declined in New Mexico, and cooling degree days (average temperature above 65°F) have risen, indicating the rising temperatures in the state overall. Linear trendlines applied to each graph. Points represent yearly cooling or heating degree days. Data from Midwestern Regional Climate Center 2018.

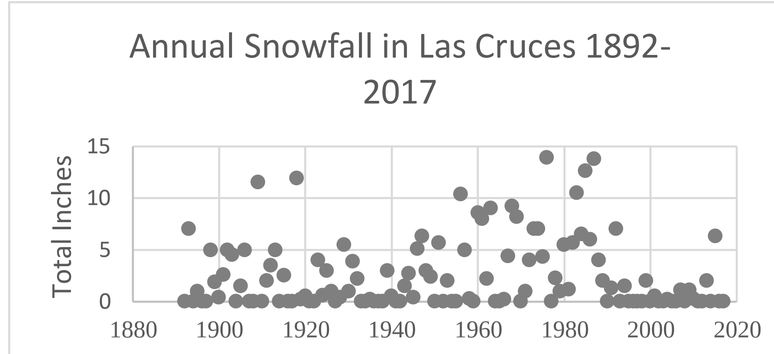

Figure 6: Annual snowfall totals for Las Cruces, NM, 1892 to 2017. While the data are highly stochastic, the number of zero snowfall years since 1995 is unprecedented within a similar time period in the weather station's record. Data downloaded from Midwestern Regional Climate Center 2018.

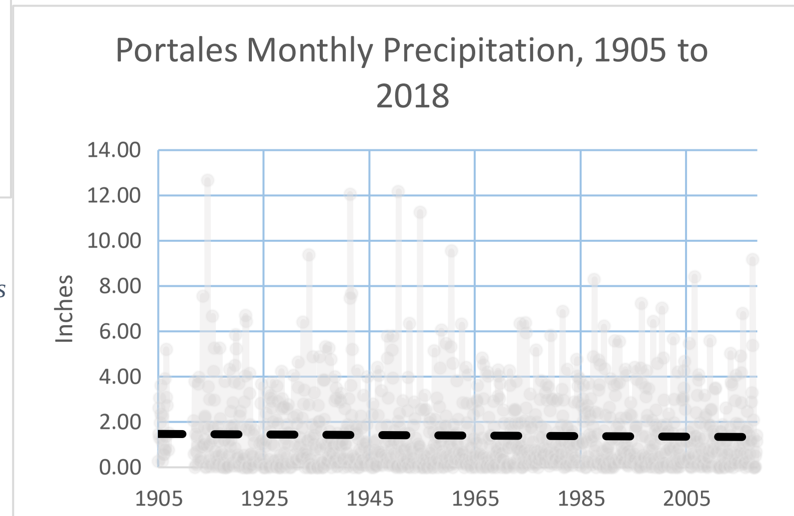

Figure 7: Monthly precipitation totals. Data missing 1907-1911. Especially high rainfall totals all fall in May-September. Linear trendline shows little change, but individual months show changed patterns. Data downloaded from Midwestern Regional Climate Center 2018.

are that, on average, surface temperatures in the Southwest will increase by 3ºF, the greatest rise in temperatures will be in the summer and fall (irrigation season), and snowpack will continue to decline (Cayan et al. 2013). Thus, the challenges experienced by the Southwest in recent droughts are likely to continue and intensify (Gershunov et al. 2013).

For agriculture specifically, changing conditions, including warmer winter temperatures, are likely to allow new pests and diseases to establish (Frisvold et al. 2013). In addition, costs of adjustment to new conditions may be high, as new irrigation, food processing, and transportation networks may be necessary. Tree crops, in particular, require high costs for adjustment, a fact especially pertinent for increasingly pecan-focused New Mexico (Frisvold et al. 2013). As shifting water from agriculture to urban areas appears to be one way of minimizing overall costs of human adjustment to climate change, agriculture will be increasingly challenged to persist without considering new crops and other alternatives to their current systems (ibid.).

The changing conditions experienced by farmers as a result of climate change are further framed by the particularities of geography and human history in each county. The physical geographic setting and the human and agricultural history of each county in the study are thus the subject of the next section. Within each county, ecology and the agricultural past offer up possibilities for changes to the farming system that could help in preparing for future change.

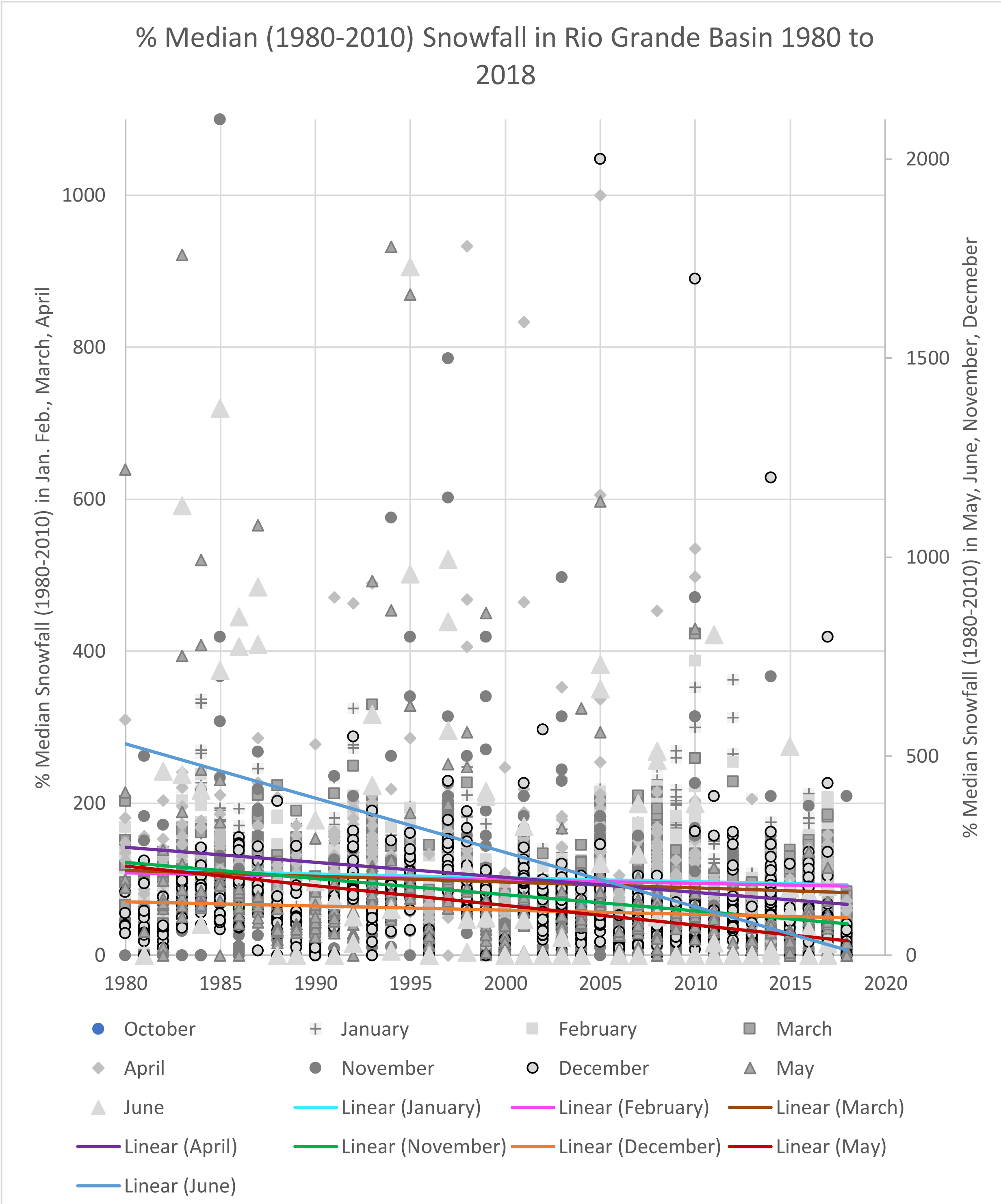

Figure 8: SNOTEL stations in the Rio Grande Basin (headwaters, upper Rio Grande and lower Rio Grande) show declining snowfall across the basin, particularly at the beginning (November) and end (May, June) of the snow season. Shapes are individual months and lines are monthly trends across the 38 years. Data from (USDA Natural Resources Conservation Service, 2018).

County Histories and Geographies

Doña Ana County

Geography

In the Basin and Range Province and flanked by mountains in nearly every direction, the Mesilla Valley that makes up much of Doña Ana County is part of the Rio Grande Rift (Chronic 1987). The surrounding mountains of volcanic origins, as well as upstream sources, have deposited a deep layer of sediment in the valley. The broad basin underlying the Rio Grande is the site of an aquifer that extends beyond the river valley to the west (Hawley, Kennedy, and Creel 2001; Land 2016b). Alluvial sediment combined with often-abundant river water have contributed to making the valley an agricultural center within the larger Chihuahuan Desert ecosystem.

The Organ Mountains to the east of Las Cruces are the highest point in the county, topping out with Organ Needle at just under 9,000 feet. The San Augustin range, Sierra de Las Uvas and West Potrillo Mountains make up some of the other major ranges surrounding the valley. The Rio Grande Valley contains the lowest land in the county, with lowest points at its southern end at about 3,700 feet (Doña Ana County, Department of Planning and Development 2002). The mountains surrounding the valley have varied origins, including the igneous (pyroclastic) origin of the Organ Mountains, the sedimentary limestone of the Robledos, the

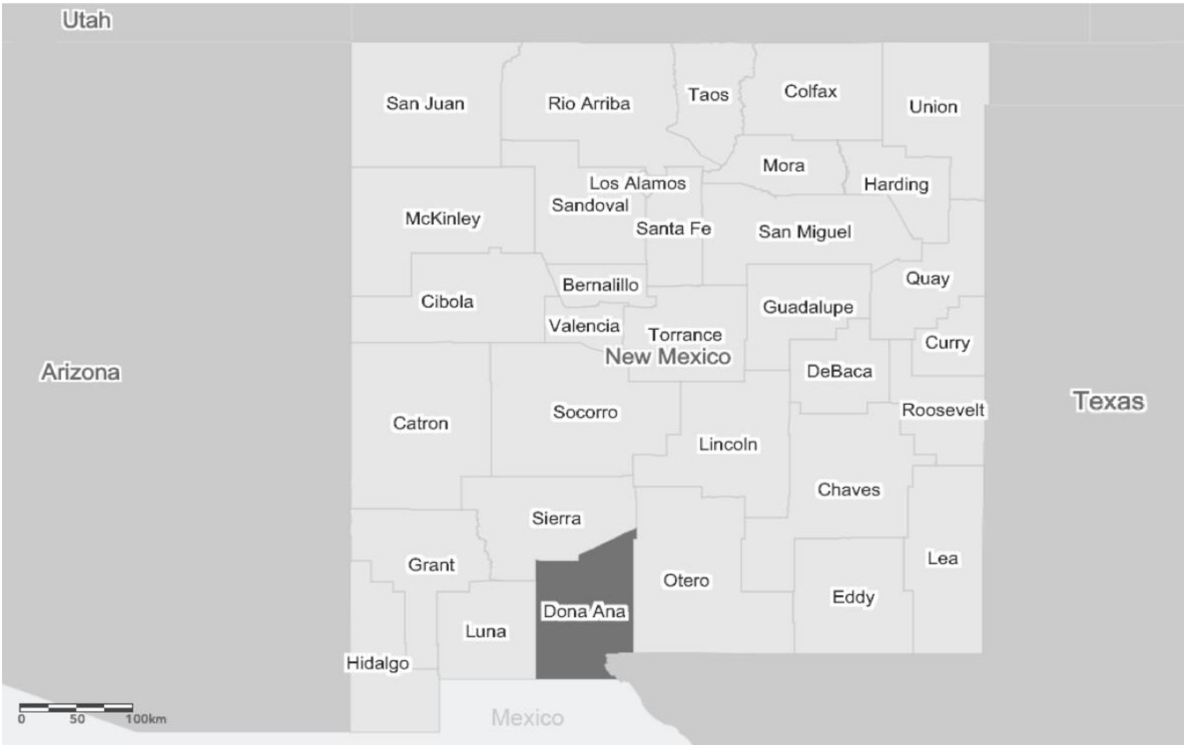

Figure 9: Doña Ana County, New Mexico locator map. Data from U.S. Census Bureau. County files (U.S. DOC 2007).

fault blocks of the Sierra de Las Uvas, and features like Aden Crater, a shield volcano in the Potrillo Mountains (Chronic 1987). The varied mountain landscape has contributed to the rich soils of the valley, which have helped make agriculture thrive when sufficient water is present.

The majority of the vegetation in the county is Chihuahuan Desert plant life (Amato 2012). Although the appellation desert tends to suggest an inhospitable environment, a significant number of these species are edible, while others contribute to supporting a complex ecology that makes the edible species more viable. For example, creosotebush acts as a nurse plant that assists a number of species in establishing themselves after a disturbance (Badano et al. 2016). Grasslands include the grasses black grama (*Bouteloua eriopoda*), blue grama (*B. gracilis*), dropseeds (*Sporobulus* spp.), and threeawn (*Arisitida* spp.) (ibid.). Chihuahuan Desert

Scrub includes creosotebush (*Larrea tridentata*), honey mesquite (*Atriplex canescens*), soaptree yucca (*Yucca elata*), prickly pear cactus (*Opuntia* spp.) and various grasses (Amato 2012). Other cacti, including scarlet hedgehog (*Echinocereus coccineus*), barrel cactus (*Ferocactus wislizeni*), and cane cholla (*Cylindropuntia imbricata*) can be found in the area (Sivinski and Division 2005) in addition to yucca (*Yucca* spp.). Additional species, including alkali sacaton, may be found on the basin floor. Another significant habitat in the county is Bosque[4] Riparian

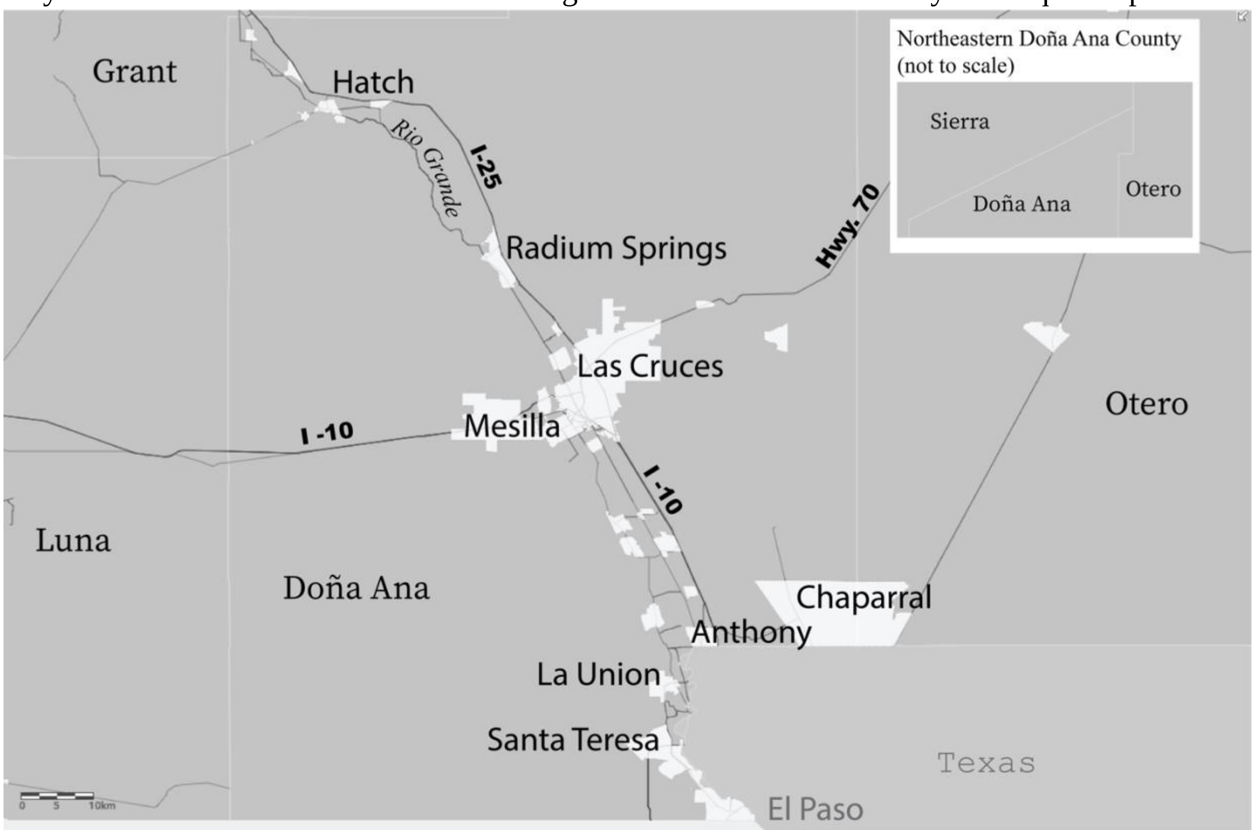

Figure 10: Doña Ana County. Las Cruces is the county seat and the second largest city in the state, estimated have a population in the metro area of about 209,000. I-10 connects it to El Paso, just over the Texas line. Santa Teresa is the eastern-most land connection between the U.S. and Mexico. Data from U.S. Census Bureau (U.S. Department of Commerce 2007, 2010, 2014).

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[4] Bosque translates from Spanish as "woods," but is usually applied in New Mexico to indicate a riparian habitat. Given the surrounding ecosystems, bosques are often the only wooded areas to be found in an area, as was largely the case in Doña Ana County with pre-European habitat.

and wetland habitats. These include species like Rio Grande cottonwood (*Populus fremontii* var. *wislizeni*), coyote willow (*Salix exigua*) and Goodding's willow (*Salix gooddingii*) (Amato 2012). Saltcedar (*Tamarix* spp.) is a species introduced from Eurasia for erosion control (Barranco 2001) that has spread widely along the Rio Grande and been subject to various control efforts, some successful. Herbaceous plants of the Bosque include grasses like wheatgrass (*Pascopyum* spp.). Shrubs include more willows (*Salix* spp.), three-leaf sumac (*Rhus trilobata*) and screwbean mesquite (*Prosopis pubescens*) (Amato 2012). From the perspective of agricultural transformation, it is important to note that a number of these Chihuahuan species are edible, including prickly pear species, creosote bush, yucca species (Brooks n.d.), cholla (*Cylyndropuntia imbricate*), sumac (*Rhus trilobata*), cottonwood, and claret cup cactus (*Echinocereus trglochidiatus*) (National Park Service 2011).

Soils in the cropped area of the Mesilla Valley are Entisols, surrounded by Aridisols outside of the river valley (Williams 1986). Most soils in the rich river valley are various loams, clay loams, sandy loams, and silt loams. According to Natural Resources Conservation Service Classifications, nearly all land in the valley is considered farmland of statewide importance, and land outside of the river's reach is all classified as not prime farmland (Soil Survey Staff n.d.). Thus despite the arid environment, the area provides a rich base for agriculture.

Water in the Mesilla Valley of Doña Ana County has two main sources. The Rio Grande provides surface water, much of which has its source in snowmelt from the mountains of northern New Mexico and southern Colorado. The Mesilla Basin Aquifer System provides groundwater in several sub-basins, of which two are important for Doña Ana County. The

Mesilla Valley Aquifer between Leasburg Dam (about 10 miles north of Las Cruces) and El Paso narrows, near El Paso, is an unconfined aquifer that typically travels southward toward El Paso at a gradient of 4 to 6 feet per mile. The water table is about 10 to 25 feet below the valley floor in much of the valley. Recharge occurs directly from flow of the Rio Grande (Hawley, Kennedy, and Creel 2001). The Mesilla Valley Aquifer varies in thickness from 300 ft to 3,000 feet (ibid.). The Palomas Basin underlies the northwest portion of the county and is the groundwater source for Hatch (well known for its chile production). The Palomas Basin tends to have high mineral content, including a mean of total dissolved solids (TDS) of almost 1,300 mg/l and chloride concentrations averaging over 400 mg/l (Land 2016a). Groundwater is recharged west of the basin and flows east toward the Rio Grande (ibid.). One additional aquifer lies in between the Rio Grande and mountains to the east—the Jornada del Muerto. The aquifer, however, lies outside of the intensively agriculturally productive area of the valley (i.e. the area with cropland), and its flow to the Rio Grande and the Mesilla Valley Aquifer is limited by bedrock to its west in the form of the Doña Ana and Tortugas Mountains (Hawley, Kennedy, and Creel 2001)

History

The Mesilla Valley was occupied from long before the Spanish first passed through. Moreover, its residents left clear signs of an agricultural and gathering system that provides potential elements for future transformation. An Archaic group, the Mogollon, left signs of having lived along the Rio Grande going back nearly 2000 years. There is evidence of pit houses at sites near Radium Springs and near Tortugas Mountain on the east side of Las Cruces (Ritter and Holden 2014). The Mogollon lived throughout southwestern New Mexico, eastern Arizona and Chihuahua, and left evidence of raising turkeys, making pottery, growing corn and beans, and gathering other plant foods (Sánchez, Spude, and Gómez 2013). There is also evidence that they practiced water control measures, including checkdams, contour terraces (Pool 2013) and irrigation ditches (Harris 1993). Excavations elsewhere in the Mogollon region have revealed the use of a diversity of wild plants, many of which live in the Mesilla Valley. Cotton, juniper (*Juniperus utahensis*), reeds (*Phragmites* communis), sotol (*Dasylirion* wheeleri), yucca (*Yucca baccata*), walnuts (*Juglans major*), pigweed (*Chenopodium fremontii*), cactus (*Opuntia* spp.), and gourds (*Cucurbita foetidissima*) are all among plant remains with signs of human use found at one Mogollon site (Martin et al. 1956) The Mogollon appear to have left the Mesilla Valley around 1450 A.D. (Ritter and Holden 2014). Their descendants the Mansos and Tiwas later grew crops in the area. The nomadic Apache also spent time in the Mesilla Valley (Hunner 2008). Apache also depended on local plants, including mescal (*Agave*) and beargrass (*Nolina* spp.) as well as wild animals (Pearce 2000). The crops grown and gathered by the pre-European inhabitants of the region were desert natives or species well-adapted to the heat and desert irrigation systems available to people in the valley. As such, they offer possibilities for future desert-adapted agriculture.

European settlement of the Mesilla Valley came far later than the early Spanish settlements on the northern Rio Grande. Don Juan de Oñate first invaded and settled the area near Santa Fe in 1598 (Hunner 2008). Traveling from today's central Mexico north to Santa Fe along a route the Spanish dubbed *El Camino Real*, the Royal Road, Oñate stopped over in the Mesilla Valley at what came to be known as the Doña Ana *paraje*, or camping place, but did not establish settlements (Owen 1999). Only after Mexican independence in 1821 were land grants offered in the Mesilla Valley and *El Camino Real* also opened to Anglo traders. In 1842, the village of Doña Ana was established along the Rio Grande. It represents "the oldest continuously inhabited [contemporary] community along the Rio Grande in southern New Mexico" (Hunner 2008). Thus, it took nearly 250 years from the first Spanish settlements for the Mesilla Valley to be occupied, which suggests the lack of potential the Spanish at first saw in the area relative to places like cooler, northern, and already-permanently-occupied Santa Fe. Early in the settlement of the Mesilla Valley, the Mexican-American War (1846-48) brought change to the region. In 1848, the United States acquired New Mexico[5] in the Treaty of Guadalupe-Hidalgo. Las Cruces was platted in 1849 to help relieve crowding in Doña Ana (Hunner 2008). But more migration took place even before Las Cruces was occupied. When New Mexico became American territory, a sliver of land bounded on the east by the Rio Grande at Las Cruces and with a northern boundary that led directly west through Arizona still belonged to Mexico. Mexicans on the east side of the river who had been subsumed into the United States chose to move across the river to maintain their Mexican nationality. There they established Mesilla (Hunner 2008). Because of support from the (Mexican) territorial legislature, Mesilla was designated the county seat, and quickly became "the mercantile and trade center of the valley" (Owen 1999). Just a few years later, Mesilla became part of the United States when the Gadsden Purchase was completed in 1854 (Hunner 2008). The purchase allowed the United States to acquire the tract of land needed for the completion of a southern transcontinental railroad (Owen 1999). Other small

[5] And all land from Texas to California that had belonged to Mexico.

communities began forming along the river at the same time as Las Cruces and Mesilla, including La Mesa and La Union, where some of the farmers in this study now live and work.

Agriculture in the early European settlement of the Mesilla Valley was largely for subsistence. Almost the first act of settlement had been when Bernabe Montoya led the digging of an irrigation ditch, or *acequia*, in 1843 in Doña Ana (Owen 1999). As was typical of irrigation systems throughout New Mexico, the *acequia* was community property, maintained by the users (Owen 1999) and, to begin with, often organized as family groups (Ackerly et al. 1992). The Rio Grande upon which *acequias* depended, however, moved often. During the U.S. Civil War, for example, floods put Mesilla on an island and then on the east bank of the river. Another flood in 1881 washed away a railroad bridge and train at Rincon, near Hatch (Owen 1999). The wild river often made agriculture challenging. The historical record includes dozens of floods (as well as multiple droughts), often with damage to crops, orchards, and irrigation infrastructure. The destruction of towns, or their stranding mid-river, as also happened to San Elizario downstream in Texas, added challenge to an already demanding desert landscape. Nonetheless, early residents grew fruit, vineyards, alfalfa, onions, wheat, and corn (Ackerly et al. 1992). The historical wildness of the river suggests that a return to agriculture with an undammed river might pose a number of challenges.

The first change that shifted the agricultural practices of Mexican and American settlers in the Mesilla Valley was the arrival of the railroad in 1881 (Owen 1999). For the first time, goods could be shipped by rail directly from Las Cruces (Mesilla having forfeited its right to a train station) and the long travel times of the Santa Fe Trail become a memory. With the ability to ship farm products, some farmers were able to afford paid labor and some began to rent out their farmland (Ackerly et al. 1992).

By the beginning of the 20th century, the Bureau of Reclamation, along with private investors, had their eye on the Mesilla Valley. They saw the potential to control the river and minimize its volatility with a dam. Although both wild overestimates of water availability (Alexander 1989) and outlandishly expensive project proposals (Owen 1999) shaped some of the early thinking about how to manage the Rio Grande in southern New Mexico, the final project appeared reasonable considering the river flows experienced by settlers. When the Bureau of Reclamation was organized in 1902, it began to plan a project finally based at Elephant Butte[6] in Sierra County to the north of the Mesilla Valley. Farmers, prepared to assist in any project that could minimize the unpredictability and damage of the river, formed a water users association (Owen 1999). Each farmer paid a yearly, per-acre fee for the project beginning in 1904 and lasting until 1971. When the dam was eventually completed, in 1916, it contained what was at that time the world's largest human-created reservoir (ibid.). Along with the achievement of statehood in 1912, the completion of Elephant Butte Dam marked a change in natural resources governance in southern New Mexico.

The dam made a great deal of difference to the predictability of irrigation water and made management of ditch infrastructure far easier. However, it did not by itself cause a significant shift in the agricultural production of Doña Ana County. However, for reasons more to do

[6] So named because of the shape of the bluff that now overlooks the reservoir.

with beliefs about the potential for profit than with irrigation management, at least one crop experienced a significant increase in numbers after the completion of the dam: apples. The excitement around the modern production of apples that had begun in New Mexico as early as the 1880s (Carleton 2017) continued in Doña Ana County from the 1910 to the 1925 census of agriculture (United States Department of Agriculture n.d.). Irrigation combined with pesticide use and the presence of the railroad for shipping all worked together to make apples a feasible crop for the Intermountain West (Carleton 2017).

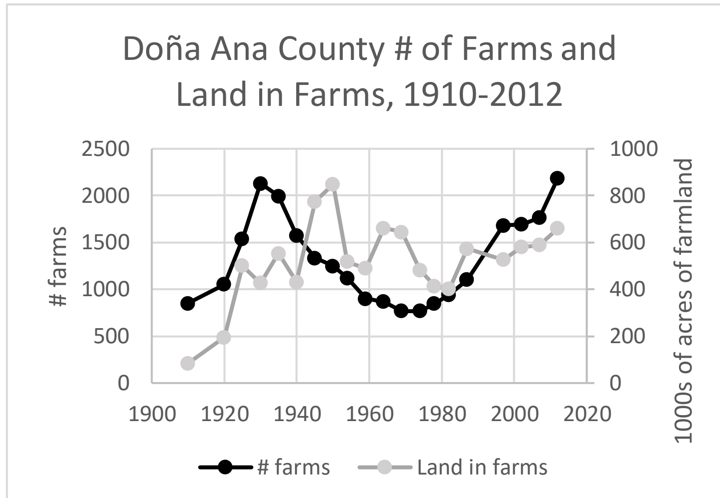

Figure 11: Data from USDA Census of Agriculture, 1925-2012 (USDA, n.d.). The census takes place approximately once in five years.

Apple trees more than doubled in number from 1910 to 1925 (16,295 to 37,243). Other fruit tree crops also grew during the same time period. Many staple crops, however, stayed the same or declined slightly, including corn, wheat, oats, and sorghum, perhaps losing acreage to the popular apple (United States Department of Agriculture n.d.). One commodity crop, however, began its dramatic rise in Doña Ana County between 1910 and 1925: cotton. From zero acres in 1910, it grew to over 25,000 acres in 1925.

Carleton (2017) narrates the shifting landscape of agriculture in New Mexico as cotton pushed aside apples as the crop of choice. Popular as they were, apples had been plagued with, "pests and disease, late frosts, distance to markets, and lack of region-wide cooperation" in terms of pest management (Carleton 2017, p. 89). Cotton, on the other hand, "seemed much better suited to the region's realities of isolation, aridity, southern latitudes, and western irrigation" (Carleton 2017, p. 89). Consequently, cotton production grew every decade from 1910 until the 1970s, often gaining 10,000 acres of space each decade. By 1964, of over 86,000 acres of crops listed in the agriculture census, more than 60,000 were in cotton (United States Department of Agriculture n.d.). After 1925, crop diversity declined even as agricultural advisors continued to counsel the importance of crop diversity for soil maintenance as well as for better spreading labor requirements throughout the year (Carleton 2017, p. 89). Wheat production fell from 2,400 acres in 1910 to just 116 by 1935, corn lost acreage between 1925 and 1935, and notably, a number of vegetable crops disappear from the census by 1935. Despite acreages in the teens and even thousands (for lettuce) in 1925, in 1935 lettuce, onions, sweet corn, and sweet pepper all disappear from the census not to reappear until the 1950s or even later (United States Department of Agriculture n.d.). The prospect of income from cotton drove out diverse crops for most growers, leaving a landscape often lacking in both ecological health and adequate supports for agricultural laborers[7] (Carleton 2017). By the early years of World War II, even the advice from agricultural experts was advocating a focus on cotton with little diversity. To support cotton, the focus was instead on creating more migrant labor camps to provide needed labor for harvest, leading to ever greater economic stratification between labor and owners (Carleton 2017). It is important to note here that the decrease in diversity was not as a result of drought or

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[7] But Carleton (2017) does point out some major exceptions, especially Stahmann Farms with diverse crops and livestock and supports for labor that included good housing and laborer pensions.

other challenges in the natural system, but a result of the social system, whose economy encouraged farmers (and eventually extensionists) to abandon what had been systems that helped to support soil fertility and minimize pest problems.

In orchards, at the same time that most fruit trees were declining in numbers in the 1930s and 1940s, pecans began to grow. From negligible numbers in the 1920s and 1930s, pecans had gained prominence by the 1940s, with over 100,000 trees in place by 1945 (United States Department of Agriculture n.d.). Two people in particular contributed to the pecan's early rise to prominence: New Mexico State University horticulturist Fabián García and Dean Stahmann. García's early experiments with pecans demonstrated their potential to contribute to maintaining diversity on farms. Stahmann, nervous about relying on price-volatile cotton, introduced pecans into his large farm (Carleton 2017). In the 1970s, the Stahmann farm shifted to a focus on pecans alone (Carleton 2017), and by then much of the valley had begun to follow the farm's example. By 1974, nearly 360,000 pecans trees were growing in Doña Ana County (United States Department of Agriculture n.d.). The exclusive focus on pecans was indeed a sign of the end of intricately interwoven, diverse systems in the valley, as the farm had first grown to its highly prosperous state on the back of a diverse and carefully integrated system including livestock and multiple crops.

In the 1970s, as cotton began to decline, a few vegetable crops regained large acreages. Onions and lettuce gained acreage, covering more than 5,000 acres in 1974 (United States Department of Agriculture n.d.). At the same time, chile began a steep rise, from 501 acres in 1964 to nearly 5,000 in 1974 (United States Department of Agriculture n.d.). The change in chile was driven both by advances in breeding and publicity efforts. Breeding had created a crop more palatable to Anglo tastes and more easily processed into canned and frozen chile (Carleton 2017). With increasing efforts to brand chile as a uniquely New Mexican product, chile grew to more than 6,500 acres by 1997, the period taken up in the next chapter (United States Department of Agriculture n.d.). As the 1997 New Mexico Agricultural Statistics Bulletin points out, by the 1990s, cattle and calves, milk, and hay were the top three sources of cash receipts in the state, and fourth was chile (New Mexico Department of Agriculture 1997). Along with chile, dairy and beef were both growing rapidly in Doña Ana County in the 1980s and 1990s. From 1964 to 1997, total cattle nearly tripled from about 20,000 head to nearly 60,000 head, and dairy cows grew 12 times from 3,221 to 39,000 (United States Department of Agriculture n.d.). Thus, the agricultural landscape by the 1990s had some diversity in terms of vegetable crops and tree crops, but it was a limited diversity increasingly dominated by a few crops and the production of cattle products. The ideal of farmers living a life of "yeomanly self-sufficiency" (Carleton 2017) had faded ever since the 1920s to be replaced by a more industrialized agriculture dependent on low-paid labor, machines, and within-field monocultures. The early agriculture that provided a model of the kinds of agroecosystems whose ecology is carefully interwoven and supports much of its own soil and plant health, thus slowly disappeared from the valley.

(Luna County, next page)

Luna County

Figure 12: Luna County, New Mexico locator map. Data from U.S. Census Bureau. County files (U.S. DOC 2007).

Geography

Located in the Basin and Range Province, Luna County has widely varied topography and ecological characteristics. Much of the county is Chihuahuan Desert grasslands at around 4,000 feet of elevation, punctuated by mountains, for an average elevation of 4,355 feet (Sites Southwest 2012). Mountains in the county include the Florida Mountains, southeast of the county seat of Deming, Cooke’s Peak, the Tres Hermanas and 29 other smaller mountains and ranges (Sites Southwest 2012).

Vegetation in the mountains includes Chihuahuan Desert species of yuccas (*Yucca* spp.), agaves (*Agave* spp.), cacti (Cactaceae genera), rabbitbrush (Asteraceae genera) and desert

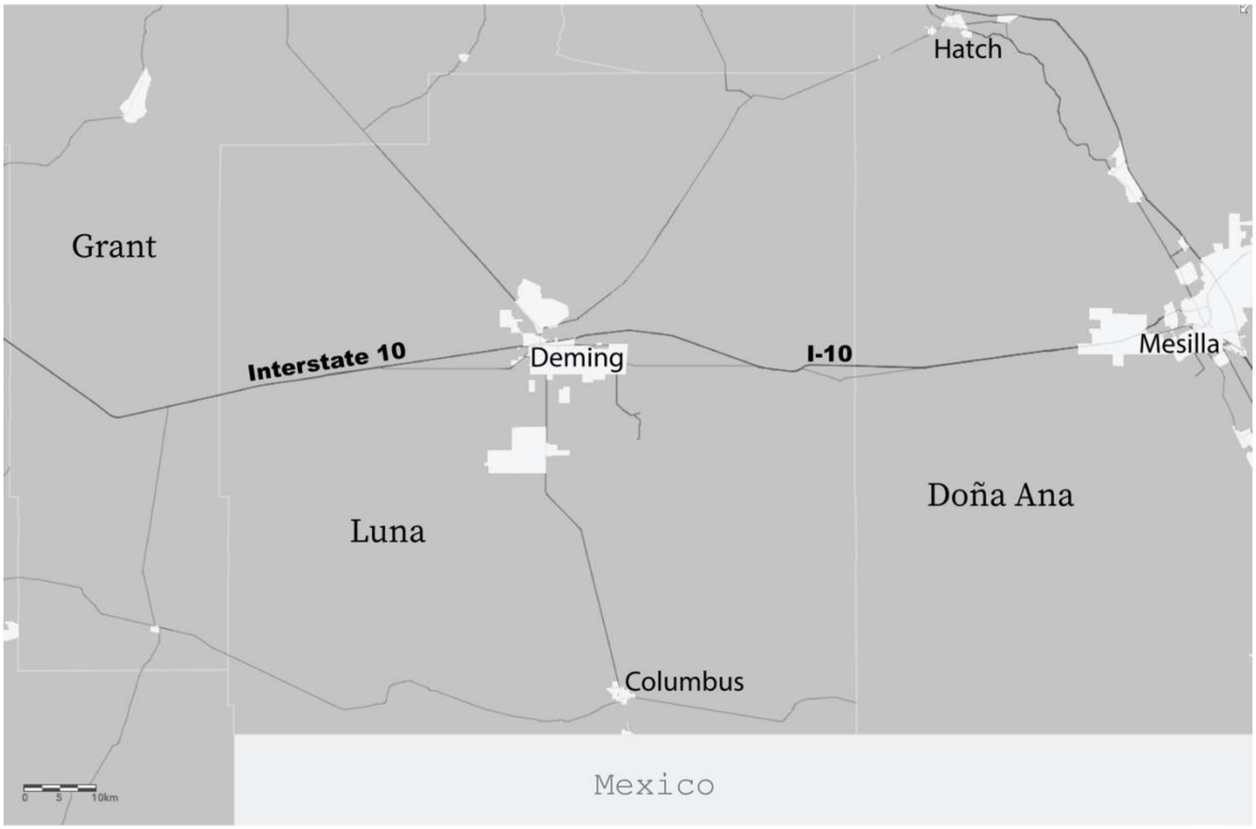

Figure 13: Luna County. Deming is the county seat and only major population center, including several suburbs of approximately 1,000 people each. Data from U.S. Census Bureau (U.S. Department of Commerce 2007, 2010, 2014).

grasses. The lower plains also include mesquite (*Prosopis*) and creosotebush (*Larrea tridentata*). When the water table is close to the surface, desert willow and cottonwood can survive (Sites Southwest 2012). As in the Mesilla Valley to the east, many of these species are edible or provide ecological services that support edible plants. A number have been eaten by past peoples, as discussed below in the history section, offering potential elements of transformative agricultural systems.

Soils in Luna County are Aridisols, making the county unsuitable for dryland agriculture (Williams 1986). Soils in the center of the county are shaped by several ages of alluvial deposits from the Mimbres River (Sites Southwest 2012), although the river rare flows farther than the northern Grant-Luna County line. Soils close to the center of the county are classified by the Natural Resources Conservation Service as farmland of statewide importance (Soil Survey Staff n.d.). In the northeast corner of the county there is also a small area classified as farmland of statewide importance. Some of the area in the northeast is also classified as not prime farmland (Soil Survey Staff n.d.), but there is an intensive area of irrigated farmland in that area, including some quarter sections under center-pivot irrigation. So, again, despite aridity, there is great agricultural potential in the county when water is present.

The source of water for humans in Luna County is the Mimbres Basin aquifer (Hawley et al. 2000), with the exception of two small pockets in the northeast and southwest of the county that are part of the Nutt-Hocket Basin and the Hachita-Moscos Basin, respectively (Sites Southwest 2012) . Just to the north of the county, in Sierra and Grant Counties, is the high country of the Gila National Forest and the Gila and Aldo Leopold Wildernesses. It is these mountains and the precipitation they help create that contributes recharge water to the Mimbres Basin (Hawley et al. 2000). As is true throughout much of New Mexico, precipitation falls most at higher elevations (Williams 1986), and the resulting precipitation infiltrates along river and arroyo channels as well as through flow from higher to lower aquifer systems (Hawley et al. 2000). Consequently, groundwater flow in the Mimbres

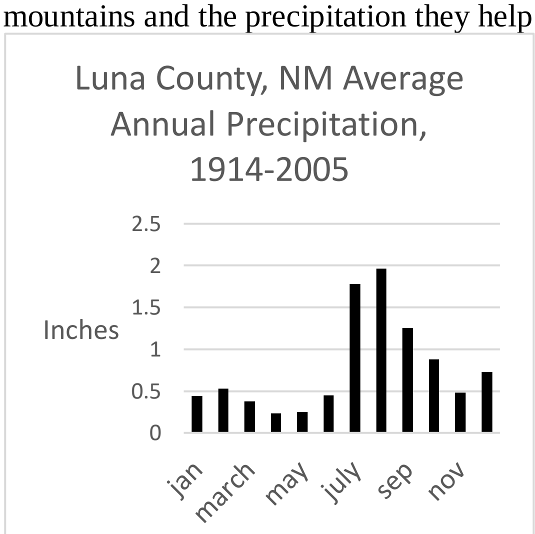

Figure 14: Data from (WRCC, 2005).

Basin is from north to south (Sites Southwest 2012) Annual average precipitation in the county is 9.35 inches (WRCC 2005), with the exception of the area surrounding the Florida Mountains and the far northwestern edge of the county, which can receive an average of 12-14 inches (Williams 1986).

With low rates of precipitation and high rates of evaporation, agriculture in the county must be irrigated. Both agriculture and human direct consumption rely on wells. In the Deming area, wells for urban and domestic water needs are expected to remain sufficient through 2060, but in Columbus, on the Mexican border, the well field is not expected to meet water demands by 2040 (Sites Southwest 2012). Agriculture consumes approximately 95 percent of water in the county, with about 32,000 acres under irrigation in 2000. Agricultural wells have "declined by as much as 200 feet since 1935 in some parts of the Mimbres basin, but . . . most wells could be deepened enough to maintain production through 2060" (Sites Southwest 2012). Thus a transformed agriculture for the area would need to consider ways to decrease use of the aquifer from the present trajectory.

History

The earliest evidence of human habitation in the Mimbres Valley (today's Luna County) is of Mimbres Indians (Dethloff and May 1982) in about 950 to 1150 A.D. (Pool 2013). Like groups in the Mesilla Valley, they practiced agriculture and gathering that can help model elements of a transformed agriculture in the region. The Mimbres are probably related to the earlier Mogollon peoples (Sites Southwest 2012) who lived in southwestern New Mexico, eastern Arizona, and Chihuahua and Sonora in Mexico. Unlike the earlier Mogollon, the Mimbres no longer lived in pithouses, but in aboveground blocks of rooms (Dethloff and May 1982). They lived and worked along the Mimbres River, and created highly regarded pottery in the form of black-on-white and corrugated ceramics (Pool 2013). The Mimbres practiced an agriculture that relied on both water conservation techniques and irrigation. These techniques included runoff agriculture with "checkdams, contour terraces, and spreaders;" water harvesting and canal irrigation (Pool 2013). Like other southwestern populations, they appear to have grown the Three Sisters—corn, beans, and squash—as well as (most likely) cotton, amaranth and sunflowers (Dethloff and May 1982). They are thought to have abandoned the area after an extended period of drought or overpopulation (Sites Southwest 2012; Pool 2013). Thus, both their presence and absence offer lessons for future agriculture in the area: desert food production is possible with little water, but it may be especially vulnerable if plans are not made for dealing with years of deep drought.

The next peoples in the region were Chiricahua Apache, who may have arrived in the southwest in the years 1200-1400 A.D. (Sánchez, Spude, and Gómez 2013). They focused far more on hunting and gathering than crop production.

Although the Spanish began to settle the northern Rio Grande region as early as 1598, neither the Spanish nor the succeeding Mexican government gave much attention to the Mimbres Valley, with its largely ephemeral water sources (Ashabranner 1989). North of present-day Luna County, the Santa Rita mine (now mined for copper) was exploited as early as 1804 (Beck and Haase 1969), but that little affected the lower Mimbres Valley. However, much of New Mexico became part of the United States in 1846, with the end of the Mexican War. In 1854, with the

Gadsden Purchase, the remainder of what would eventually become Luna County entered into the United States (Ashabranner 1989).

The desire for a southern railroad that drove the Gadsden purchase would also drive the early development of the Mimbres Valley. The development of the area began with investment in mining claims north of present-day Luna County, including the area that would eventually become today's immense Santa Rita copper mine. Although the area was not heavily exploited at first because of Apache control, by the 1870s Americans gained control over the mine area (Beck and Haase 1969). In the 1850s and 1860s, stagecoach routes began to run through present-day Luna County, south of the mines. The Butterfield line ran through the territory, with way stations north of modern-day Deming (Williams 1986). The founding of the county seat took place, though, in 1881, when the Southern Pacific Railroad and the Atchison, Topeka & Santa Fe Railroad met in Deming, joined by a silver spike. Locals expected that the joining of the two great railroad projects would allow Deming to become a major shipping center, but El Paso, TX, earlier to come online for the Southern Pacific Railroad, overtook tiny Deming's hopes (Beck and Haase 1969; Ashabranner 1989). The railroad was nonetheless important to Deming. Early expectations were that mining wealth, driving the construction of smelters in Deming, would sustain the town. When local veins petered out, cattle became a mainstay of the economy, shipped out by railcar (Ashabranner 1989).

Luna County itself was organized in 1901, formed from parts of Grant and Doña Ana Counties (Beck and Haase 1969). Some speculate that Deming's rivalry with Silver City, a mining town in Grant County to the northwest, drove the creation of a separate county (Sites

Southwest 2012). The two indeed had very different trajectories, as Silver (as locals call it) focused on mining and more recently on catering to retirees from elsewhere, while Deming began as a cattle town and continued as an agricultural town with the area south of town dotted with irrigated agriculture. The two gained similarity as retirees increasingly found Deming a good location toward the end of the 20th century (Measday and Measday 1982).

The county's ties with Mexico are extensive, especially as Mexicans and immigrants have continued to become interwoven with the agricultural fabric of Deming. The town of Columbus, on the Mexican border, centers on its relationship with Palomas just across the border. Columbus was the site of Pancho Villa's famous raid, in which the Mexican revolutionary and bandit killed seventeen American civilians (Ashabranner 1989). In the early days of Deming, several families immigrated from Mexico and at least one from Spain (Measday and Measday 1982). Deming also had the first elementary school Spanish language program in the state (ibid.). Today's Columbus educates hundreds of American citizen children some of whose parents do not have American citizenship. Children cross the international border on a daily basis for access to a good education and English language-learning (Santiago 2017). In short, the connections run deep, and Anglo farmers in contemporary Deming often speak fluent Spanish to communicate with their workers who do not speak English[8].

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[8] Deming's combined Anglo and Hispanic (and other) cultural history is important to remember in formulating an agriculture of the future. Anglo residents are still the dominant owners of farmland, and a transformed agriculture might benefit from considering how to enable land access for more Hispanic growers. Such a change could both help to diversify thinking on agriculture and decrease the economic and food insecurity of many residents.

Despite its diverse regional connections, Deming grew slowly, lacking the railroad-inspired vigor the townspeople had expected. It grew from 1,864 people in 1910 to 3,212 in 1920, inching up to 5,672 by 1950 and eventually to 14,885 in 2010 (U.S. Census n.d.). In the 1910's the valley as a whole was thriving, scattered with homesteads and with a population of about 12,000. Homesteads of 160 acres, though, were not enough for most to make a living, and during the early 1930s, many left (Ashabranner 1989). Cattle continued to be important to the area, with total county herd size after 1910 staying near 30,000 from year to year with some variation, including one dip during the 1950s drought (United States Department of Agriculture n.d.). In the 1930s, the government also killed thousands of cattle because of drought (Ashabranner 1989). Other livestock were also important to the diverse farming economy of homesteaders, including goats, sheep, and chickens but they were minor compared to the cattle (United States Department of Agriculture n.d.). In the early 20th century, cattle were grazed on unfenced open range, but ranchers' cattle options were limited by access to water. Buying a ranch meant buying a spring, sometimes from a previous homesteader or rancher, and sometimes directly from the government under the homestead laws (Ashabranner 1989).

Although ranching continues to be important today, in the early 20th century irrigated farming also became an element of Luna County life. Early settlers had dug wells for home use and gardens as early as the 1880s. One was the Billingslea family farm in the area of Mowry City (now a ghost town) in the late 1880s. They grew some vegetables and fruit to sell in Deming, Silver City, and Fort Bayard (Measday and Measday 1982). But the first wells for large-scale irrigation were not established until 1909 (Ashabranner 1989). From the first wells

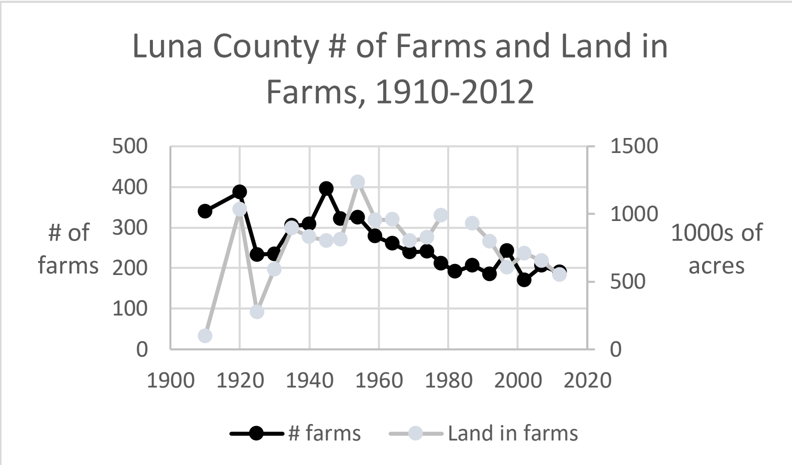

Figure 15: Data from USDA Census of Agriculture, 1925-2012 (USDA, n.d.). The census takes place approximately once in five years. Data for 1982 were withheld to avoid disclosing data for individual farms.

dug, the aquifer gained a reputation for high quality water—it was even sold to buyers as far away as El Paso in the 19th century (Measday and Measday 1982). The cropping era in Deming and surrounding areas began with a bang because it built off earlier, smaller-scale projects. In 1910, the census of agriculture counted more than 3,000 acres of hay, 330 acres for corn for grain, 22 acres of sorghum for grain, 2,098 acres of dry beans, 73 acres of vegetables, and 1,554 fruit trees (United States Department of Agriculture n.d.). In 1911, nearly a hundred pumps had been sold to area settlers (Measday and Measday 1982).

By 1925, there was less hay acreage and corn acreage, but more sorghum. By that year, the cotton era in southern New Mexico had also made a small start, at 490 acres in Luna County, and there were 66 acres of wheat, as well. Most striking, however, is the diversity of other crops grown for sale, including 890 acres of dry beans, 69 of tomatoes, and 38 of watermelons and small acreages of sweet potatoes, cabbages, cantaloupes, lettuce, onion, sweet corn,—as well as ever more fruit trees from apples to peaches to pears. Pecan trees also appear on the record for the first time in 1925 (United States Department of Agriculture n.d.). Once again, the agricultural past provides elements of a model for the agricultural future, in that the diverse crops grown in the area provided a variety of food for people in the county. Agriculture was part of cultural food life rather than being an economic engine alone, as it often is now.

In addition to plant diversity, the Deming era was home to more ethnic diversity than Mexican, Anglo, and other European arrivals. The Lew family, immigrants from China, established the Tai Yow Yuen (Chinese Gardens) homestead in the 1880s, and were among those producing fruit and vegetables for sale in the area until they lost the farm during the Great Depression. They relocated close to Columbus, but Chinese businesses remained an important feature of Deming early in the 20th century (Measday and Measday 1982). Losses like those of the Lew family came to many farmers after the early boom brought by irrigation. Drought and the loss of World War I-era Camp Cody from Deming in the mid-1920s caused many to sell out and leave ranches and farms (ibid.)

Despite the loss of farms and ranches in the 1920s and 1930s, crop diversity remained high. A variety of vegetable and tree crops gained numbers through the 1930s, from apples, peaches, grapes, and cherries to sweet potatoes and tomatoes (United States Department of Agriculture n.d.). In 1927, the local Farmer's Association voted to open a tomato cannery, which likely contributed to the continued growth of tomato acreage, which had expanded to 97 acres by 1935. (Measday and Measday 1982). Most staple crops (hay, corn, sorghum) remained fairly steady during this time, although acreage of dry beans increased to 2,336 acres (from 890 ten years before) (United States Department of Agriculture n.d.).

World War II shaped Luna County economically and agriculturally for a time. In 1942, Deming Army Airfield was constructed, employing locals (Measday and Measday 1982). After the war, it was converted into Deming Municipal Airport. As many left the county to serve in the war, the need for agricultural labor rose. For the 1945 growing season and through early 1946, a POW camp at Deming supplied German POWs to help with cotton harvest and other tasks in the field (Lanse 2010). Help with the cotton harvest was key, because it was becoming an increasingly important crop in the county, reaching 2,740 acres in 1945, from 326 ten years before. Vegetable crops became even more important during the war, and fruit trees did as well (United States Department of Agriculture n.d.). Apples had begun a slight decline, probably due to the codling moth having begun to make management of the crop difficult since it had now been established for two decades (Carleton 2017). Grapevines and plum trees increased, however, with nearly 6,000 grapevines and 880 plum trees by 1945. The introduction of the far more effective turbine pump for wells began to make irrigated agriculture far easier in the 1940s (Ashabranner 1989).

After the war, the county continued to need agricultural labor, and in 1951, 2,000 workers were registered in Luna County under the Bracero Program[9] (Measday and Measday 1982). As agricultural advisors began increasingly to encourage farmers to specialize in their crops, the diversity of the county's agriculture declined somewhat, with vegetable crops mainly centered on tomatoes and chile in the 1950s. Sorghum, dry beans, and corn all more than doubled their acreage, but it was cotton that was becoming the county's dominant crop, with nearly 14,000

[9] Signed by Mexico and the U.S. in 1942, the Mexican Far Labor Program Agreement, or Bracero Program, formalized temporary agricultural labor entry by Mexican workers coming to the U.S. Continued until 1964, the agreement required a 30-cent minimum wage and adequate shelter, food and sanitation (Koestler 2010).

acres of production out of the 25,000 listed in crop production in 1954 (United States Department of Agriculture n.d.). That remained the reality in the 1960s. Sorghum as grain also increased its importance, however, and cotton and sorghum together made up 22,000 of the 37,000 acres of crops listed in the county in 1964. At the same time, as tree fruit crops dwindled (with the exception of plums and peaches, which held on), pecan trees had multiplied 10 times as compared to ten years before (United States Department of Agriculture n.d.). The increase in pecans reflected the success pecans were experiencing in neighboring Doña Ana County where they had begun to replace cotton (Carleton 2017). In Luna County, cotton and sorghum continued to dominate in the 1970s, with 38,000 out of 43,000 acres of listed crops. In the 1970s, chile, onions, and lettuce began to regain ground for vegetables, with nearly 500 acres in chile alone (United States Department of Agriculture n.d.). Chile's increase was profiting from both breeding work and the promotion of chile through events like the Hatch Chile Festival, which got its start in 1971 (Carleton 2017).

The farm crisis caught up with Luna County in the 1980s, as was true in much of the country. Farmers in the early 1970s "were caught up in the good years" and got deep in debt for purchases like new machines (Ashabranner 1989, p. 78). Later in the decade, however, costs were high for fuel and fertilizers, and crops were hard to sell because of an inflated dollar. Foreclosures caused some farms to go out of production entirely (ibid.). As a result, grains and cotton dwindled by the 1987 census, with sorghum falling to less than 3,000 acres and cotton falling under 10,000. By the 1995 census, they made up only 6,600 acres altogether. Chile and onions also diminished to under 50 acres in 1987, but by 1995, the growing chile processing factories and onion sorting houses meant that the crops took up 12,000 acres combined, with 8,200 acres in chile alone (United States Department of Agriculture n.d.). The trend in orchards also continued, with pecans occupying 78% of the county's 1,471 acres of orchards in 1997. With few of the pests common in the southeastern states, Luna County's pecans were thriving in the 1990s (Ashabranner 1989). By the period taken up in the next chapter, then, horticultural crops were one of the strongest elements of Luna County's agricultural economy. Like its neighbor Doña Ana, however, it was not a highly diverse system, but rather a set of specialized vegetable and nut production systems that had replaced the highly diverse agriculture present in the county at the beginning of modern irrigation. Thus, the early models of agriculture that offered a variety of sources of food as well as fiber (e.g. from sheep) were lost in the continued shift toward simplified agriculture systems toward the end of the twentieth century. And, again, the diversity of the past may offer elements of a transformed agricultural future.

(Roosevelt County, next page)

Roosevelt County

Geography

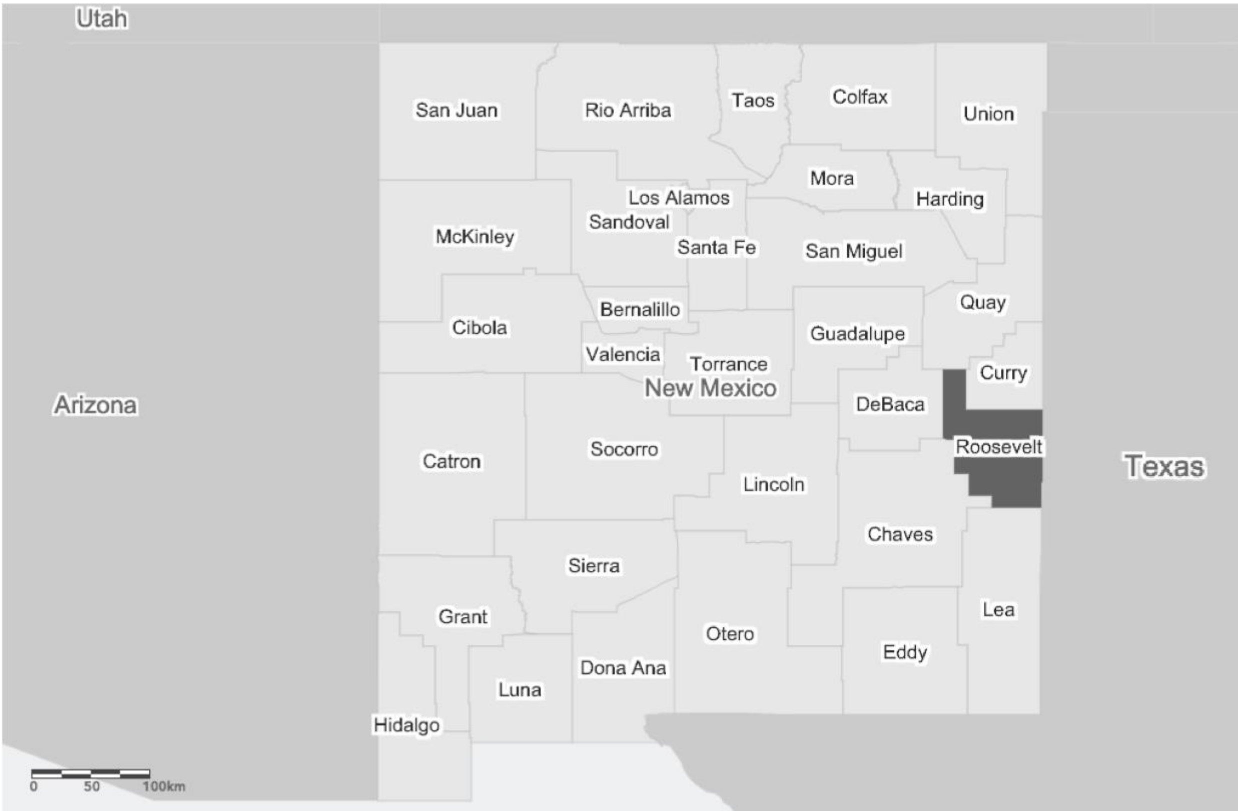

Figure 16: Roosevelt County, New Mexico locator map. Data from U.S. Census Bureau. County files (U.S. DOC 2007).

Located in the Great Plains Province, Roosevelt County has a county seat, Portales, elevated at about 4,000 feet above sea level, but the county is fairly flat. Portales lies in the Portales Valley that was formed by the ancient Brazos River, which no longer runs through the county (Soil Conservation Service (SCS), USDA and New Mexico Agricultural Experiment Station 1967). Portales Valley is now considered part of the larger Pecos Valley (Williams 1986). The county generally slopes downward from the tip of the northern panhandle (at 4,600 feet) to the southern county line, except for the Portales Valley, which is lower than the surrounding area (Soil

Conservation Service (SCS), USDA and New Mexico Agricultural Experiment Station 1967). The lowest area in the county is a playa[10] called Salt Lake, sitting southeast of Portales at 3,900 feet, part of Grulla National Wildlife Refuge. The northern panhandle of the county touches on the Llano Estacado[11], the middle of the county is technically a subsection of the Pecos River Valley, and most of the southern half of the county is also part of the Llano Estacado (Williams 1986). The Pecos River runs through De Baca and Chaves Counties to the west.

The county's geology contributes to the particular characteristics of the Ogallala Aquifer that are important to current water availability. Weathered sedimentary sea deposits, called the Triassic Red Beds, "represent the floor of most of the water wells being drilled throughout the county" (Soil Conservation Service (SCS), USDA and New Mexico Agricultural Experiment Station 1967). Farmers drilling a well talk about knowing they have reached the floor of available water by saying that they have hit red bed. The water bearing formation above the Triassic Red Beds was created as the Rocky Mountains rose. Streams deposited larger material in alluvial fans, and the finer materials spread further away from the mountains, reaching the area of contemporary Roosevelt County (Soil Conservation Service (SCS), USDA and New Mexico Agricultural Experiment Station 1967). That material contains today's Ogallala water supply in Roosevelt County (ibid.).

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[10] Playas are flat-bottomed depressions in continental interior basins. Because of their low and arid locations, without outlets to other drainages, precipitation in these basins evaporates and leaves behind salt deposits.

[11] The "staked plain" located mostly just to the east in Texas. Several ideas exist about the origin of the name. Some contend its name came from the fact that it looked so flat to early European arrivals that it could have been rolled out and staked flat like the groundcover for a tent. A more currently accepted idea is that "'estacado' refers to the palisaded. . .appearance of the caprock in many places" (Wishart 2011).

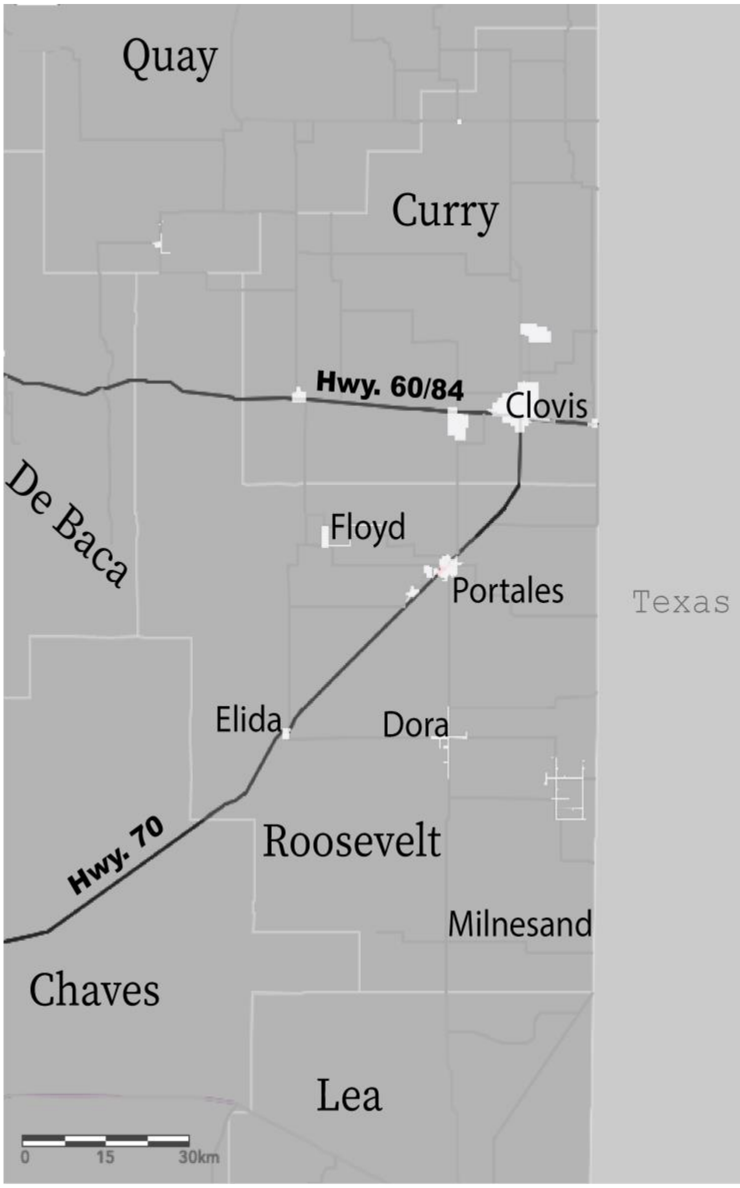

Figure 17: Roosevelt and Curry Counties. Clovis is the county seat of Curry County, and Portales the county seat of Roosevelt County. Just over the line in Texas is well-known cotton country. Data from U.S. Census Bureau (U.S. Department of Commerce 2007, 2010, 2014).

Although much of the native vegetation has been reduced in Roosevelt and Curry Counties by grazing and cropland, native Great Plains species are still present. Common Great Plains grass species in eastern New Mexico include Blue Grama (*Bouteloua gracilis*) and Buffalograss (*Buchloe dcahtyloides*) (Dick-Peddie 1999). Soaptree Yucca (*Yucca elata*) is common on both Conservation Reserve Program (CRP) land and less disturbed land, and the presence of the species has increased over the past 140 years (ibid.). Forbs make up much less of Great Plains vegetation in New Mexico than do grasses but may indicate where vegetation that has degraded to Desert Grassland once constituted Great Plains Grassland. Shrubs scattered in eastern New Mexico include small Soapweed (*Yucca glauca*), rabbitbrush (*Chrsothamnus* spp.)

and Broom Snakeweed (*Guterrezia sarothrae*)—the latter two in areas with erosion or heavy grazing (Dick-Peddie 1999). The High Plains grasses in the county speak to the area's past as the home of bison as well as to possibilities for a polycropped grassland future that potentially includes some grazing. Species like yuccas are edible. Moreover, some version of the Land Institute's perennial polycropping systems (Cox et al. 2010) might be worth experimenting with here.

Soils in Roosevelt County are a mixture of Alfisols, Mollisols, and Entisols (Williams 1986). Soil associations in the county include loams (Amarillo-Clovis loams association), fine sandy loams (Amarillo-Clovis fine sandy loams association), loamy fine sands (Amarillo-Clovis loamy fine sands), sands (Tivoli-Springer-Brownfield sands association, and rocky, shallow soils (Potter-Mansker association) (Soil Conservation Service (SCS), USDA and New Mexico Agricultural Experiment Station 1967). The Amarillo-Clovis loams association is considered good wheat land and reasonable grazing land if carefully managed, but mild to very serious wind erosion is a hazard with all these soils, particularly the last three (Soil Conservation Service (SCS), USDA and New Mexico Agricultural Experiment Station 1967). In terms of Natural Resources Conservation Service farmland classifications, an examination of the area in the Web Soil Survey reveals that much of the county is classified as "not prime farmland." In the panhandle, nearly 100% of land is classified as such, although parts of it are under irrigation. In the rest of the county, the land declines in agricultural quality, , from north to south, with about 40% of land in a 75,000 acre tract stretching from Floyd to Portales classified as "farmland of statewide importance" (the rest classified as "not prime farmland) to 100% of a 97,000 acre tract near Milnesand being classified as "not prime farmland" (Soil Survey Staff n.d.). So, the northern area of the county has some fairly strong cropping potential, but the southern part of the county is probably best left to grazing.

Water supplies for Roosevelt County come from the Ogallala Aquifer. Because the county lies above the Pecos River Valley to the west, the aquifer does not receive recharge from the Rocky Mountains still farther to the west. Consequently, its recharge comes only from precipitation on the High Plains (Soil Conservation Service (SCS), USDA and New Mexico Agricultural Experiment Station 1967). Playas provide some recharge to the aquifer, but recharge overall is minimal, making the Ogallala here a "limited natural resource" (Rawling and Timmons 2017). Moreover, groundwater pumping has caused significant aquifer decline (see Figure 14). Irrigation wells, most drilled beginning since the 1950s drought, have contributed substantially to the decrease in available water in the aquifer. Both irrigation and domestic wells have declined in yield and some have gone dry (see Figure 9) (Rawling and Timmons 2017). One proposed solution has been to transport water from Ute Lake in Quay County to the north. In 2007, the cost of the project was estimated at $436 million, and New Mexico Governor Bill Richardson promised at least $5 million to the project (Stevens 2007). Construction on a Ute Lake intake facility began in 2013 despite a request for an injunction by authorities in Logan, home of the lake (Howalt 2017). The project has met with substantial controversy both in Quay County (Ute Lake water pipeline project on hold following injunctions n.d.; Hundreds Protest Ute Lake Pipeline n.d.) and with affected landowners in Curry County (Grieder 2018).

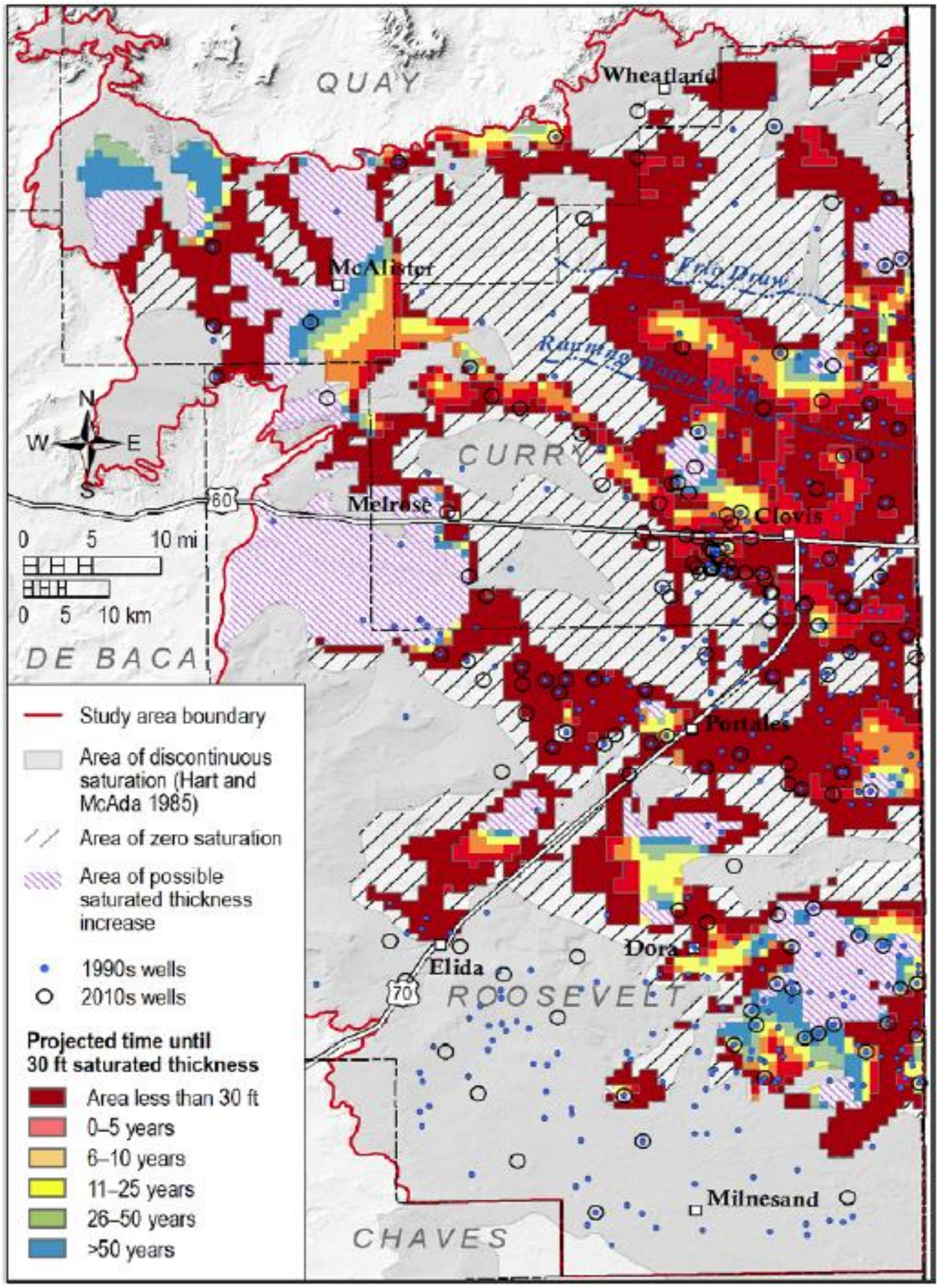

Figure 18: "This aquifer lifetime scenario portrays the projected time until water levels decline to a point at which large-scale irrigation is no longer sustainable. Many regions of the High Plains Aquifer have essentially zero remaining water and can no longer sustain extensive irrigation (show on the map by 'discontinuous or zero saturation'). The standard rule-of-thumb is that 30 feet of water in the aquifer, or a saturated thickness of 30 feet, is the minimum needed to operate large-capacity irrigation pumps (yielding hundreds to thousands of gallons per minute). This scenario is based on the rate of water-level decline observed over the last two decades." Text and figure from Rawling and Timmons, 2017. Used by permission of the authors.

Note: Roosevelt and Curry County Histories are covered jointly after Curry County Geography, below.

Curry County

Geography

Like its neighbor to the south, Roosevelt County, Curry County is in the Great Plains Province. All of Curry but the southwestern edge lies in the Llano Estacado, and the southwestern edge lies in the Pecos River Valley, the valley created by the ancient Brazos River (Williams 1986). The county ranges in elevation from 4,700 feet in the northwest to 4,150 in the southeast, with the county as a whole sloping gently southeast (Buchanan and Ross 1958). The county seat of Clovis lies at 4,268 feet of elevation. The county is crossed northwest to southeast by Running Water Draw, Frio Draw, and Tierra Blanca Creek, none of which are perennial streams (Buchanan and Ross 1958).

Also, as in Roosevelt County, Curry County depends on the Ogallala Aquifer. The same geology of Triassic (or Permian) Red Beds overlaid with sediments washed from the rising Rocky Mountains created the aquifer used in Roosevelt County. When sufficient precipitation is present, the 506 playas in the county may fill with surface water, recharging the aquifer and offering habitat for migratory bird species. Playas cover 1% of county land area (Sites Southwest LLC 2016).

Vegetation in the county also resembles that found in Roosevelt County. Rangelands in the county “are representative of the Southern Shortgrass Prairie Ecoregion and the Western Great Plains Shortgrass Prairie Terrestrial Habitat Type” (Sites Southwest LLC 2016). Common

Figure 19: Curry County, New Mexico locator map. Data from U.S. Census Bureau. County files (U.S. DOC 2007).

grasses include buffalo grass (*Buchloe dachtyloides*), blue grama (*Bouteloua gracilis*) and western wheatgrass (*Pacopyrum smithii*) (ibid.). The eastern New Mexico Great Plains also ommonly include Soaptree Yucca (*Yucca elata*), scattered forbs (e.g. Red Globemallow, *Sphaeralea coccinea;* Curly Cup Gumweed, *Grindelia squarosa;* coneflowers, *Ratibida* spp.), and other shrubs along degraded and eroded land (Dick-Peddie 1999). As in Roosevelt County, it seems useful to consider whether the agricultural future could conceivably include perennial, polycropped systems like those of the Land Institute (Cox et al. 2010).

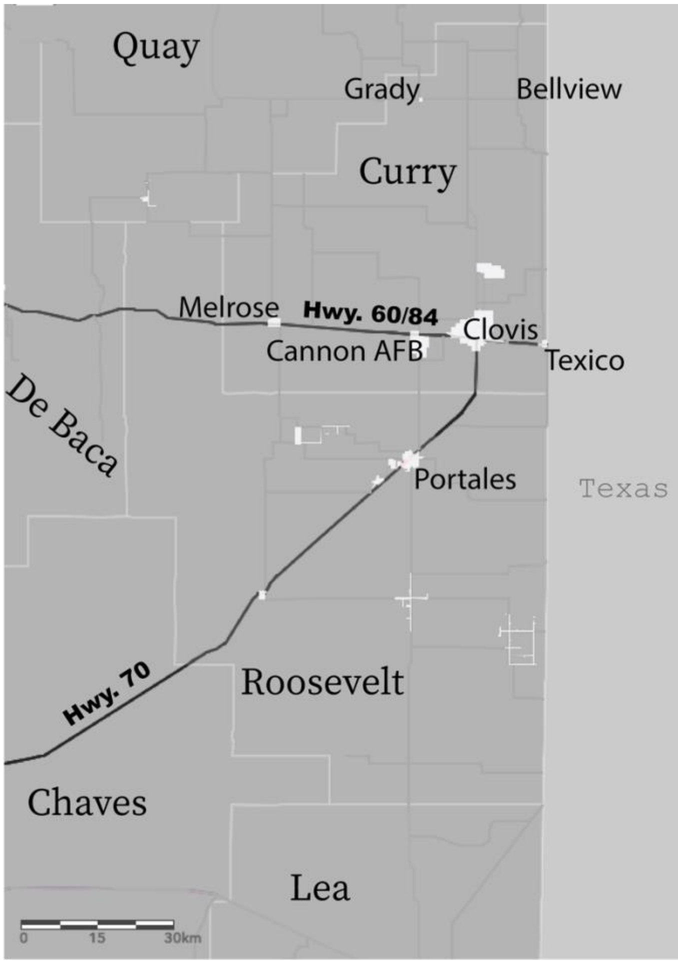

Figure 20: Curry County, NM, with its closely entwined neighbor, Roosevelt. The county's population is concentrated along U.S. Highway 60/84, with 78% of the county population in Clovis as of 2014 (Sites Southwest LLC, 2016).

Soils in Curry County are predominantly Mollisols in the northern half of the county, then a band of Alfisols to the south, with a patch of Entisols in the southwestern corner (Williams 1986). Sandy loams (Amarillo, Clovis) and clay loams (Pullman) predominate (Buchanan and Ross 1958). In Curry County, all cropland has been designated as highly erodible land (Natural Resources Conservation Service, New Mexico 2013). Using the Soil Web Survey to examine farmland classifications in the county reveals that a 90,000 acre rectangle in and surrounding Clovis is classified as more than 90% "prime farmland if irrigated" or "farmland of statewide importance." A similar rectangle around Melrose reveals only 25% of land classified as "not prime farmland," and more than half as "farmland of statewide importance." A rectangle in the center of the county reveals a similar balance, although more than 60% of the land there is "prime farmland if irrigated." Finally, in the northern tier of the county around Grady and Bellview, the balance is almost identical, with more than 75% of land classified as “prime farmland if irrigated” a code 321(Soil Survey Staff n.d.). In short, despite high erodibility, the Natural Resources Conservation Service (NRCS) classifies Curry County overall as far more amenable to agriculture than Roosevelt County.

The water situation in Curry County is also much the same as that in Roosevelt County (see Figure 14). The county is elevated above the Pecos River, which cuts it off from recharge from the Rocky Mountains to the west. The precipitation that infiltrates is far from sufficient to recharge the aquifer at current pumping rates. Depletion of the aquifer is estimated at 137,000 acre-feet per year (afy) within the county, but recharge is estimated at only 40,000 afy (Sites Southwest LLC 2016). Consequently, the plan to pump water from Ute Lake is as important to Curry County as it is to Roosevelt. However, the lake is also very important for tourist revenue in Quay County, drawing 30,000 visitors a year to Logan (population 1,024). Moreover, the lake declined in storage during the height of the drought, from 190,000 acre-feet in 2010 to 118,000 in 2013 (Uyttebrouck 2013). As the plan to carry water from Quay County to Curry and Roosevelt depends on funding from the federal government, and lake levels appear to be just a little less in jeopardy than Ogallala Aquifer levels, it remains to be seen whether the plan will finally be carried out in its entirety.

The water shortage, combined with drought, would seem to be the major limitation to continued cropping in Curry and Roosevelt Counties. Systems from elsewhere (e.g. desert permaculture systems), requiring some irrigation for establishment but very little for ongoing growth therefore seem to offer some potential here.

History of Roosevelt and Curry Counties

Because the histories of Curry and Roosevelt Counties are closely entwined, they will be covered together. The Curry and Roosevelt area are the site of the "oldest unequivocal evidence of humans in the Americas, dating between 11,500 and 10,900 radiocarbon years before the present"[12] (Waters and Stafford 2007). These people, Paleoindians, were first identified by the presence of distinctive, large projectile points found with mammoth remains near today's Clovis, NM, on the Roosevelt County side of the county line. Based on the evidence, they are thought to have been nomadic hunters and gatherers (Cordell 1997). Little evidence exists for later prehistoric groups occupying the area after the Archaic Period (lasting until about 1,500 B.C.) (Burroughs, Padon, and Grove 1975). There was, however, extensive evidence of the Plains cultures contemporary with European arrival (ibid.).

In 1541, Francisco Vasquez de Coronado passed through the area on an exploratory expedition (Sánchez, Spude, and Gómez 2013). His guides through the area were Tewa Indians from the Rio Grande area, suggesting they had some familiarity with the region despite not having permanent settlements there (Burroughs, Padon, and Grove 1975). In the early 18th century, the Comanche lived and hunted for bison in the area (Sites Southwest LLC 2016). Despite the surface dryness of the area today, springs were often evident at the surface (Clark 1987), which may have helped to support the presence of nomadic groups like the Comanche.

[12] Although that is certainly a contention now fraught with additional controversy (e.g. Joyce 2017), I will use that as our current best understanding of the earliest peoples in, at least, today's Curry and Roosevelt Counties.

However, the evidence suggests that no agriculture was practiced in the area before the advent of American settlement around the turn of the 20th century.

The area was among the last to be permanently settled in New Mexico. Pueblo and probably Mogollon peoples had lived along the Rio Grande since at least the migration of Ancestral Puebloans away from the Four Corners regions (Childs 2008), and the Spanish had begun settling the Santa Fe area starting in 1598. Europeans, however, did not settle far eastern New Mexico under the Spanish. In the late 19th century, however, as American cattlemen spread from the east over the Great Plains, the area's grasslands began to be an important resource for cattle raising (Sites Southwest LLC 2016). The first ranch was established in what is now Roosevelt County in 1879 (Burroughs, Padon, and Grove 1975). As with Luna County, however, it was the railroads (along with the Homestead Act of 1862) that brought permanent communities to today's Curry and Roosevelt Counties. A transcontinental railroad had already been completed in the 1880s connecting New Mexico north through Colorado at Raton Pass. The route proved difficult, however, with steep grades through the mountains that drove up costs. Consequently, railroad officials began to search for an east-west route through Central New Mexico, connecting eastern New Mexico to Belen on the north-south line (Stevens 2007). Before that connection was made, a railroad line between Amarillo, TX and Roswell, NM was completed in 1898. A tent city along the Amarillo-Roswell line eventually became Portales and its train depot (Portales Main Street Program 2018). As the area began to undergo development, Roosevelt County was organized in 1903 (Beck and Haase 1969). The same year, work began on the east-west tracks that had been dubbed the Belen Cutoff. Several existing townsites were proposed for the terminal of the east-west connector, but eventually the site was placed at modern-day Clovis when a railroad official bought a homesteader's claim for the terminal (Stevens 2007).

Clovis was platted in 1907 and lots were quickly sold (Stevens 2007). Curry County was organized in 1909 (Beck and Haase 1969). With homesteaders and railroad staff arriving, both counties quickly grew, with Curry reaching 11,443 people by its first census in 1910, and Roosevelt reaching 12,064 (University of Virginia Library 2007). Both county seats grew at first as well, with Portales attaining 1,292 people by 1910 and Clovis 3,255 (Stevens 2007; US Census Bureau 2018). The early and ongoing influence of the railroad, however, helped to sustain Clovis far better than Portales. As homesteaders realized the difficulty of sustaining a family on 160 acres of high plains grassland (Burroughs, Padon, and Grove 1975), the population of both counties decreased, with Roosevelt losing nearly half its population by the 1920 census. Curry County, on the other hand, lost only about 200 people (University of Virginia Library 2007) and Clovis gained nearly 2,000 people. Both counties grew steadily from the 1920s through the 1950s, although Roosevelt County grew at half the pace of Curry (University of Virginia Library 2007).

Despite starting out later than many homesteaders elsewhere in the West, homesteaders in Curry and Roosevelt County experienced many of the same conditions often associated with homesteading. Edd Stephinson, for example, moved to the Elida area as a child, and his parents filed a claim in southeast Roosevelt County in 1923[13]. When his family arrived in New Mexico, they had only 6 horses and two mules for livestock, and when moving to southeast Roosevelt

[13] Having previously "proved up" on a claim in Texas.

County, did so by wagon. His father supported them at first by building fence for a large operation, the Slaughter Ranch. In 1939, Stephinson and his wife also filed a claim, and moved into a dugout (Burroughs, Padon, and Grove 1975). Other settlers mention experiences like carrying water from a neighbor's house to the one-room schoolhouse, walking from town carrying a sack of flour, digging wells by hand, and hauling water in a tank wagon to a waterless claim (Burroughs, Padon, and Grove 1975). Even with the railroad to bring supplies, early 20th century Curry and Roosevelt Counties were challenging places to homestead.

In the 1910 agricultural census, both Curry and Roosevelt reflected their ranching beginnings, with 7,460 and 13,349 head of cattle, respectively (USDA n.d.), Roosevelt having more cattle than people. However, the homesteading presence was also apparent even in livestock numbers, with dairy cows, then mostly distributed as a few cows per farm, numbering 2,909 in Curry County and 3,410 in Roosevelt, and with other work and production animals numbering in the thousands, including horses, mules, burros, swine and sheep (USDA n.d.). After dry years around 1910, dairying was seen as one alternative to crops, one that could potentially keep farmers from failure. Roosevelt's dairying, in particular, took

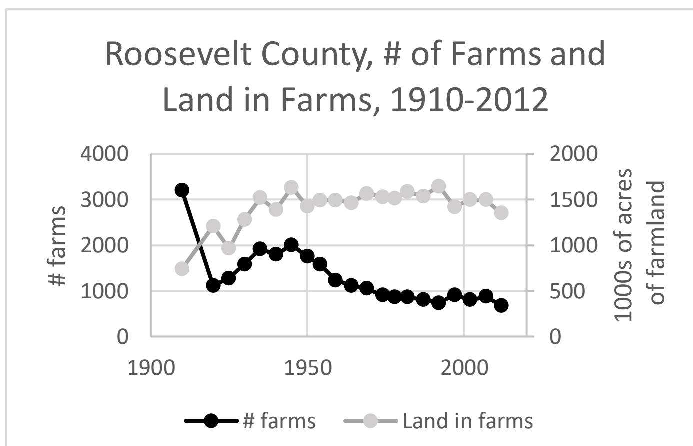

Figure 21: Data from USDA Agriculture Censuses.

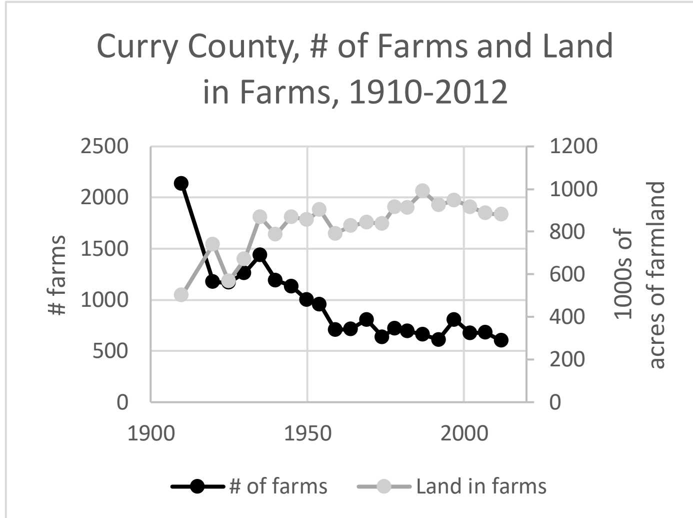

Figure 22: Data from USDA Census of Agriculture, 1925-2012 (USDA, n.d.). The census takes place approximately once in five years.

off with the first creamery arriving in the nineteen-teens. The creamery business was an economic girder for the area until the 1970s, by which time all the creamery businesses had closed (Burroughs, Padon, and Grove 1975). Not until the 1990s would dairy cattle once again begin to rapidly expand in numbers, tripling in Roosevelt County from 1995 to 2005, and increasing fivefold in Curry County during the same period[14] (NASS 2018b).

Underground water had been found in the area as early as 1882, when a dry summer dried up George Causey's springs and encouraged him to dig on his ranch south of Clovis (Stevens 2007). In 1903, R.O. Yoakam was the first to irrigate land in Roosevelt County, and the Portales Irrigation Company was organized in 1908 (Burroughs, Padon, and Grove 1975). Outside investors spurred an irrigation project carried out by the Portales electric co-op in 1909. The project was organized around a central well system and farmers paid to make use of the new water. Ten-thousand acres were under irrigation in Roosevelt County by 1910 (Burroughs, Padon, and Grove 1975). Whether as garden plots irrigated by windmills or full quarter-sections

[14] Roosevelt dairy cows: 1995, 20400; 2005, 59,000; peaking at 74,000 in 2006; 2017, 54,000. Curry dairy cows: 1995, 13,000; 2005, 62,000; 2010, 87,000; 2017, 82,000.

irrigated by electric pumps, it is clear that both counties had substantial irrigated lands by 1910, when the agricultural census shows Curry having hundreds and Roosevelt thousands of fruit trees, particularly apple and peach trees[15]. Grape vines, too numbered in the thousands (USDA n.d.). Apples and fruit orchards more broadly grew rapidly in late 19th and early 20th century New Mexico, seen as part of a movement toward modernization of agriculture with their dependence on extensive irrigation and careful management (Carleton 2017). New Mexico placed itself as a strong competitor with other fruit growing areas of the U.S. (ibid.), and Roosevelt and Curry Counties were no exception. Overly optimistic assessments of water availability (Alexander 1989), included those of early settlers who believed that the water under Roosevelt County was an underground river flowing from the Rocky Mountains (Burroughs, Padon, and Grove 1975). There thus seemed reason for optimism about agriculture in the two counties at the beginning of the 20th century, despite drought around 1910-11 (Burroughs, Padon, and Grove 1975; Midwestern Regional Climate Center 2018).

The realities of both water and orcharding caught up with farmers in the 1920s and 1930s. As pest problems spread throughout the state, invading areas within years of orchards being established (Carleton 2017), and drought hit in several years before 1930 (Midwestern Regional Climate Center 2018) , orchards declined and many farmers left the area. By the mid-1930s, crops like sweet potatoes, cotton, and peanuts dominated in Roosevelt County alongside

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[15] Roosevelt in 1910 agricultural census: 26,624 apple trees and 5,114 peach trees. Curry: 520 apple and 725 peach.

staples including corn, wheat, and the long-dependable sorghum[16] (USDA n.d.). Crops like tomatoes, snap beans, and sweet potatoes also received a boost from a cannery that opened in Portales 1926 and expanded through the 1940s (Burroughs, Padon, and Grove 1975). At the same time, Curry County's dominance in wheat production began to emerge, growing from 1,034 acres in 1910 to 81,0139 by 1935 (USDA n.d.). Like much of the southern U.S., Curry and Roosevelt's invested in cotton production in this period (Carleton 2017), with tens of thousands of acres in Roosevelt County starting in 1925 and thousands in Curry (USDA n.d.). Both counties maintained some crop diversity through the 1940s, including a variety of small grains in Curry (barley, rye, oats), some vegetable crops in both counties (cantaloupe and sweet corn among them), and a continued, though much decreased presence of fruit trees (USDA n.d.). By the 1960s and '70s, the number of fruit trees, though, had dwindled to mere tens in each county, and vegetable crops like those once grown for the cannery mostly disappeared (ibid.). The cannery was forced to close in 1955 as costs of transportation and labor overtook profits (Burroughs, Padon, and Grove 1975). By the late 1980s, the balance of agricultural production had shifted, with ever-growing cattle numbers gaining increasing importance. In terms of crops, sorghum, peanuts, wheat, and hay (particularly alfalfa) gained more and more importance in both counties. Hay acreage in Roosevelt County grew to over 15,000 acres, levels not seen since before 1925. The proportion of that coming from alfalfa, however, had increased to more than

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[16] Sorghum was a novel crop to most when it was first farmed in the two counties at the beginning of the 20th century (Burroughs, Padon, and Grove 1975). In the 1910 agricultural census, it was referred to as "kaffir corn and milo maize," (USDA n.d.) reflecting its African origins. Most farmers in Curry and Roosevelt Counties currently refer to it as milo.

half as compared to a mere 5 acres in 1910 and 139 in 1925 (USDA n.d.). Alfalfa's heavy irrigation needs differentiate it from the dryland hays that were heavily produced in Roosevelt County in the 1910s.

By the 1990s, then, which is the beginning of the period of focus in the next chapter, grain and hay crops predominated in Curry and Roosevelt Counties. The landscape had undergone substantial shifts over a century, from bison rangeland to cattle ranches to diversified farming and finally to grain and hay crops. As drought and diminishing irrigation water brought renewed challenges, even grain crops would decline. For two counties rapidly running out of underground water, irrigated agriculture seems unlikely to be a long-term part of their future. In addition to options for the agricultural future that focus only on dryland production and grazing, however, it may be worth experimenting with desert permaculture (MacKintosh 2014) or perennial polyculture (Cox et al. 2010) that have worked in slightly different systems.

Conclusion

The four counties each have substantial biophysical limitations to crop production, but humans have developed a variety of means of adapting to those limitations both in prehistory and during the past 170 years. The uses of native plants, of mixed crops and rotations, and of integrated systems including livestock all suggest possibilities for the agricultural future of the four counties.

Chapter 3. Factors Shaping New Mexican Farms, 1995-2016

Introduction

Given the negative impacts of climate change on multiple aspects of agriculture (J. R. Porter et al. 2014), some argue that incremental adaptation to climate change will be insufficient (Howden et al. 2007; Dowd et al. 2014) and that transformative change is necessary (Park et al. 2012; Dowd et al. 2014). One approach to understanding how transformative adaptation occurs is the three spheres of transformation framework described in chapter 1 (O′Brien and Sygna 2013). The three spheres are three nested elements of the social world: the personal (beliefs, worldviews, paradigms), the political (laws, institutions, markets) and the practical. The practical sphere includes the ways in which technical reactions to climate change occur, and is where most adaptations to climate change currently take place (O′Brien and Sygna 2013). The practical is nested within the political sphere, which is itself nested within the personal sphere. The placement of the spheres is to emphasize how the greatest changes may take place. Changes in the personal sphere of beliefs and worldviews can have resounding impact and are more likely to produce transformative change as compared to changes in the political and the practical. Similarly, changes in the political sphere have more potential to produce transformative change than do changes in the practical sphere (O′Brien and Sygna 2013). For example, in agriculture, a farmer who comes to believe that future water availability will make his current crop choices untenable (a change in the personal sphere) may choose to move toward an entirely new suite of crops to prepare for the future challenges—a transformative change. The change occurs in the practical sphere as influenced by the personal sphere. Change may also occur because of a change in policy, a change in the political sphere. The shift from direct subsidies to insurance-based farm support, for example, is a change in the political sphere that may cause some farmers to abandon a crop that was previously directly subsidized, such as cotton. When the focus is on producing change in the practical sphere, on changing attitudes, behaviors, and choices rather than beliefs and worldviews, change is often incremental and is framed by understandings of what is "'concrete, achievable and manageable'" in the present rather than the kinds of change that might produce better long-term outcomes (Shove 2010).

Nonetheless, making sense of how those "concrete, achievable and manageable" changes occur is important to understanding the constraints under which farmers operate. On a daily basis, farmers must make decisions that are influenced by diverse elements of their farm networks. From neighbors and family to banks, suppliers, and sellers, farmers operate within a complex decision environment. They are influenced by the ways that they understand advice and signals from members of their networks. But they are also influenced by the ways in which they perceive how their own farm system is working and how weather, soils, wild animals, machinery function, and the regularity of their own observation of the system affect their farm outcomes. But changes in all three spheres of transformation can influence the decisions farmers make about what to plant.

Farmer Decisions Based on Farm Observation

The most immediate level at which farmers make decisions about the management of their farms is in in reaction to what they see happening on the farm landscape. Specific observation, underpinned by specific sets of knowledge, shape farmer decisions about specific practices such as integrated pest management, improving irrigation management, no-till or conservation tillage, weed management, soil management, or precision agriculture (Baumgart-Getz, Prokopy, and Floress 2012). Concerns about yield losses from inadequate nitrogen lead to more use of manufactured fertilizers (Stuart, Schewe, and McDermott 2014). The perception of weeds in farm fields leads to use of herbicides, especially in genetically modified crops resistant to herbicides (Owen et al. 2015). Observation that wind or water erosion is causing major field losses may encourage a farmer to adopt no-till systems (Derpsch et al. 2010). New knowledge and regulation can change these in-field decisions, as has been the case for a move from pesticides to integrated pest management of perennials in the western U.S. (Farrar, Baur, and Elliott 2016), but such practices rely even more closely on the farmer's observation of and reaction to what is happening in the field. Farmer's observation also applies to systems of management. In noticing that fuel costs are burdensome or that net profit is affected by the number of tillage passes over a field, for example, farmers may lean toward adopting conservation or no-till systems (Allmaras and Dowdy 1985). New technologies may offer farmers new means of observation and new detail about highly localized problems, and therefore encourage farmers to react in new ways to their knowledge of their farm fields. Remote sensing and unmanned aerial systems, for example, are offering, quite literally, new perspectives on fields. They can offer diagnostic information about farms, "such as biomass, Leaf Area Index (LAI), disease, water stress and lodging" (Zhang and Kovacs 2012). For farmers adopting precision agriculture, using GPS maps to apply carefully calibrated inputs of water, fertilizer, and pesticides (Schimmelpfennig and Ebel 2011), this changed observational technology promises the possibility of reducing the use of inputs (Zhang and Kovacs 2012). It thus appears to promise a reduction in spending and in environmental harm. Farmer observation is therefore an important element of how farmers make decisions. But because a farmer's direct observation of the system is only one of several influences on farm decisions, it is important to look at the farm system through the three spheres approach (O'Brien and Sygna 2013). With the three spheres approach, it is possible to parse the ways in which farmer thinking, agricultural institutions, and farm-system observation can all shape farm decisions.

This chapter is intended to introduce the ways in which agriculture has changed in the state and in study counties during the study period of 1995-2016[17]. This focus serves two purposes: 1) it offers a broad-based background against which subsequent chapters' descriptions of barriers and supports to transformation on particular farms can be understood, and 2) it offers an opportunity to introduce the way in which on-farm decision-making—in this case decisions about which crops to grow—can be shaped within each of the three spheres of transformation. I argue that most of the cropping changes made in New Mexico have been incremental (not transformational), and that an explanation for that incremental change can be found in how each of the three spheres affects the decisions made. As such, the chapter is structured as follows.

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[17] Some statewide and county trends are traced further back to provide further support to explanations of more recent changes. In addition, although a number of farmers were able to offer some information about what their systems were like as far back as the mid-nineties, and some even earlier, the period of focus for in-depth farmer histories was the ten years previous to the interview with the farmer, so 2006-2015 or 2007-2016. Nonetheless, since some farmers offered some detailed explanations of change in their own farming as far back as the mid-nineties, I frame that as the start of the study period here. Given the diverse nature of farmers' oral histories of their farms, it was necessary to frame a somewhat arbitrary starting point for this chapter's analysis.

First, I will examine the New Mexico state-level change in agriculture during the 21st century based on data from the U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS) and organized by the New Mexico Department of Agriculture. That change will then provide a background for an outline of county-level change based on the same data sets. Finally, I will introduce a few of the farmers in the study in order to demonstrate some of the ways in which their cropping choices have been shaped in the three spheres of transformation.

Methods

This chapter draws together two different sets of data. One is drawn from the New Mexico Department of Agriculture (NMDA). NMDA prepares annual agricultural statistics bulletins[18] based on surveys conducted by NMDA staff and by USDA National Agricultural Statistics Service (NASS) staff. Surveys are stored by NASS (NASS 2018b, 2018a). The bulletins include information about New Mexico agriculture at the state level, as well as individual counties. I draw on the annual narratives in the bulletins, as well as annual production numbers to produce summary statistics demonstrating agricultural change over time. Data on both the state and on the four counties are included in this study.

I also conducted farmer surveys in the four counties. The four counties in the study, Luna, Doña Ana, Roosevelt and Curry, are located in southern and eastern New Mexico. They were selected based on reports from extension agents of climate-related challenges (drought, in particular) that were affecting agriculture in those counties during preliminary research in 2012. In each county,

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[18] The first bulletin was produced in 1962 and the latest in 2016.

initial contacts with county cooperative extension, USDA Farm Service Agency or Natural Resources Conservation Service staff, or university professors were made via internet searches of available contacts. Those initial contacts led to farmer contacts. Farmers were subsequently identified based on a snowball technique which led to two roughly identifiable groups in each two-county area: large-scale growers and smaller direct-to-market growers. I conducted 26 farmer surveys with 30 farmers (four pairs of farmers were two members of a family who work together on the farm). In-depth surveys asked farmers to discuss their history of decision-making over 10 years or as many years as the farmer was able to discuss, if less than 10. For the purposes of this chapter, I identified significant decisions that resulted from farmer observations of their farm systems. I analyze those narratives within the larger context of the state and county.

Change in New Mexican Agriculture

Number of Farms and Land in Farms

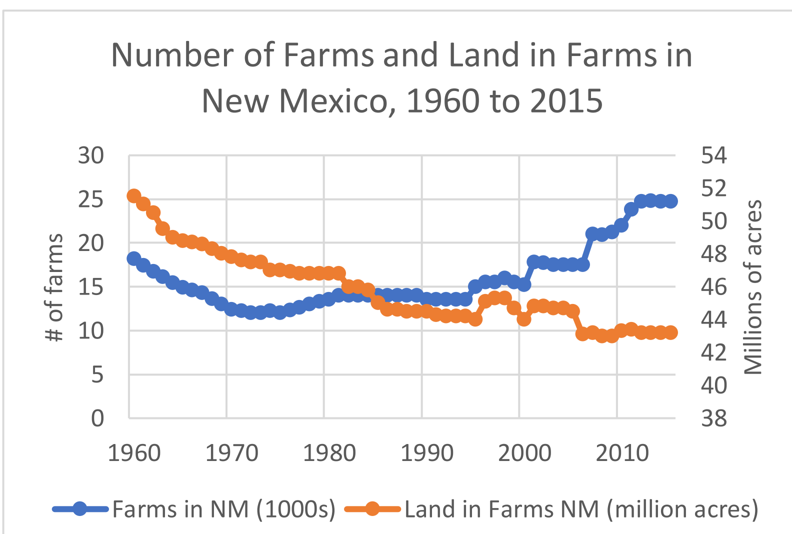

Figure 23: Data from NMDA Annual Statistical Bulletins, 1962-2016

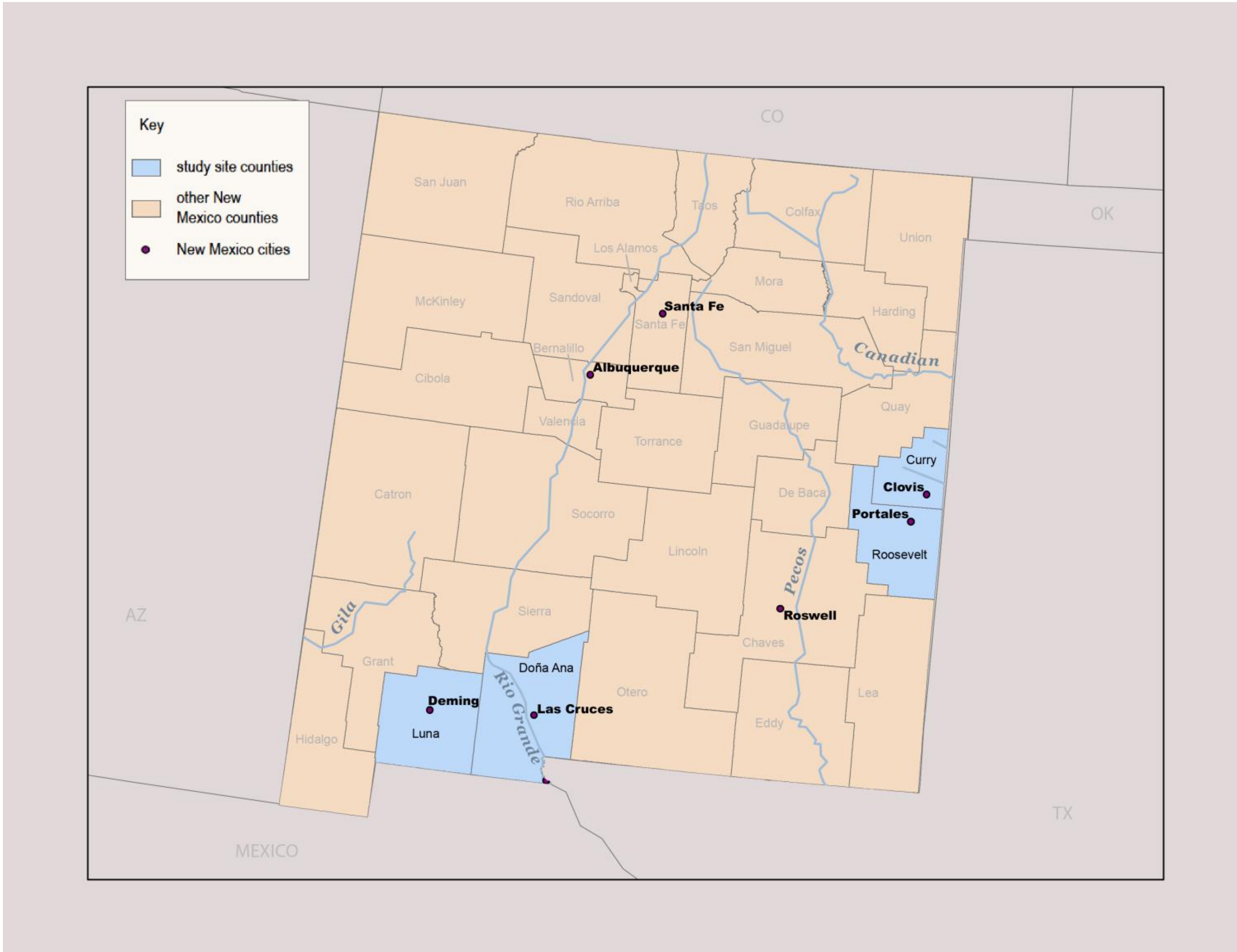

Figure 24: New Mexico counties included in the study: Doña Ana, Luna, Roosevelt, and Curry. Study area counties are blue. Their county seats are included along with a few major New Mexico cities.

By 1935, the number of farms in New Mexico had grown to 38,800. That number declined steadily from 1935 through the 1970s, but then slowly began to climb again. At the same time, however, the amount of land in farms has declined (mostly) steadily ever since 1950 when the number was first tracked[19] (USDA, New Mexico Crop and Livestock Reporting Service, and Statistical Reporting Service 1975; NMDA 1990, 1995; USDA NASS 2000, 2005; USDA NASS and NMDA 2010, 2016). The advent of larger, more industrialized farms that led to a decline in farm numbers was thus followed by an increase in small farms, including farms whose principal operator may not consider farming to be their primary occupation (USDA 2014).

Cropping Changes

As discussed in the dissertation's introduction, the covers of the NMDA Annual Bulletins (hereafter NMDAAB) reflect some of the change perceptible in New Mexican agriculture. Recently, some farmers and extension professionals have come to see pecans as one of the best choices for irrigated agriculture because of its high return on water used. The choice of pecans for the cover of the most recently issued bulletin (2016) is a symbol of the increasing dominance of pecans. Going back to the first year with a cover (1962 through 1971 are bare, text-faced bulletins), 1972 saw the advent of a roadrunner—the state bird—in a Chihuahuan Desert landscape. It reflected New Mexican heritage[20], certainly, but spoke little to agriculture. The roadrunner lasted through 1987 (no doubt due to the relative difficulty of producing new images

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[19] *Land in farms: "The acreage designated as 'land in farms' consists primarily of agricultural land used for crops, pasture, or grazing. . .. Land in farms includes CRP, WRP, FWP, and CREP acres" (National Agricultural Statistics Service, 2012).*

[20] The roadrunner is the official state bird.

compared to the present), and from 1988 forward, a transition in the ideal of New Mexican agriculture can be traced. Nineteen eighty-eight's windmills and 1989's windmills and cowboys both strongly evoke New Mexico's ranching tradition. But then the major crops associated with modern New Mexico begin to appear: 1990—cotton, 1991—dairy cattle, 1992—red chile being machine processed, 1993—apples. Existing images (a number are missing) from the late 1990's and early 2000's evoke a pastoral simplicity much in line with that illustrated on the contemporary egg, meat and dairy products we can find in stores: a table set with a variety of New Mexican foods, nursery flowers, and trees. As American agriculture steadily increases its focus on industrial-style production, then, a prettier past is conjured, in which farms are places of diverse crops and wholesome eating. Then, the images from 2009 and forward reflect the New Mexican agriculture that has been part of this study. Green chile, tractors, Elephant Butte Dam. After 2009, the only crop given a cover of its own is pecan. The covers during the last decade partly reflect a long-term decline in some of New Mexico's iconic crops, while large-scale dairies have become an increasingly important part of the landscape.

Chile, one of New Mexico's iconic crops (Carleton 2017), has been produced in New Mexico for at least four centuries (Skaggs, Decker, and VanLeeuwen 2000). Chile has long been associated with New Mexico, as suggested by the adoption of the official state question in 1999: "red or green?" The question refers to whether to have green or red sauce (or the "Christmas" combination of the two) applied to one's entrée of enchiladas, chile rellenos, and the like. The sauces are made from the same varieties of chiles, the green from immature mild or hot chiles, and the red from powdered, mature chile. As the cuisine would suggest, the crop is closely associated with New Mexico's Hispanic culture, having been brought by Mexican settlers as they moved north along *El Camino Real* (the Royal Road) through El Paso del Norte (today's El Paso) and on to Santa Fe. In fact, "Hispanic farmers throughout New Mexico grew the chile pepper more than any other non-grain crop, and regarded it as a symbol of their heritage" (Carleton 2017). In 1884, the *Rio Grande Republican* called the chile the "'national dish'" of Las Cruces Hispanics (Carleton 2017). The 20th century success of the chile was closely linked to the famed Fabiàn García, horticulturist and breeder at what would become New Mexico State University. He developed chiles that were both more palatable (i.e. milder) to Anglo tastes and far easier to process for canning—in addition to having improved disease resistance (Carleton 2017).

In the U.S., chile consumption has risen, doubling between 1980 and 2013. At the same time, U.S. production has stayed more or less level, while imports have risen steeply. Chile production in New Mexico peaked in acres planted in 1992. Chile pepper imports are the major reason for the decline in New Mexico production, with fresh market chile from Mexico and dried chiles from other countries providing competition with New Mexican producers (Skaggs, Decker, and VanLeeuwen 2000; Hawkes, Libbin, and Jones, Brandon A 2008). Chile producers interviewed in this study consider Mexico to be their major competition. Mexico has lower labor costs, electricity costs, and, for crop producers, subsidized diesel fuel (Hawkes, Libbin, and Jones, Brandon A 2008). Although Mexican producers face some challenges, including questions about land ownership, difficulty shipping their product over the northern border, and slightly less advanced technology, overall, Mexican producers are able to grow chile more cheaply (Hawkes, Libbin, and Jones, Brandon A 2008; Hawkes 2012). The change is perceptible even in the statistics for individual chile types grown in New Mexico. The NMDAAB stopped including jalapeño in its published statistics in 2007, as acreage was declining to a negligible level (just 500 acres in 2006). Mexico has largely taken over jalapeño production. The other major categories of New Mexican chiles have also been on the decline.

Cotton is another of New Mexico's iconic crops (Carleton 2017). It was grown almost from the time Elephant Butte Dam was completed in 1916. It was first grown as an experimental crop in the El Paso Valley in 1918, and its potential was quickly identified (Autobee 1994). Within a few years, ninety percent of irrigators in the Rio Grande Project area were growing cotton, with cotton covering 110,000 acres by 1928 (Autobee 1994). Nonetheless, New Mexican production of both widely grown Upland cotton and the longer-staple Pima peaked in the early 1960s and has generally (although not continuously) trended downward ever since. This has followed nationwide trends, as cotton consumption has declined, production can cost more than the crop earns, and a longstanding subsidy was taken from cotton farmers as part of a settlement with Brazil. The subsidy was lost as part of the 2014 Farm Bill (Prentice 2015)

Other crops slowly fall from the list, as well. Potatoes, for example, reached peak acreage in the 1980s and 1990s, declining from 10,500 acres in 1995 to 6,000 in 2010 before being left out of annual reports altogether from 2011 on. Evidence of changed on-farm diversity is clear in comparing a 1960s NMDAAB to a bulletin from the current decade. In 2011, sixteen crops are listed as "principal crops" (NMDA 2011), but in 1962[21], thirty-four are counted as "principal"

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[21] The earliest available bulletin.

(NMSU 1962). Livestock, too, disappear from the list, with 1962's bulletin including chickens, turkeys and bees in addition to the cattle, sheep and lambs, and hogs and pigs listed in 2011 (2011 does include goats, though, which are not on the 1962 list) (NMSU 1962; NMDA 2011). These two points of comparison reflect a changed farm landscape found in tracing through the bulletins. There is more focus in the present on a limited selection of both animals and crops. The shift is the continuation of a trend from the World War II era of increasing focus of New Mexico's agricultural regions on a few select crops (Carleton 2017).

As iconic as chile and cotton are in New Mexico broadly, so is wheat the quintessential crop of the High Plains (USDA OCE n.d.). The eastern New Mexico counties in this study, Curry and Roosevelt, fall in the band of High Plains counties that have long focused on wheat production. Nonetheless, like chile and cotton, wheat production has gradually declined in New Mexico, even as prices have sometimes spiked substantially higher. Production rose to a peak in 1983 and has trended toward decline ever since. The decline in acreage is perhaps the clearest sign of decreased farm focus on winter wheat since the 1980s.

Peanuts were long an important crop in eastern New Mexico, especially Roosevelt County. Declining water availability, however, encouraged some farmers to choose to abandon peanut production (Smith 2017). Then, the Roosevelt County organic peanut butter processing plant, Sunland, Inc., was shuttered due to a salmonella outbreak. The company declared bankruptcy in 2013 (Christina Calloway 2013). An already declining crop in the area had received the nail in its coffin. By the time the plant reopened under new ownership in 2015, most farmers had moved on to other crops, including forage crops intended for the area's dairies.

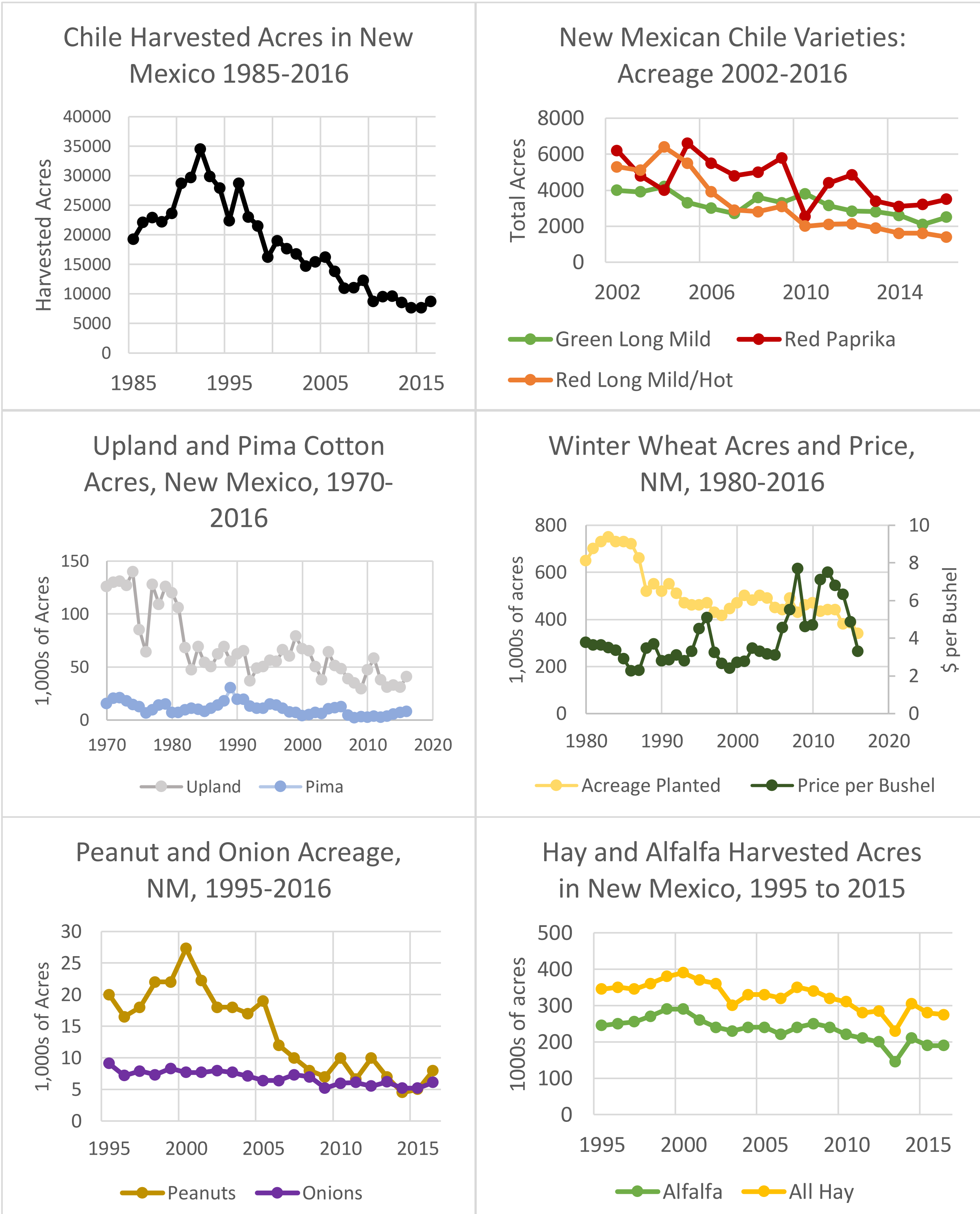

Figure 25: Statewide change in cropping systems in New Mexico. Data from NMDA Annual Statistical Bulletins, 1970-2016.

Back in the irrigated Mesilla Valley and in Luna County, next door, production of another typical crop also declined. Onion acreage rose until the 1990s and has largely been on the decline ever since. A price spike contributed to some return to onions in 2015 and 2016, but it remains to be seen whether it will have a longer-term effect on the downward trend.

Hay production peaked a little later than did other crops, reaching its greatest production in 1999, and peaking in acreage in 2000. In the past decade, the most notable change in harvested acres comes in 2013, after two of the most severe years of drought throughout much of the state. It was the first time harvested acreage of alfalfa had fallen below 150,000 acres since 1960. Sorghum, most often harvested now for forage rather than grain, has also declined, from a peak in the late 1960s and early 1970s. Most noticeable in sorghum is the rapid change in how much acreage is harvested for grain. Although there have always been years when the weather has made it more difficult to grow grain sorghum, or when it was more cost-effective to harvest sorghum for silage, a noticeable gap opened in the early 2000s between acres planted and acres harvested for grain. Instead of a periodic gap, the gap appeared more permanent. The gap coincides fairly closely with what some informants identified as the earliest part of the drought. Since 2000, however, there have been only two years in which more than 75% of the sorghum was harvested for grain (81% in 2005 and 77% in 2016). This is compared to previous high grain years, as for example 1992 when 95% of the sorghum was harvested for grain. The gap relates not only to the advent of the long-term drought, but also to the increasing demands of large dairies in places like the Mesilla Valley and far eastern New Mexico.

Sorghum's relative, corn, has had a fairly steady recent history, unlike most of its major crop counterparts in New Mexico. In 1942 (the first year on record in the 1962 NMDAAB),

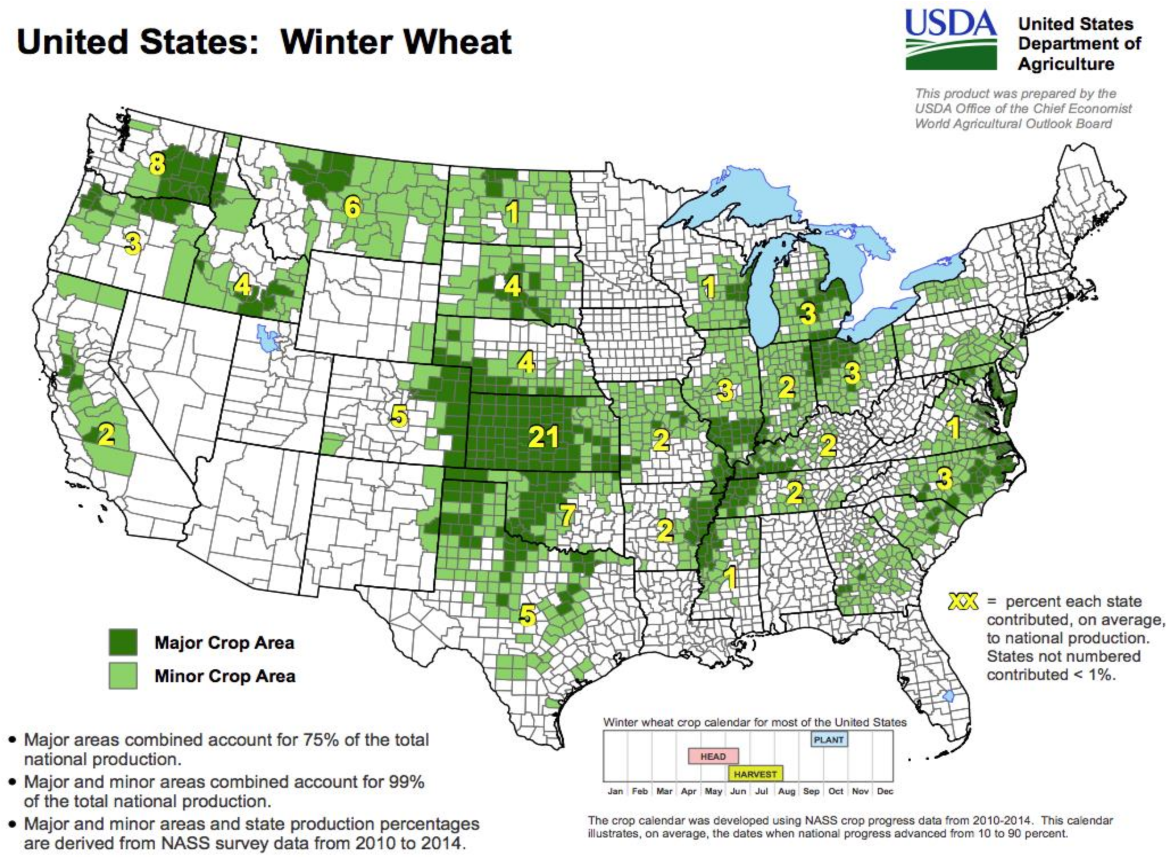

Figure 26: Winter wheat growing areas in the U.S. Note the concentration of dark green (major crop area) in Kansas, Oklahoma and Texas, with four counties in New Mexico falling into the same growing area. Map from USDA OCE, n.d.

219,000 acres of corn were grown. However, the drought of the 1950s drove production far below the levels of the 1940s, to just 60,000 acres in 1955 and continuing to decline through the 1960s with production on just 35,000 acres in 1965. Changing breeding technologies and new hybrids contributed to a return to increased corn acreage, though, despite corn's relatively high water needs. In the early years, nearly all corn was harvested for grain, as in the 1940s and 1950s, when 80%-90% of corn was commonly harvested for grain (NMSU 1962). The situation was much different in the past two decades, however, with technologies for silage playing a significant role in increasing the amount of corn harvested for silage rather than grain.

With all the crops whose acreage decreased, one may well wonder what has taken their place. Certainly, much of that decline has come from the overall decline in farmland, as discussed earlier in the chapter. Another important replacement of cropland, however, starting in 1986, was Conservation Reserve Program (CRP) land. The current Conservation Reserve Program is a descendent of New Deal legislation addressing soil erosion (Coppess 2017). After World War II, a new focus on conservation led to the Eisenhower Administration's Soil Bank program. The Soil Bank was, like its New Deal predecessor, as focused on preventing excess agricultural production as it was on soil conservation. In 1985, however, concerns about conservation brought about the existing version of CRP, in which land is retired under contract for 10 or 15 years (Coppess 2017). The current CRP systems began enrolling acres in 1986, and by 1990 had reached nearly the level of enrollment nationwide that it maintained until 2008, at 32 to 36 million acres (Farm Service Agency (FSA) 2017). In New Mexico, enrollment rose even faster than in the nation as a whole, reaching its 1990s level by 1989 (Farm Service Agency (FSA) 2017).

In addition to declining farmland and CRP, there are other influences changing the use of cropland. One is the icon of contemporary agriculture in the Mesilla Valley of Doña Ana County: the pecan. Granted its own cover on the NMDAAB in 2016, the pecan has quickly been

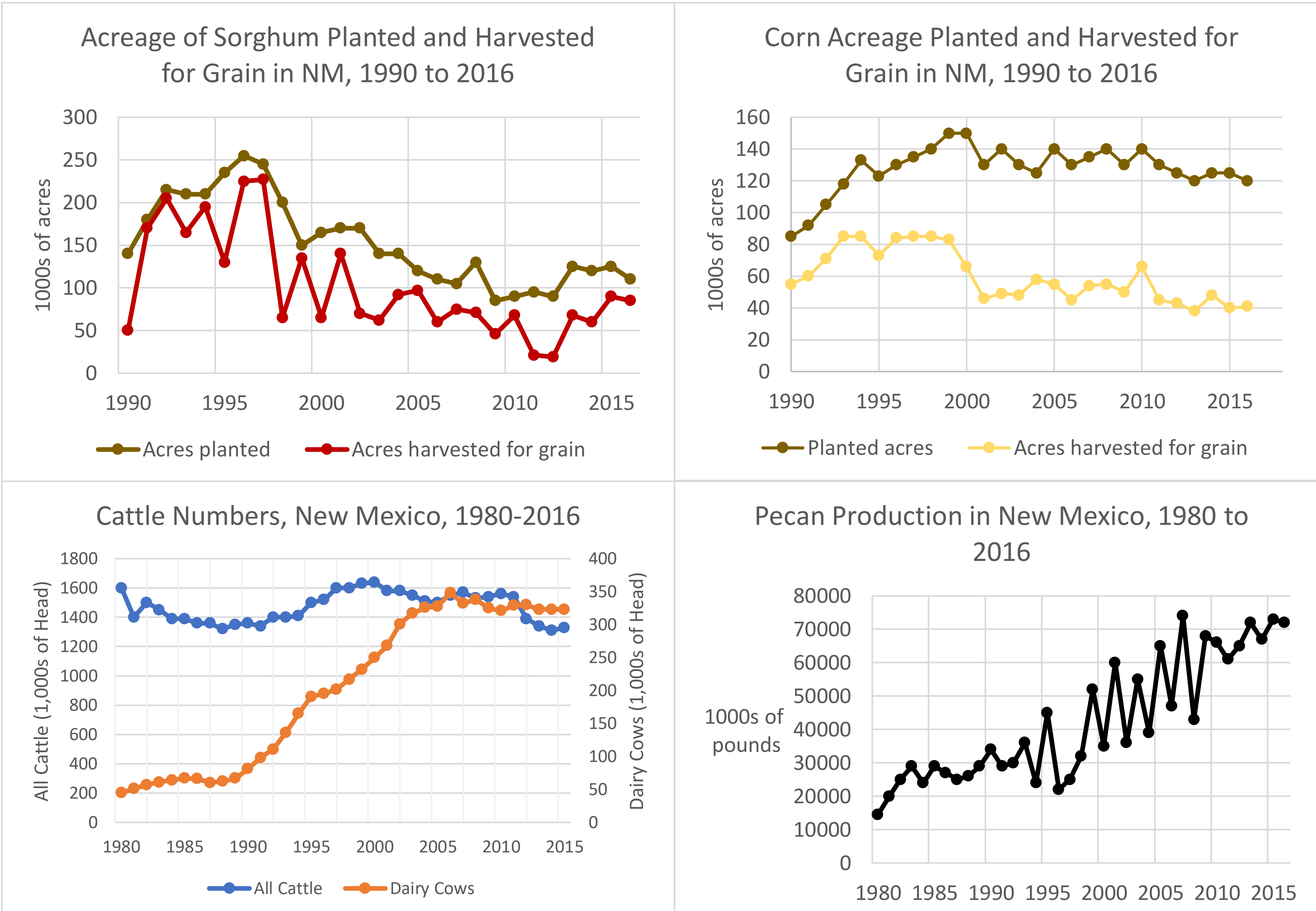

Figure 27: New Mexico statewide cropping and cattle changes. Data from NMDA Annual Statistical Bulletins, 1980-2016. Note that pecan acreage is not tracked on a yearly basis, so production data stands in for acreage.

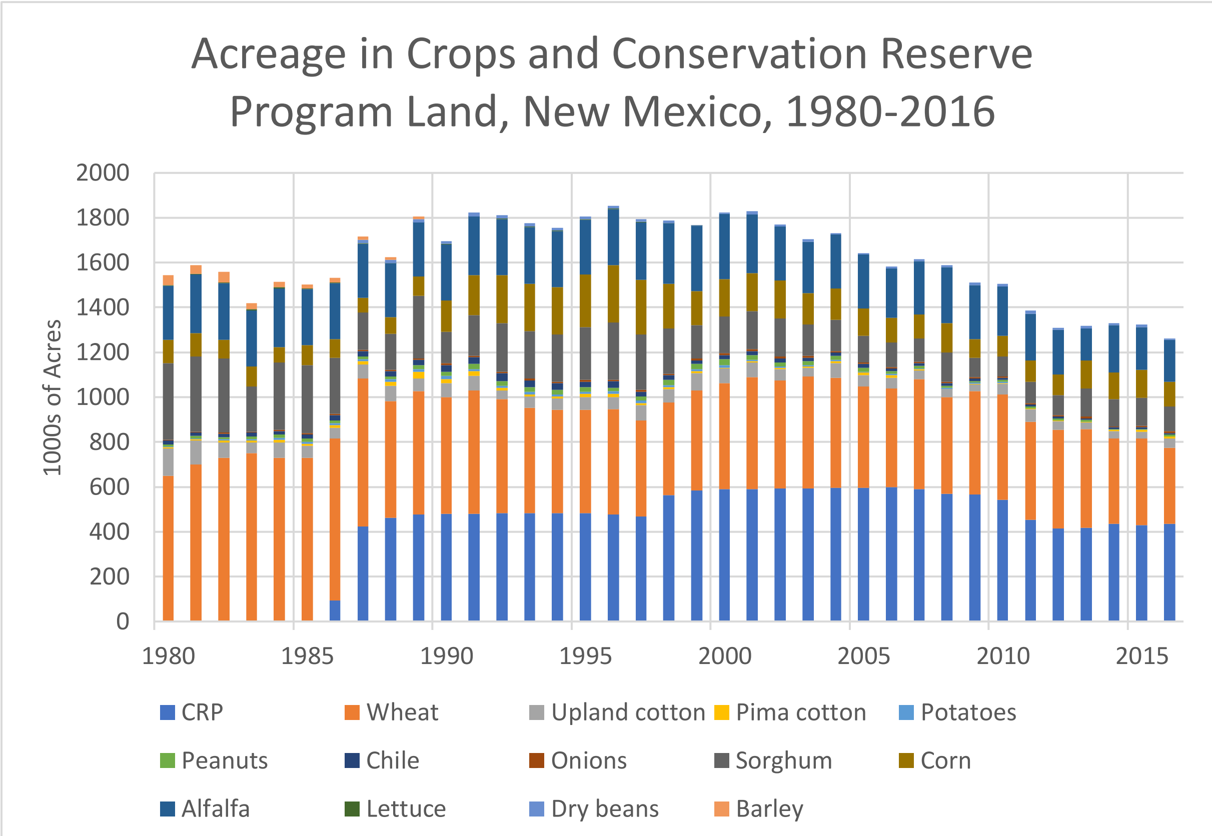

Figure 28: New Mexico Conservation Reserve Program (CRP) and crop acreage, 1986 to 2016. The current CRP program began enrolling acreage in 1986. Some crops not included here because their acreage is not tracked annually (e.g. pecans, apples). Data from NMDAAB 1986 to 2016 and FSA (2017).

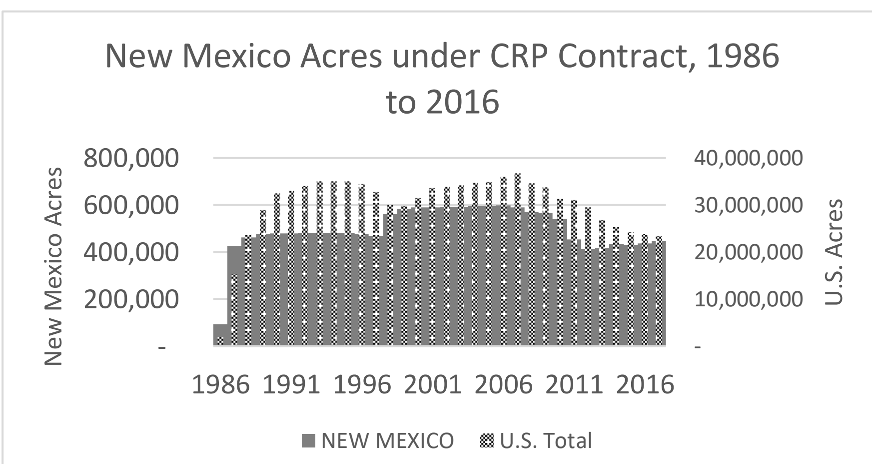

Figure 29: Data from Farm Service Agency Conservation Reserve Program Statistics (FSA 2017).

supplanting other crops in Doña Ana, Luna, and Chaves Counties. Unfortunately, acreage has not been tracked in the same way as it has for other crops, only being recorded in the five-year agricultural censuses, and only since 1985. However, looking at the change in production over time offers a clear image of the degree to which pecans have assumed a dominant role in New Mexican agriculture—although the alternate-bearing nature of the tree, in which one year a tree bears abundant nuts and the next far fewer, can make the trends a little more confusing to observe. As more trees have come into full bearing, including some planted that bear heavily in opposite years from others, the trend has begun to smooth out. By 2015, pecans had taken pride of place in New Mexican production, earning cash receipts of $164 million dollars, and trailing only milk and cattle for the lead in economic productivity.

Finally, an additional force of change in New Mexican agriculture has been the change in dairying. The presence of cattle for meat has not changed rapidly over the past few decades and has generally declined. On the other hand, dairies have expanded radically. Cash receipts from milk overtook the state's meat cattle cash receipts in 2001 (NMDA 2001), as yet another New Mexican agricultural icon left its pedestal. Repeatedly in the early 2000's, the narratives in the NMDAAB about the New Mexican agricultural economy point to increases in the livestock sector making up for continued losses in cropping from previous years. Moving through the 21st century, those bonuses from the livestock sector increasingly come from milk (NMDA 2001; NMDA and USDA NASS 2002, 2015).

County-Level Change

Table 2. Farms and land in farms in Doña Ana County.		
Year	**# of Farms**	**Land in Farms (Acres)**
1997	1681	581,436
2002	1691	580,769
2007	1762	589,373
2012	2184	659,970
Source: NMDA Annual Statistical Bulletins for 1997, 2002, 2007, and 2012 from five-year census of agriculture.1997 land in farms directly from census (not in NMDAAB).		

Doña Ana County

Doña Ana County is in many ways the agricultural center of New Mexico, despite its location on the southern border. It often trails Chaves County (home of Roswell) in rank for greatest cash receipts, partly because Chaves County includes intensive irrigated lands as well as extensive High Plains grazing land—as opposed to the Chihuahuan Desert grazing available in Doña Ana County. However, Doña Ana County is home to the state's land grant institution, New Mexico State University, as well as the home of the New Mexico Department of Agriculture. It is also home of the self-proclaimed world's largest family-owned pecan orchard. Over the last 25 years, Doña Ana has undergone substantial change to its agricultural system.

One of the most significant changes has been in the water allocation farmers in the area receive from the Rio Grande through the Elephant Butte Irrigation District. From a full allotment of 3-acre feet/acre (DeMouche 2004) during the 1990s, water allocations began to drop early in the 2000s as drought began to affect the region. As discussed in chapter 2, the majority of the water in the Rio Grande originates in southern Colorado and northern New Mexico. As snow pack has declined in the north, and temperatures have risen in the Elephant Butte Irrigation District, the water levels in Elephant Butte Reservoir—source of nearly all water for irrigation south of the dam—have fallen away (Figure 30). As a result, low water allocations have made agriculture increasingly challenging.

The challenge is apparent in examining the numbers on hay production during the worst of the drought (Figure 31). Production and acreage fell so low that they were left out of the NMDAAB for Doña Ana County[22]. The resulting gaps fall clearly in drought years, and, for hay, they continue to the present. Fortunately, the NMDAAB continued to track cash receipts for hay by county. However, cash receipts give a less clear indication of production levels, especially since as a commodity (in this case, bales of hay) becomes scarcer, its price often rises. According to my informants, that was the case for hay. Prices rose steeply at the height of the drought. Nonetheless, the cash receipts do at least give some indication that hay was still being produced. However, one additional force began to affect hay production within the past few years. Informants say that Mexican hay, produced more cheaply, has begun to displace their hay production. They are often not able to sell what they produce, even though dairies are just down the road. As a result, informants said, they have begun to decrease their hay production.

Chile acreage (Fig. 31 for all Doña Ana County acreage changes) has been following statewide trends of decline. Production has only been tracked by county since 1999, so long-term trends are harder to see (especially because chile, even when fully harvested, can have very different weights depending on the weather in the year it grew). The decline in acreage, however

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[22] To protect grower privacy, when very few farmers surveyed report acreage and production for a crop, the numbers are not included in the NMDAAB.

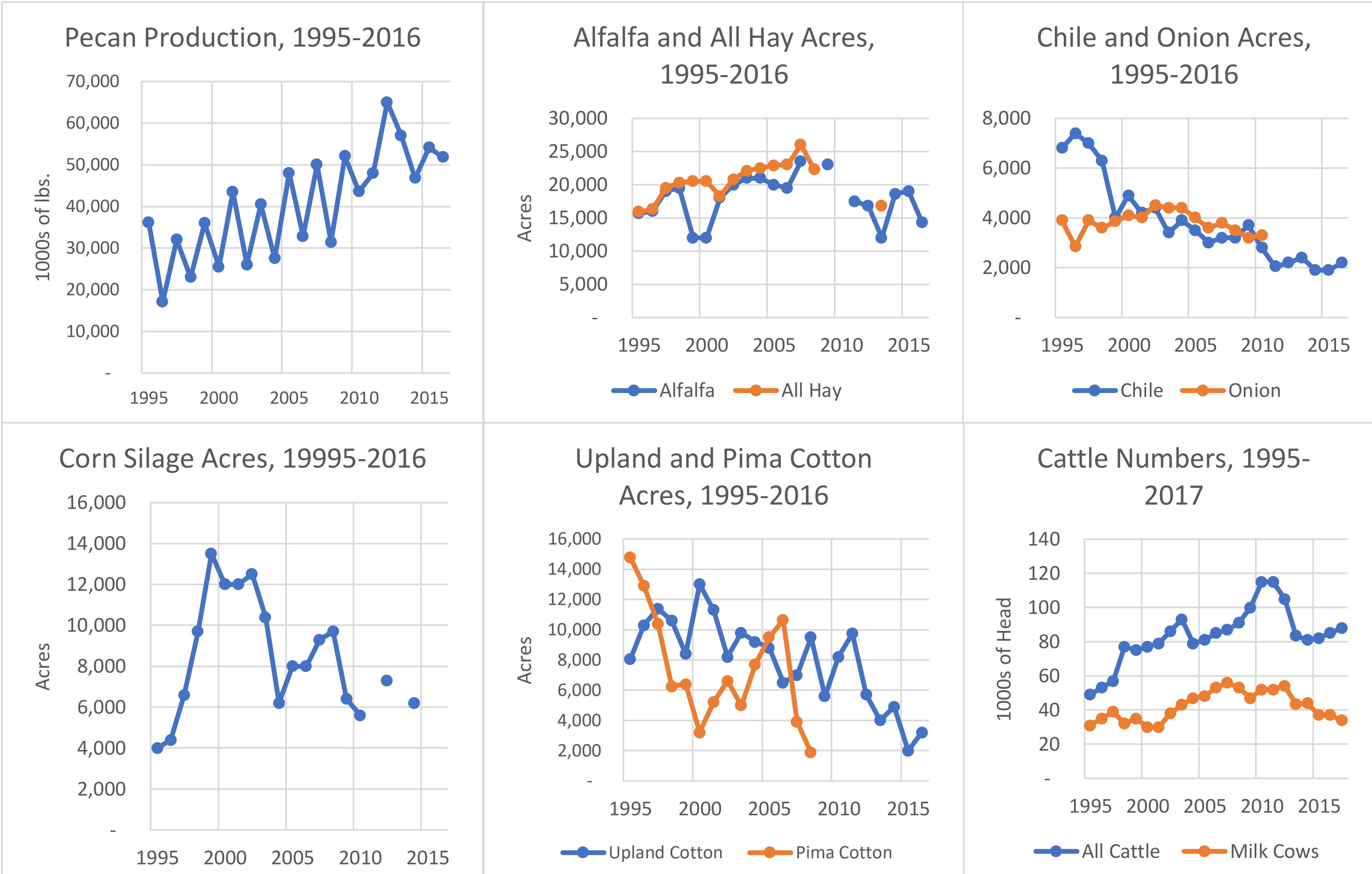

Figure 30: Doña Ana cropping and cattle change. Data from NMDA Annual Statistical Bulletins, 1995-2017.

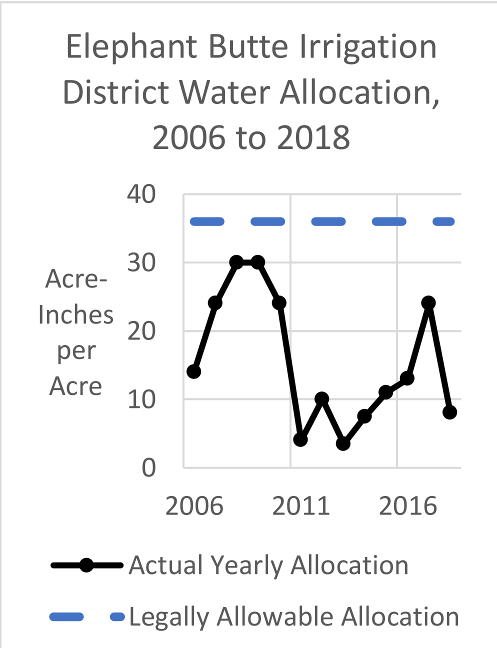

Figure 31: Data compiled from 2006-2013 Elephant Butte Irrigation District Meeting Minutes, articles in the Las Cruces Sun-News, and articles in the Albuquerque Journal.

is unmistakable. Competition with foreign imports from Mexico and elsewhere has had a strong impact on farmers' decisions on whether to plant chile.

Corn silage production, rising into the late 1990s, also mostly fell during the 21st century. Drought years in 2011, 2013, and 2015 left so little production that the numbers could not be reported due to privacy concerns. Corn silage, as another dairy feed, was also increasingly challenged by competition with Mexican imports. With corn's characteristics as a high water-user and its high production expenses in terms of genetically modified seed, fertilizers, and pesticides, its displacement by cheaper production from Mexico was unsurprising.

Cotton, too, lost ground in Doña Ana County during the 21st century. Despite its low water use. The combined challenges at the national level, of high costs of production, low price, declining demand, and the loss of the cotton subsidy have played a role in Doña Ana County just as they have at the state level.

Onions are a Doña Ana County crop that did relatively well in the early 21st century, with little change before the height of the drought. With their relatively low water use, certainly compared to pecans, irrigated onions did reasonably well during the early drought. With the height of the drought, however, their numbers disappear from the NMDAAB report on Doña Ana County, and do not return.

As the statewide numbers would suggest, pecans did well in Doña Ana County, steadily increasing. Several informants suggested that pecans represented a good hedge against the uncertainties involved in growing annual crops that were increasingly losing their competitive edge compared to Mexican imports. Although pecans take seven years to begin producing, farmers have been investing farm space in the nut crop. The result is a steadily increasing production (marked by pecans alternate-year heavy bearing).

Dairy cows grew in number in the beginning of the 21st century, but, like so many crops, declined during the height of the drought, as acquiring quality feed became more challenging. Overall cattle numbers declined during the worst of the drought years, although they have more recently begun to recover.

Broadly speaking, the drought and new competition with Mexico had substantial impacts on Doña Ana County, especially in 2011 and after. As snowpack has been particularly low in the past year, and water levels in the Rio Grande north of Elephant Butte Reservoir have drifted downward, and, in places, the river has dried up, the climatic future of Doña Ana County seems already to be arriving (Paskus 2018a). It remains to be seen whether water hungry pecans will continue to dominate the Mesilla Valley over the coming years.

Luna County

Luna County, too, has undergone substantial change over the past two decades. Their changes, too, have been partly shaped by water. The county's agriculture depends entirely on an underground aquifer, the Mimbres Basin. The Mimbres River, which dries up without reaching

Table 3. Farms and land in farms in Luna County.		
Year	**# of Farms**	**Land in Farms (Acres)**
1997	185	603,428
2002	243	709,518
2007	206	653,558
2012	190	550,174
Source: NMDA Annual Statistical Bulletins for 1997, 2002, 2007, and 2012 from five-year census of agriculture.1997 land in farms directly from census (not in NMDAAB).		

the county seat of Deming except in rare cases, provides only a little recharge to the Basin. Most recharge occurs in the upper basin adjoining the Gila Wilderness (Hawley et al. 2000). Over the past decade, farmers have increasingly installed subsurface drip irrigation to water their crops, an innovation that has made it possible to concentrate on a more limited selection of crops, particularly forage crops grown for area dairies (Jack Blandford, extension agent, personal communication, 2018).

The two crops that have stayed relatively constant in recent NMDAABs are chile and alfalfa (Fig. 32). In most of the NMDAABs from 2011 forward, they are the only two crops to appear associated with Luna County. However, there was a much broader array of crops in the recent past. Hay, including alfalfa, is one of the constants, although its measurement disappeared during the drought, even as alfalfa remained in the bulletin. The rise in hay, including alfalfa, over the past few years has been in part a reaction to the dairy presence in the region (Jack Blandford, personal communication, 2018), including dairies in neighboring Doña Ana County.

Most of the crops that were commonly grown in the late 1990s and early 2000s have disappeared from the NMDAAB. Corn grown for silage, for example, stopped appearing at the

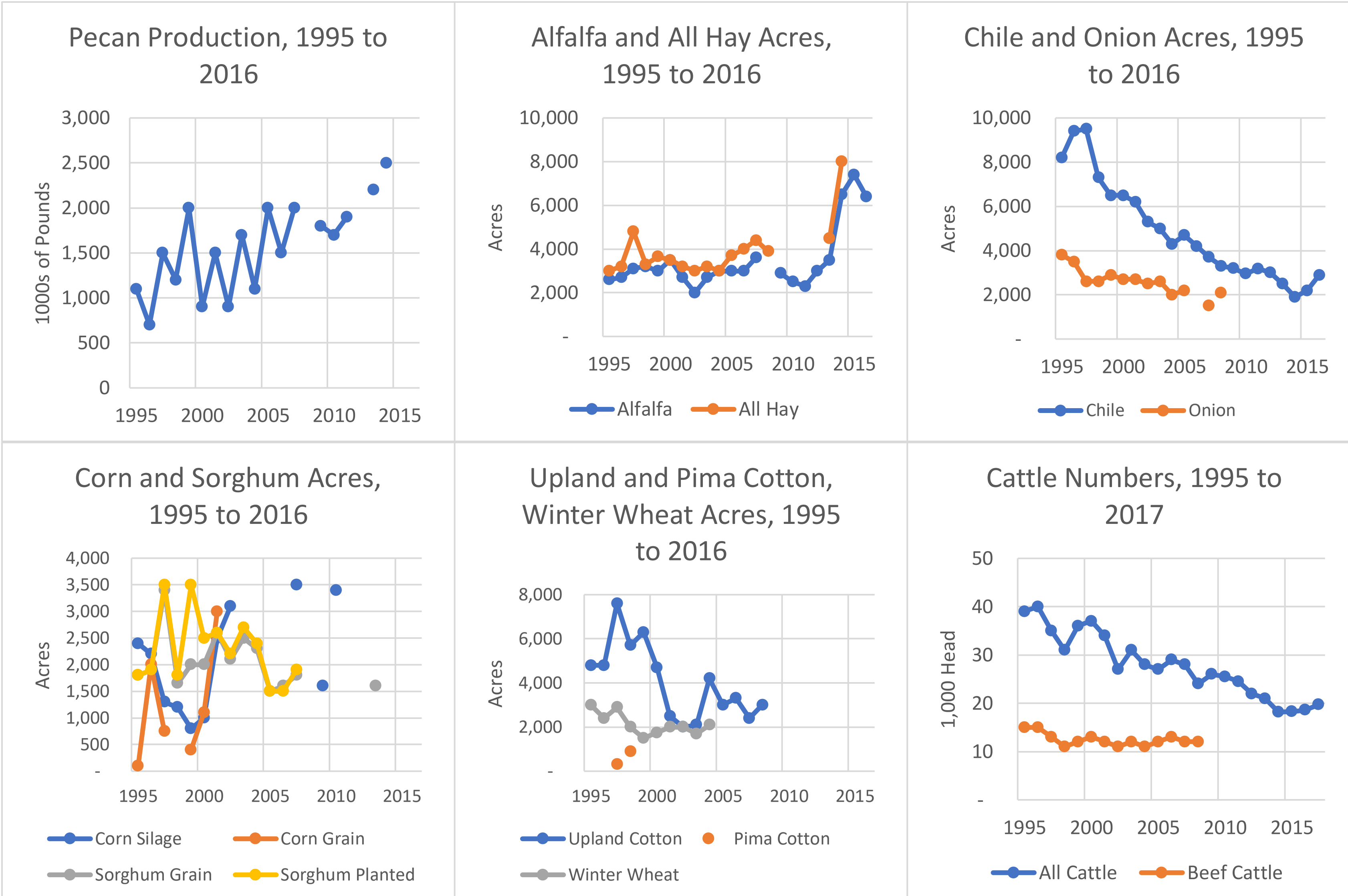

Figure 32: Luna County cropping and cattle changes. Data from NMDA Annual Statistical Bulletins, 1995 to 2016. Note that acreage data are not available for pecans, and production data is provided in its place.

height of the drought in 2011. Corn for grain last appeared in 2001. Sorghum for grain was last listed in 2013, but had previously not been listed since 2007, before which it always appeared. Upland cotton appeared every year through 2008, then abruptly disappeared. As in Doña Ana County, however, pecan production[23] has steadily risen.

Perhaps the most notable element of Luna County as it is presented in the NMDAAB is that much of the relevant growing appears to be underreported, especially since about 2007. Total cash receipts for 2016, for example, are listed at $112,914,000, but the crops and livestock for which cash receipts are included add up to only $15,597,000. Other forms of production not listed in the bulletin are evidently making up the difference. Forage crops like wheat hay and sudan hay make up a large part of what is missing from the statistics (Jack Blandford, personal communication, 2018). Given the small number of farms in the county (190 at the 2012 Census of Agriculture), the difficulty of adequate surveying is unsurprising. One of my informants noted that he thought there were only about 15 farm families now in the Deming area—the county seat. When the number of full-time, large scale farmers becomes that small, there may often be too few farmers to provide adequate survey results. As several of my informants noted, farmers are surveyed often, and many experience survey fatigue and refused most survey requests.

Since only two of my informants come from Luna County, the background provided by the NMDAAB provides enough to sketch a picture of the agricultural situation in which they are working. They were selected partly because of their associations with Las Cruces (one is a seller at the Las Cruces Farmers and Craft Market, the other an attendee at the Chile Conference in Las

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[23] Pecan acreage is only counted at the once-in-five-years census, and in one of the four censuses in this period, was not included for privacy reasons.

Cruces), so it is as much their role in the larger south-central New Mexico agricultural setting as in Luna County itself that is important for making sense of their work.

Roosevelt County

Roosevelt, along with its northern neighbor, Curry, has long been one of the most important agricultural counties in the state. Every year from 1995 to 2016, the county came in fourth in total agricultural cash receipts for the year. Curry has lately come first, and Doña Ana and Chaves are the other two competing for the top spot.

Table 4. Farms and land in farms in Roosevelt County		
Year	**# of Farms**	**Land in Farms (Acres)**
1997	913	1,419,250
2002	804	1,500,821
2007	876	1,494,051
2012	680	1,349,222
Source: NMDA Annual Statistical Bulletins for 1997, 2002, 2007, and 2012 from five-year census of agriculture.1997 land in farms directly from census (not in NMDAAB).		

With its very different cultural history from the Hispanic and Mormon influenced Doña Ana and Luna Counties, Roosevelt also has a very different agricultural history. Its location on the High Plains sets it in a different zone for weather, growing season, and ecology from the southern counties that make up part of the Chihuahuan Desert.

Roosevelt County has also experienced substantial change over the past two decades and more. Once again, of the important influences on change is water. Since it sits over the far southwestern edge of the Ogallala Aquifer, an edge that is rapidly drying up, Roosevelt County irrigated agriculture has been shifting from its 20th century shape. One way in which this shift was most apparent was in changes in alfalfa acreage during the worst drought years. Although demand for alfalfa was being driven up by the growing dairy industry, the always-irrigated crop disappeared from the surveys in multiple years during the drought.

Between just-adequate wells and severity of the drought, alfalfa often fared poorly (Fig. 33). Hay as a whole also experienced similar disappearances from the record.

Corn displayed a similarly drought-sensitive trend, but also one influenced by the increasing presence of dairies. The emphasis for corn moved from harvesting it for grain to harvesting it for silage. Corn can be harvested for silage when it is not experiencing adequate conditions to bring it to grain stage, but farmers in dairy areas also choose to produce silage as a preferred product of dairies. Note that in the years around the height of the drought, corn silage temporarily disappears from the record, and corn grain disappears and has not yet returned.

Sorghum displays a similar pattern to corn, with declining grain production, but continuing production overall, including some for forage, according to several of my informants. Note that the measurement of sorghum changed a little in 2008. In 2007 and before, the listing for sorghum harvested was "harvested for grain." In 2008 and after, it was "harvested." Therefore, some forage sorghum may be included in the numbers for sorghum harvest after 2007. No sorghum acreage was reported planted after 2007, and there was a gap in reporting of harvest.

Roosevelt County abuts cotton counties across the border in Texas. Like the counties around Lubbock, Roosevelt County has grown cotton, although never to the degree of landcover seen on the other side of the state line. However, drought affected cotton, too. There are several breaks in the cotton record in the first decade of the 21st century, and cotton no longer appears in the record after 2010. During my fieldwork, several informants said they did not know of anyone growing cotton in the county, although in 2015 one informant knew of a cotton field along a road

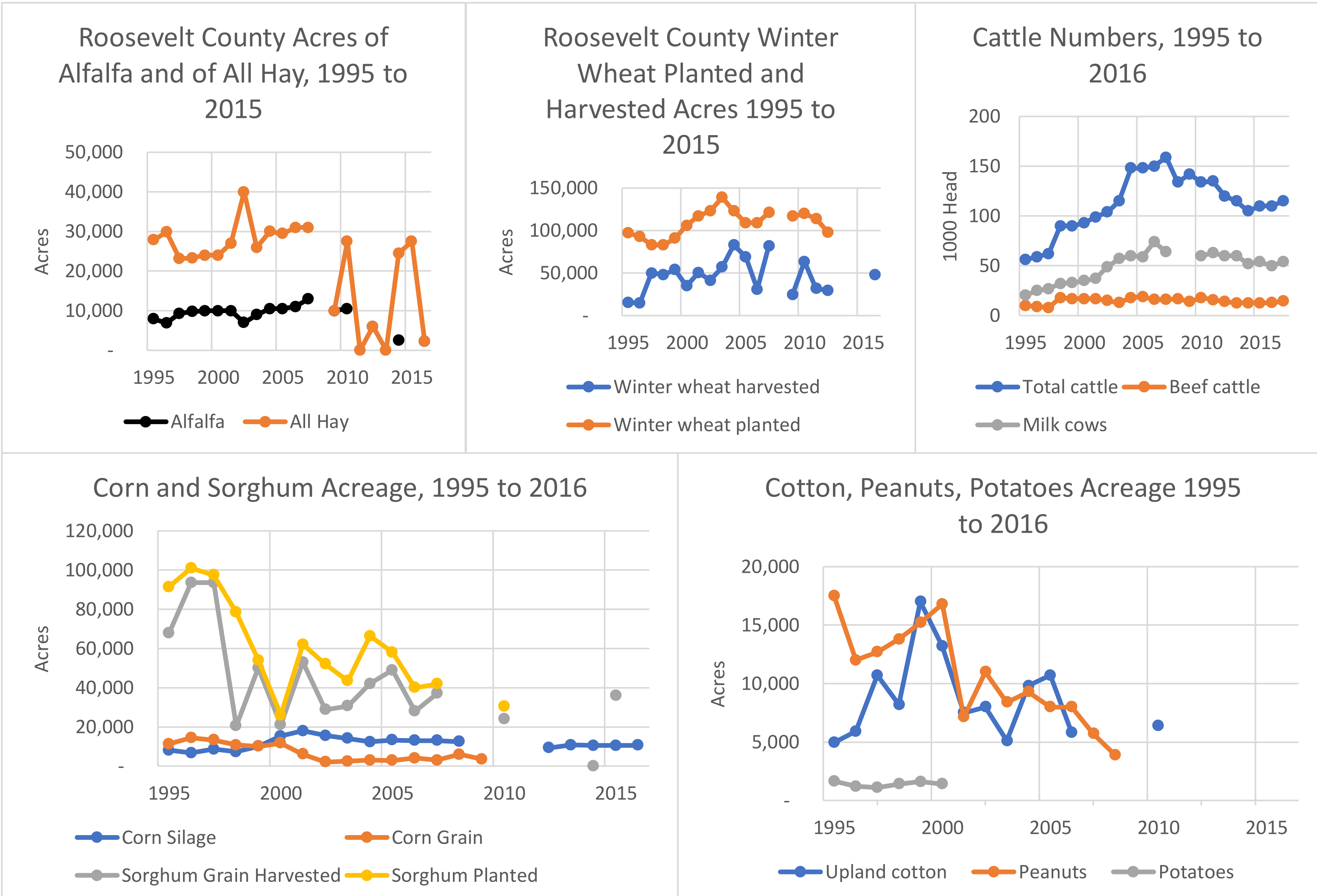

Figure 33: Roosevelt County cropping and cattle changes. Data from NMDA Annual Statistical Bulletins, 1995 to 2016. Note that "sorghum harvested" numbers for 2007 and before were listed as "harvested for grain."

south from Portales. He said it was the first cotton he had noted in several years. The cotton pattern in Roosevelt County, then, mimics that seen through much of the country.

Winter wheat in eastern New Mexico follows a pattern that is striking to a Montanan used to all wheat being harvested as grain. Some farmers in Roosevelt and Curry Counties grow wheat for cattle to forage on during the winter. If grain prices look good, some of them take the cattle off early to let the wheat get a healthy head of grain. If prices don't meet a desired threshold, then the whole value of the wheat is gained through adding weight to cattle that are then resold for a more substantial profit than the grain can often provide. This pattern is part of what is perceptible in the winter wheat numbers for Roosevelt County. One can also see that wheat reporting fell off in the years around the height of the drought.

Finally, among crops, the peanut was the icon of Roosevelt County for a number of years. Although little known in other parts of the state, the peanut grew well in the light, sandy soils present in much of Roosevelt County. As described above, however, declining water availability along with the shuttering of the main buyer of peanuts both contributed to peanut decline and finally its near-disappearance from Roosevelt County.

As with the other counties, the multiple stories of declining crops lead one to question what has replaced them. In Roosevelt County, as elsewhere, there are multiple answers. One change has been the increasing presence of dairies and dairy cattle. Increasing water and other county resources are used to support the dairies. Another lies in continued use of the Conservation Reserve Program (CRP). Roosevelt has the second largest acreage in CRP in New Mexico, second only to Curry County, at 133,533 acres in 2014 (EWG 2015). CRP enrollment has not changed a great deal since about 1990, however, so the explanation also lies in the declining number of farms and land in farms during the 21st century.

Curry County

Curry County, Roosevelt County's northern neighbor is home to a significantly larger county seat (38,000 people rather than 12,000) and plays a larger role in New Mexico's agriculture. Between 2008 and 2016, Curry County had the highest cash receipts in the state for six different years. Nonetheless, Curry has been subject to the same challenges as has Roosevelt County. Although my informants reported fewer urgent irrigation shortages[24] in Curry County than in Roosevelt, the county is similarly challenged by the declining Ogallala Aquifer (Rawling and Timmons 2017).

Table 5. Farms and land in farms in Curry County.		
Year	**# of Farms**	**Land in Farms (Acres)**
1997	808	947,748
2002	677	916,320
2007	681	887,491
2012	600	880,822
Source: NMDA Annual Statistical Bulletins for 1997, 2002, 2007, and 2012 from five-year census of agriculture.1997 land in farms directly from census (not in NMDAAB).		

In addition, the landscape is much the same as Roosevelt County in terms of ecology and weather, so the deepest years of the drought have also hit Curry County hard. However, Curry County began the period from 1995 to 2016 with the highest production levels in the state for wheat, sorghum, and grain corn (Fig. 34). For wheat and sorghum the county was producing more than twice what the second-ranked county was growing. So, Curry County was a dryland grain powerhouse relative to other New Mexico Counties (NMDA 1995). That

[24] My Curry County informants using irrigation were mostly in a band just west of Clovis that is not yet experiencing urgent shortages (Rawling and Timmons 2017).

high production is important to keep in mind in making sense of how much some of the county's production has declined.

Sorghum for grain, for example, was grown on far fewer acres as of 2010 than in 1995. County-level production of sorghum grain has not appeared on the NMDAAB since 2010. The decline came despite price increases, including a near-doubling of price in 2006 and another steep jump in prices (increasing by a third) in 2010. When numbers were still tracked for irrigated and non-irrigated production, through 2008, a third to half of sorghum was irrigated. The decline in sorghum production is likely due to a combination of factors, including replacement of sorghum acreage with CRP land (Rakshit et al. 2014), the challenge of reaching grain stage (i.e. physiological maturity) in dry years, and the general decline in farm acreage.

Wheat has experienced less decline than sorghum. As in Roosevelt County, the pattern in which much of planted wheat is used for direct grazing rather than for grain production is apparent from the numbers. The fact that much of the county's wheat in any given year ends up as wheatgrass in cattle bellies rather than as grain goes some way toward explaining its persistence. Cash receipts for livestock far outpace cash receipts from any other form of agriculture in the county in every year, and that has become increasingly true over time. In 1995, for example, livestock accounted for $98,551,000 of Curry County's receipts, while crops accounted for $38,755,000. By 2016, the difference had grown. Cash receipts for livestock amounted to $446,681,000, and for crops only $59,029,000. Clearly, farmers have found more value in livestock than in crops as the period progressed. Thus, wheat often represents a way to fatten and resell cattle for a profit. It is worth noting that wheat grain acres disappear from the counts in 2013, toward the close of the worst of the drought. So, drought was likely an influence to move out of grain production, despite raised prices.

Drought also had an influence on hay, especially irrigation-dependent, drought-sensitive alfalfa. Before the height of the drought, alfalfa production was increasing, partly to feed the area's growing dairies. For multiple years around the height of the drought, no alfalfa numbers were reported. Production dropped off steeply during the worst drought years for hay as a whole, and alfalfa production has not recovered. Some farmers reported harvesting ordinarily worthless CRP grass (as permitted by the USDA in the worst drought years) because of the high price it was receiving, since little other hay was available.

The pattern for corn highlights a move toward increasing production for dairies. Between 1995 and 2016, the production of corn grain diminishes and, during the drought, disappears from the reporting. At the same time, silage production slowly increases. Not only does silage represent an often-desired product for dairies, but it can be produced even when conditions are too droughty for corn grain.

Cotton follows a statewide (and nationwide) pattern of decline exacerbated by drought. Cotton acreage was not reported for Curry County starting in 2011 and has not yet returned to the NMDAAB reports.

Finally, two common horticultural crops in the county before the 21st century were peanuts and potatoes. The two rapidly declined in the Curry County reports of the NMDAAB from 1995 to 2005, and then disappeared altogether. As in Roosevelt County, peanut decline can be linked to drier conditions and, later on, the loss of the Roosevelt County processor. I did not encounter

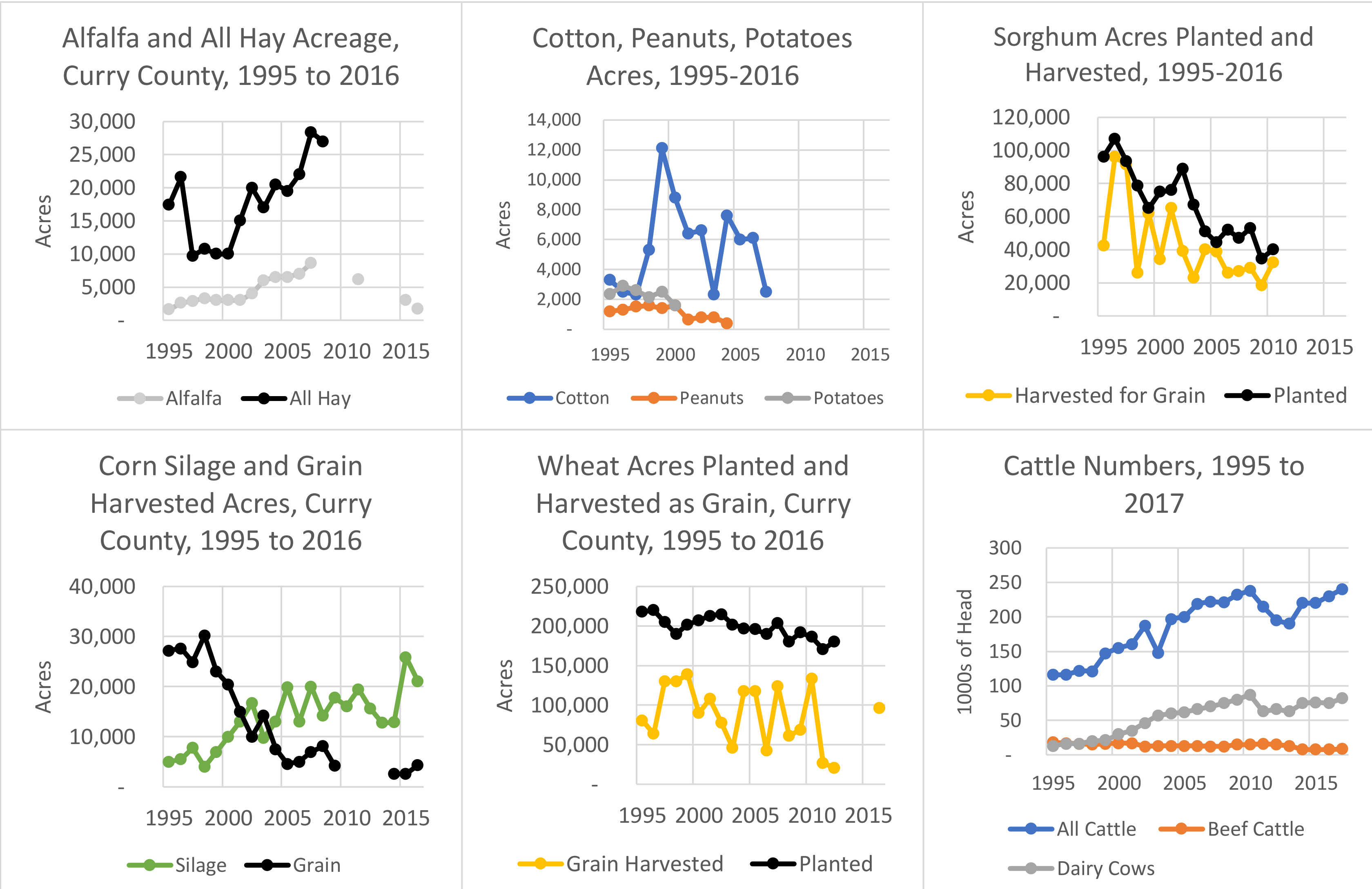

Figure 34: Curry County cropping and cattle change. Data from NMDA Annual Statistical Bulletins, 1995 to 2017.

anyone growing potatoes, but one grower previously grew potatoes. His reasoning for leaving them behind was their greater water requirements.

Farmer Observations Leading to Change

Overview of Farmers in the Study

Farmers in the study represented a highly varied group (see table below), so I have categorized them by location and by farm size/style. For the purposes of overview and to protect farmer confidentiality, I place them into a southern group, made up of farmers from Luna and Doña Ana Counties, and an eastern group, made up of farmers from Roosevelt and Curry Counties. Large-scale growers include all growers who farm acreage on the scale of 100s of acres rather than 1s or 10s. Small-scale growers nearly all grow on less than 10 acres, with one exception who farms with a business partner who shares the acreage, and the acreage is closer to 30. The crop selection is widely varied between farmers, even when comparing within groups. However, some of the common main crops include those reviewed for the state and for the counties, above. For Doña Ana and Luna County large-scale growers, for example, common crops include alfalfa, chile, cotton, pecan, and wheat. Lettuce and cabbage are somewhat less common presently than in the recent, pre-drought past. For Roosevelt and Curry County large-scale growers, common crops include alfalfa, haygrazer (i.e. sorghum-sudangrass hybrids), sorghum, and wheat. Smaller, direct-to-market growers typically grow a range of vegetable crops from asparagus to watermelon, and some grow fruit (e.g. jujube). However, none of these mixes of "common" crops fully represents any one grower in the study.

Table 6. Crops grown by farmers in the study				
	Southern New Mexico		**Eastern New Mexico**	
	# of farmers	Crops grown	# of farmers	Crops grown
Large-scale growers	8	Alfalfa, barley, cabbage, carrot, chile, corn, cotton, lettuce, onion, pecan, squash, wheat (durum)	11	Alfalfa, black-eyed peas, chile, corn, grape, haygrazer, pumpkin, sorghum, watermelon, wheat (winter)
Small-scale (direct-marketing) growers	5	Horticultural crops including: asparagus, beet, broccoli, cabbage, carrot, chile, collards, cowpea, cucumber, garlic, herbs (various) greens (various), Jerusalem artichoke, jujube, lettuce, onion, pea, radish (various), squash, tomatillo, tomato, watermelon	2	Horticultural crops including: beet, cantaloupe, carrot, chard, chile, corn, cucumber eggplant, green bean, kale, lettuce, okra, onion, pea, potato, pumpkin, squash, tomato, turnip, watermelon
Note: Farmers are divided into two broad categories: southern (Doña Ana and Luna Counties) and Eastern (Roosevelt and Curry Counties), and large- vs. small-scale grower. Large-scale growers usually grow some commodities, and some sell fresh-market produce as well, but the majority of the production for these growers is sold indirectly, as through commodities markets or produce brokers. Small-scale growers farm smaller land areas (in the range of 10 acres or fewer for most) and sell most of their produce directly to consumers. Farmers are counted by farm, rather than individual, when including the extra four interview participants. The grouping of both crops and regions is intended to contribute to protecting farmer confidentiality.				

Cropping Decisions and the Three Spheres of Transformation

This final section of the chapter is intended to offer a glimpse of farmer decision-making from the perspective offered at the beginning of the chapter. In other words, the chapter has so far examined change from the state- and county-levels. This section offers a first look at change at the farm level. In the three spheres construct (O'Brien and Sygna 2013), practical, political, and personal sphere concerns all affect decisions made on the farm. Many farm decisions are made in the practical sphere, in which the farmer observed the farm system and makes adjustments to it. The concern raised by O'Brien & Sygna (2013) is that when it comes to altering systems to better prepare for climate change, interventions in the practical sphere are often too small—incremental and inadequate for the challenge at hand. Yet, for many farmers, the practical sphere is one of the most important ways in which they understand their systems. The political sphere, however, matters at least as much when it comes to making decisions about crops to grow.

One crop that has become increasingly significant in New Mexico over recent years is pecans. Pecans are heavy water users, preferring 6-acre-feet of water on each acre, whereas most other common crops in the area use much less. At the same time as pecans have become increasingly popular, the state has experienced ongoing drought. So, what is driving the move toward pecans? Profitability. As Jeffrey[25] puts it, "It's, you know, on a ten-year average, once they come into production, how they should net more than any crop in New Mexico." So, the political sphere, in the form of markets, is what is driving farmers to choose to plant pecans. It is not, however, the market for pecans alone that has driven the change. Jeffrey's comment came in the context of broader change affecting his farm, and he identified several other influences leading him toward pecans. He says:

> The main thing that's—labor has went up. Then, it's like everything has went up at a lot faster rate than the market process. . .. Like the first tractor we bought, our big tractor was about $40,000. And right now, you pay over $200,000 for that same tractor. . .. Technology is good, but I don't know if we can afford it if the markets, you know, don't sustain it. But we've changed crops to allow that. We really watch the markets, and we invested in trees many years ago. And that's really what's saved us.

So, for Jeffrey, the choice to move toward a crop that is very poorly adapted to an increasingly limited water future, was shaped by a diversity of political sphere influences. According to several of my informants, the addition to tractors of bells and whistles like real-time kinematic

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[25] All names are pseudonyms.

(RTK) positioning systems[26] has contributed to a steep rise in tractor prices. At the same time, labor prices have risen, and markets for sales of crops have not kept up with the rise in either input. Thus, a number of market forces have encouraged Jeffrey to undertake a maladaptive transformation (i.e. not a deliberate transformation in the sense of one desired for adaptation to climate change) to a water-hungry perennial. The same forces have contributed to a decline in acreage for some of Jeffrey's other crops, particularly alfalfa.

Aside from pecans, the other segment of the agricultural landscape undergoing a steep rise in New Mexico over the past two decades has been dairies. Since my focus was on cropping systems change, I did not talk to dairy owners, but I did talk to several growers who have sold to dairies. Jeffrey is one, as he grows alfalfa. Another is Robert. Robert explains why his feed production has also declined:

> R: Yeah, [we grow] corn silage. So, I mean, last year we grew like 150 acres. A year before that, we grew like 250. But the dairies started buying less corn silage.
> Interviewer: Why?
> R: They're starting to buy a lot of feed from Mexico. . .. So, they buy really cheap alfalfa and all that. So, yeah, we—I don't think we're going to grow it this year at all because they're not—the dairies aren't going to buy any.

Instead, Robert suggests that they will likely grow more acres of cotton and pumpkins. Again, the political sphere in the form of market shifts affects the cropping decisions farmers are making. Despite a rise in a market that would appear to support the production of feed crops (dairies), competition with Mexico's lower-wage labor and less expensive production is encouraging farmers to leave feed crops behind. In the case of alfalfa, this might be considered a

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[26] RTK allows for centimeter-level positioning information by correcting GPS satellite data using a base-station on Earth. The technology also allows for permanent paths to be stored and reused so that farmers can cover the same set of rows in the tractor in every pass, e.g. for seeding, cultivating, and harvesting.

climate-adaptive change, because it, like pecans, likes as much as 5-6 acre-feet of water. However, other feed crops grown in the state, like milo (sorghum) have also generally declined, and some are far more conservative water-users than alfalfa or pecans.

The story of decline in the state's crops is fairly similar across different crops. Christopher, for example, says that he has cut down his acreage of wheat because, "the market just didn't, wasn't there." Several growers cite competition with Mexico[27] driving down the prices of chile and encouraging them to decrease or leave off their production of chile. However, statewide trends are not universal, and the reasons for growing crops are not as strictly market-based as these narratives have so far suggested. For example, Camila mentions that:

> Right now cotton is, for this year, cotton's our crop that we are growing the most of. Just because it, you know, cost effectiveness. And like I said, we've got this new farm we're trying to clean up[28]. And the water issues.

So, the market certainly matters for cotton. With its increased productivity compared to the past (so Jeffrey says), it can earn enough income to make up for its inputs. But the genetic characteristics of cotton, its herbicide resistance, is also coming into play in the decision to grow it. It is being used to prepare the fields for other crops. In addition, as the drought was hitting the county hard that year, using less water became a sufficient consideration to influence crop choice. In the case of herbicide resistance, it is the practical sphere of technical responses that is shaping decisions. Decision-making in the practical sphere is also a useful way to think of how the of lack of water affected this cropping decision.

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[27] In reality, it is competing with several chile producing nations in both Latin America and Asia, but farmers tended to mention mostly Mexico.

[28] Genetically modified (GM), RoundUp-Ready cotton allows for herbicide spraying that can decrease the total weed population in a field and help to cut down the future weed seed bank.

The political sphere of transformation does play an important role in shaping the cropping decisions of conventional farmers, but decisions often have a variety of influences. Although it does not involve a major crop in New Mexico, the case of Christopher is helpful for a last example in considering how crop selection is undertaken. In the midst of the worst of the drought years, Christopher got a call from a grass seed company. They needed someone to grow forage grass seed, and they were going to pay well. Christopher agreed, and for two years, he grew seed. Christopher watched how the crop progressed on his farm. In the first year, he made good money growing it, and so decided to try again. From the beginning, though, he noticed that the harvest process was throwing wrenches into his operating practices:

> It's a nightmare to harvest it. . . . It just goes through a machine like rocks. I mean, you combine it when it's high-moisture. It doesn't go through the machine very good at all. It tears things up. It's slow, tedious. I'm not afraid of work. I actually work every day, but being that we're so spread out [in terms of farmland locations], you know, 10 miles that way and thirty miles that-a-way, I really have to have things where I have a guy that I can get him started and leave. And not to say that I always leave, but when I have something like the grass seed turned into, that I have to be there 10 hours a day myself, it lets other parts of the operation go south.

In the second year, hit hard by weather conditions at harvest, the crop did not produce as well, and so did not offer quite the gold mine that the first crop did. So, Christopher decided to abandon forage grass seed as a crop. Christopher's considerations included farm income (he noted that the lower returns of the second year did not fit his "business plan"), his time, the wear on his machines, and the ability of his workers. All of those considerations were important in his decision about whether to continue to produce the crop.

Conclusions

Crop selection can involve complex decision-making practices, like Camila's and certainly Christopher's. However, the majority of decisions appear to be reflecting a reaction to one major set of considerations: market prices and how they compare to the cost of inputs. As I will discuss in later chapters, drought is providing some of the impetus for the declines in crop production seen in New Mexico, but markets for agricultural commodities are playing a leading role. Since the two agricultural industries that are growing—pecans and dairies—are intensive water users, it would seem that most of the changes in crop production are counter to successful adaptation to a future predicted to include increased drought. None of the influences the farmers described seemed to suggest that their decisions were being influenced by personal sphere transformation (changes in values, beliefs). Moreover, most of the political sphere influences named above were market-based alone. So far, then, the farmer decisions outlined seem to suggest that (political sphere) market forces and practical-sphere influences are encouraging incremental and sometimes maladaptive change. How could agricultural decision-making look different? How might making room for change in the personal sphere change the shape of decision-making? Those are the questions to which this dissertation is seeking answers. In the next chapter, I will move a little closer to answering these questions by considering what the goals of a transformed agriculture might be.

Chapter 4. Goals of Transformation in Agriculture

Introduction

Agriculture is currently both a major contributor to climate change through its greenhouse gas emissions (Smith et al. 2014), and a sector very vulnerable to climate change impacts (J.R. Porter et al. 2014). Given the risks that Earth system feedbacks could cause extreme warming well above 2ºC if we approach that temperature threshold (Steffen et al. 2018), the mitigation opportunities for agriculture are important to consider. Adaptation is equally important: negative impacts of climate change on food production have already been evident in much of the world outside of the high latitudes (J.R. Porter et al. 2014).

Given the importance of both goals, then, how can agriculture best approach them? One approach to research on agricultural adaptation defines three levels of adaptation: 1) incremental, 2) systemic, and 3) transformational (Park et al. 2012; Rickards and Howden 2012). Incremental change is constituted of "technological fixes, intensification of farming, improvements to crop varieties and breeds of livestock, or water and soil management practices" (Dowd et al. 2014, p. 558). Such approaches may be ineffective and even maladaptive in the longer term (ibid.). Further, incremental approaches "maintain the essence an integrity of an incumbent system or process at a given scale" (Park et al. 2012, p. 5). Consequently, we can expect incremental adaptation to further the current systems that depend on fossil fuels for petrochemically-based fertilizers and pesticides as well as for fueling tractors and transport.

Systems adaptation has so far been minimally defined and studied, but Rickards and Howden (2012) offer examples such as climate-change ready crops, climate-sensitive precision agriculture, and diversification and risk management (based on (Howden, Crimp, and Nelson

2009)). The first two examples have little potential for greenhouse gas mitigation. Precision agriculture has so far been heavily reliant on high technology use, including use of highly technologically sophisticated tractors that continue to rely on fossil fuels. At best, precision agriculture is likely to produce only marginal change in use of fossil fuels (Schimmelpfennig and Ebel 2011). Moreover, farmers have been less likely than anticipated to adopt the expensive systems (Schimmelpfennig and Ebel 2011). Climate change-ready crops, by themselves, are unlikely to substantially change the inputs of fuels and fertilizers used to produce them. In addition, they have so far shown only limited improvement when grown on-farm (Varshney et al. 2018). Diversification and risk management appear to offer potentials for greenhouse gas mitigation, but as so far written about in regard to systems change, are perhaps too ill-defined to offer clarity on the question of mitigation. Systems adaptation overall may well offer some potential for greenhouse gas mitigation, but it is so far unclear exactly whether and how that might be the case.

More has been written on transformational adaptation and its potential in agriculture. In considering what "'good adaptation'" might look like, Rickards and Howden (2012) note that scholars increasingly argue that it should include criteria like "equity (distributional justice, including future generations); social legitimacy (procedural justice); and sustainability (including interspecies justice" (p. 246). In this conception, then, transformational adaptation of agriculture goes beyond creating effective responses to climate stressors alone, and addresses, "the long-standing ecological, social and economic vulnerabilities that climate change exposes, such as soil degradation, biodiversity losses, dependence on declining oil reserves, low financial equity, and an aging farmer population" (Rickards and Howden 2012, p. 241). Major changes in goals or in processes of production, including moving the location of production, constitute transformational adaptation (Kates, Travis, and Wilbanks 2012; Rickards and Howden 2012). For example, wine and peanuts producers in Australia have shifted their production to new locations in response to climate changes in their traditional growing regions, and other Australian producers have begun to adopt biodiesel as a means of diversifying production (Dowd et al. 2014). Yet, although these adaptations have been defined as transformational, and are indeed providing helpful outcomes for the farmers in question, they do not necessarily meet the other half of the puzzle—transforming agriculture to produce greenhouse gas mitigation.

Nonetheless, a major change in agricultural goals *could* more explicitly encompass strategies that include targeting decreased greenhouse gas emissions. Indeed, in framing deliberate transformation, O′Brien (2012), notes that the concept includes an intentional effort to avoid dangerous future climate change, not simply to make systems that will deal with such change. Multiple conceptions of transformational adaptation persist in regard to agriculture (Panda 2018), but I contend that O′Brien's (2012) concept of deliberate transformation, allied with Pelling's (2011) of adaptation as transformation are key touchpoints for agricultural transformation[29]. Both emphasize the importance of transformation for addressing vulnerabilities created by wider social processes, including as they interact with and are revealed by weather stressors (Pelling 2011; O′Brien 2012; O′Brien and Sygna 2013). And addressing those social and economic vulnerabilities must necessarily include forms of adaptation that work to minimize

[29] As Rickard and Howden’s (2012) formulation would suggest.

future greenhouse gas emissions, as the most socially and economically vulnerable are also those most affected by climate change, largely as a result of those very vulnerabilities.

To understand how deliberate transformation occur, O'Brien and Sygna (2013) offer a model that they term the three spheres of transformation. The three spheres approach provides a means to conceptualize the multiple means through which change must happen in order to produce deliberate transformation. The three spheres of transformation are nested within one another, with the practical sphere innermost, then the political sphere, then the personal (O'Brien and Sygna 2013). The practical sphere includes, "'technical' responses to climate change. . . including changes in management practices, the introduction of new technologies, and socio-technical and cultural innovations. It also includes changes in strategies, practices and behaviors" (ibid. p. 5). Surrounding the practical sphere is the political. In the political sphere are the "economic, political, legal, social and cultural systems" that shape and delimit the possibilities available in the practical sphere (ibid. p. 6). Finally, outermost is the personal sphere, of "beliefs, values and worldviews" (ibid. p. 6). The placement of the spheres is intentional, with changes in outer spheres having greater power to effect transformation than inner spheres (O'Brien and Sygna 2013; O'Brien 2018). In the case of agriculture, for example, a farmer working 20 acres might decide to work with animal traction rather than fossil fuel-

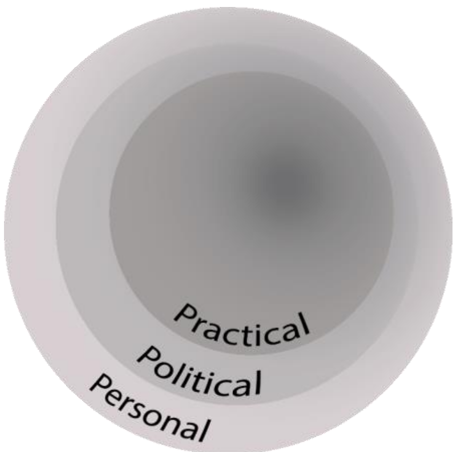

Figure 35: Representation of the three spheres of transformation. Based on O'Brien and Sygna (2013). The personal sphere corresponds to goals, values, beliefs, and worldviews; the political to systems and institutions; and the practical to "technical and behavioral interventions" (p. 155).

powered tractors, a practical sphere transformation. Such a decision might be enabled by a political sphere context in which a carbon tax is implemented, making a tractor more expensive to run. However, even more important than the political sphere context is the personal sphere. A farmer whose worldview encompasses the beliefs that integrating livestock into the landscape helps with nutrient cycling, that farmers have a responsibility to minimize their greenhouse gas emissions[30], or that farming in collaboration with animals is more enjoyable than working with machines, will be far more likely to adopt the system than another farmer working within the same political constraints. Transformations in the personal sphere, although sometimes difficult to effect, can have “more powerful consequences” than transformations in the other spheres (O’Brien and Sygna 2013, 6).

Change in all three spheres must occur to produce a transformed agricultural system. This returns the discussion to the original question. How can agriculture best approach a transformation that offers the potential for both mitigation of greenhouse gas emissions and adaptation to expected changes to the system? Pelling (2011) and O’Brien and Sygna (2013) suggest that those most affected by change must be among the decision-makers shaping what change will look like if we wish deliberate transformation to succeed. As such, any suggestions for particular goals for agriculture are necessarily contingent and malleable. Yet it is important that those of us who research and consider climate change adaptation closely offer ideas, because

[30] But the details of this particular example are certainly debatable. Should there be any plowing at all if the farmer wants to reduce greenhouse gas emissions? Is no-till with a tractor actually a better option? Are there perennial or polycultural systems appropriate for this landscape that might not require any sort of mechanical plowing or cultivation?

farmers often have far less time to consider questions beyond the practical and immediate realities of their own farm systems.

Consequently, this paper offers a vision of a transformed agriculture. The vision is laid out in the form of four interrelated goals that owe a debt to many who have thought about agricultural sustainability (Altieri 1995; Kroma 2006; Pretty 2008; Lin 2011). After the goals, I offer discussion of the potential for synergies and tradeoffs between them, followed by a discussion of how change in all three spheres is necessary to achieve them. Finally, I lay out the past scholarship on barriers to transformative change in agriculture, including economic and regulatory barriers. This discussion suggests some of the particular barriers to be addressed if the goals of a transformed agriculture are to be achieved.

What would be the goals of a transformed agriculture?

Pelling (2011) notes that “the root causes of vulnerability are made most visible when latent vulnerability is realized by disaster” (p. 87). Such vulnerabilities include those created by those with more wealth and power at the expense of those with less (ibid.). In the case of agriculture, vulnerabilities are often exposed by weather crises. Drought, for example, imposes its greatest negative effects on those farmers with the fewest economic resources to adjust by acquiring water from alternate sources (e.g. new wells) or taking time to seek more drought-resistant crops that may require new suppliers and buyers. The economic insecurities of smaller farmers may be exacerbated by government policies requiring expensive new oversight and paperwork (see Chapter 5). Farmers with fewer resources may fall into bankruptcy and even leave farming. Deliberate transformation that would successfully create new modes of living that not only prepare society for climate change impacts, but also involve a move toward greater global justice to address these complex vulnerabilities, would involve collaborative creation by many voices, including those most vulnerable to change (O′Brien & Selboe, 2015). This collective creation of alternatives constitutes an emergent phenomenon (Slaughter 2011) in which outcomes may not be entirely clear in advance and may therefore require embracing "the humility of Not Knowing" where change will lead (Meadows 2009).

Nonetheless, even when embracing the potential for emergent change, goals represent, at the least, a starting point for discussion. In the case of an agriculture that meets long-term ecological and human needs, a number of goals can be identified. First, with climate change in mind, one overarching goal is to limit global average temperatures to 1.5°C of warming, taking the Paris agreement seriously (O′Brien, 2018). With climate mitigation goals in mind, then, and without losing sight of the underlying social and economic vulnerability orientation of deliberate transformation (O′Brien, 2012), I suggest goals for a transformed agriculture of the Global North.[31] The following are the transformative goals I propose:

1. **Increase organismal diversity in farming systems.** I use "organismal" rather than species or genotype diversity here because there are multiple levels at which diversity can affect agricultural systems. From a range of studies, Lin (2011) summarizes the ways in which diversity can be important in crop systems. For example, genetic diversity within a

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[31] *Note that since coming up with this set of goals, I have encountered four similar "principles for sustainability" (Pretty 2008). Pretty (2008) focuses on processes rather than organisms for a first goal, and on all non-renewable inputs for his second. The ends reflected in our two sets of goals can be construed as broadly similar (i.e. creating more closely integrated, on-farm systems with fewer inputs transported from off-farm), despite slightly different means. His social goals are different, but still reflect a similar orientation toward making effective use of the humans who play a part in farming systems. The difference in Pretty's (2008) social approach as compared to mine is in a less overt focus on social justice and care.*

given crop or crop variety or animal breed can help mitigate against pest and disease problems. The Irish potato famine (Brown 1993) and 1970s episode of Southern Corn Leaf Blight (Ullstrup 1972) both represent cautionary tales of the potential dangers of limited within-crop genetic diversity. Mixing varieties can suppress disease and make production more stable (Zhu et al. 2000; Di Falco and Perrings 2003; Lin 2011). Structural diversity of plants and presence of non-crop plants in field margins can suppress pests (Lin 2011). Further, greater forms of diversity like polycultures (two or more species within a field), agroforestry, and mixed landscapes each have multiple positive effects such as disease suppression, climate change buffering, and increased production (Marino and Landis 1996; Perfecto et al. 2004; Tengö and Belfrage 2004; Boody et al. 2005; Tilman, Reich, and Knops 2006; Armbrecht and Gallego 2007; Lin 2007, 2011; Dalin, Kindvall, and Björkman 2009). Diversity of species within a system determines an ecosystem's "productivity, stability… and nutrient dynamics" (Tilman 2016). Increasing the functional diversity of the plants in an agroecosystem can increase the ecosystem services that a given system can provide (Finney and Kaye 2017). Moreover, a focus on increasing soil biodiversity, as through systems that maintain cover (e.g. no-till systems, cover cropping systems), can improve soil function and health as measured across multiple indicators (Mitchell et al. 2017). Systems that maintain cover and increase plant diversity can also, with careful management, sequester soil carbon, mitigating greenhouse gas emissions (Cong et al. 2014; McDaniel, Tiemann, and Grandy 2014; Kane 2015). Improved soil biodiversity may also improve the nutritional qualities of foods (Rillig et al. 2018). Further, carefully integrating livestock into farm systems as one ingredient of a highly interdependent crop-livestock system has benefits including improved soil fertility and social and economic benefits to the farm (Martin et al. 2016). In sum, increased organismal diversity on the farm brings a range of environmental, agronomic, social and economic benefits that are often missing from simplified farm systems (Altieri 2000; Millennium Ecosystem Assessment (Program) 2005; Veres et al. 2013). A diverse farm ecology thus offers a flexibility for future change on the farm that can provide multiple options to the farmer when climate, social, or economic conditions shift while also increasing the support the farm offers to local ecosystems and wild organisms. In addition, a focus on increasing perennial cover and polycultures that maintain cover can decrease agricultural greenhouse gas (GHG) emissions from land cover change and tillage (Baah-Acheamfour et al. 2016). One additional form of diversity—human diversity—is discussed in #3, below.

2. **Decrease agriculture's greenhouse gas (GHG) emissions.** Agricultural greenhouse gas emissions come from multiple sources, including land use/land cover change, livestock emissions, and fossil fuel use. Fossil fuels are used on farms, directly or indirectly, to manufacture and power farm machinery, manufacture fertilizers and pesticides, and create and run irrigation systems, among other uses (Helsel, 1987; Stout, 2012). Energy inputs to farming constitute approximately 1000 liters of fossil energy per hectare (Ringler, Bhaduri, and Lawford 2013). The majority of greenhouse gas emissions (65% in 2010 as measured in $GtCO_2$ equivalent per year) are of carbon dioxide emitted as a result of fossil fuel and industrial processes (Pachauri and Meyer 2014), making decreased emissions from fossil fuel use an important change in agriculture. Energy

inputs into U.S. farming could be decreased by 1/3 by shifting from fossil-fuel-based synthetic fertilizers and pesticides to alternatives (Ackerman-Leist 2013). Increasing the biological diversity of agricultural systems is among the most important contributions to creating alternative sources of fertility and pest control.

Use of machines powered by fossil fuels represents approximately one-third of total agricultural fossil fuel use (Pimentel 2006), and thus represents another important area in which fossil fuel emissions could be decreased. No-till systems are one way in which machinery use can be substantially decreased (Soane et al. 2012), and no-till systems can result in yield increases (Martínez et al. 2016). No-till systems, however, can also be pesticide intensive, and concentrate pesticides in runoff (Elias, Wang, and Jacinthe 2018). In the longer term, therefore, systems using human or animal labor power may be important alternatives, but would necessitate an increased agricultural labor force (Pimentel et al. 2008; Ackerman-Leist 2013).

Worldwide, land-use change, livestock, and other non-fossil fuel inputs from agriculture contributed 56% of non-CO_2 greenhouse gas emissions in 2005 (Smith et al. 2014). Intensification of agriculture during the late 20th and early 21st century is posited as having decreased emissions from land use change that have otherwise occurred (Burney, Davis, and Lobell 2010). Burney et al. (2010) contend that continued intensification need not be out of line with otherwise sustainable changes to the farming system, including “careful and efficient management of nutrients and water by precision farming, incorporation of crop residues, and less intensive tillage” (p. 12055). Such a vision of change may be compatible with both continued use of modern computing and geolocating technology in farming, but also with increased employment in agriculture. However, systems that move toward the incorporation of mixed perennials may have additional benefits over annual systems alone in terms of further reducing greenhouse gas emissions (Wolz, Branham, and DeLucia 2018). A still more intensive system based on permaculture principles and heavily intermixed crops has promise for greenhouse gas mitigation as well, given its heavily perennial-orientation and lack of motorized tools or traction. Research has so far supported its financial viability (Guégan and Leger 2015; Morel, San Cristobal, and Léger 2018), but studies of the particular environmental impacts of the system have yet to be undertaken.

Finally, livestock contribute substantially to agriculture's share of greenhouse gas emissions, including methane, a far more potent greenhouse gas than carbon dioxide in terms of its warming potential. Total livestock emissions during the period 1995 to 2005 were between 5.6 and 7.5 $GtCO_2$ equivalent per year, with methane representing 43% of emissions (Herrero et al. 2016). However, improving feed digestibility, manure management, grassland management, and productivity of livestock and pastures all have potential to reduce greenhouse gas emissions (Herrero et al. 2016).

In sum, there are a variety of means to decrease agriculture's greenhouse gas emissions, and useful options overlap significantly with a goal of increasing organismal diversity in agricultural systems.

3. **Increase ties between communities and agriculture. Diverse economies and care.** The first two goals are very much based on the biophysical environments in which farming takes place. This goal and the fourth are most focused on the human communities in

which farming takes place. Goals #3 and #4 emerge from two theoretical concerns: diverse economies (Gibson-Graham 2006) and matters of care (Puig de la Bellacasa 2011). The diverse economies framework (addressed further in chapter 6) posits that many of the interactions in our society are not capital or market-based, but that, instead, they may occur, for example, because of a concern for fellow human beings or for the environment (Gibson-Graham 2006). Matters of care is a related concept. Puig de la Bellacasa (2011) notes that care is "a signifier of necessary yet mostly dismissed labours of every day maintenance of life" (Puig de la Bellacasa 2011). Within goals #3 and #4, then, I seek to identify ways in which *both* capital/market-related relationships and other forms of relationships within farming can help in the production of agricultural systems that more fully meet both environmental and human needs.

The idea of goal #3 is to integrate farms more fully into life of the broader, rural communities where most conventional farms are located. Currently, many conventional farms have substantial ties to buyers of their products who sell their product elsewhere, often on national or international markets. Many of their most-frequented ties to their communities are to sellers of the products of large agribusiness corporations, bankers, and accountants. As mechanization increasingly displaces labor inputs on farms, connections between farm operators and the rural poor decline. Conversely, some of the options proposed in goals #1 and #2 require, through increased labor demands, an increase in the number of people employed in agriculture. The U.S. farmer population is aging (USDA ERS 2017). The number of workers in agriculture is expected to remain stagnant over the next 10 years (Bureau of Labor Statistics 2018). Pay for agricultural labor is low, at $23,730 annual pay in 2017, as compared to a median of $37,690 for all workers in the U.S. (Bureau of Labor Statistics 2018). Moreover, growth in rural employment is expected to be greatest in low-paying jobs requiring little formal education beyond a high school diploma or a few years of college (Perdue 2017). Farming households, however, tend to have higher average income than the average U.S. household (Schnepf 2017). More intensive agricultural production, in which well-trained, well-paid hand labor replaces some of the work now done by machines represents one means of increasing the welfare of rural areas, increasing equity of income distribution, while still supporting robust farm incomes. Moreover, such a move supports the overall argument for needed change in the agricultural system. Younger farmers are more likely to engage in innovations that could drive agriculture in new directions (Läpple, Renwick, and Thorne 2015). A more diversified agriculture in terms of age and ethnicity could contribute to spurring more innovation to create additional organismal diversity on farms. With food deserts a common challenge in rural areas (and sometimes a steeper challenge than in urban areas due to lack of transportation and long distances) (Walker, Keane, & Burke, 2010), a more diverse agriculture has the potential to alleviate the challenges of rural food deserts. Increasing farm connections to farmers markets, community-supported agriculture systems, small stores, and local food pantries could all be means to decreasing rural food insecurity.

Systems like farmers markets and community-supported agriculture systems are commonly thought of as part of the alternative agricultural system. Most conventional farms simply produce too much to be absorbed by local, rural markets. Yet, a diversified farm system with more varied production could find more local outlets. By creating systems in which people know their producers, and perhaps work on and visit their farms, a sense of rural community can be fostered and rebuilt. Those who consider farms as an integral part of their daily, rural lives, despite not being farm owners, can feel a greater sense of belonging to the rural areas, inspiring a greater motivation for young people to stay, alongside the motivation provided by new agricultural jobs. Other community connections might include gleaning, already an activity undertaken in some smaller alternative systems, as in Sarasota, FL (Transition Sarasota 2018). Such programs would address issues of physical health for the gleaners (in terms of exercise) and for recipients (in terms of food security).

4. **Create an agricultural system that cultivates farmer and farm household mental, physical, and social well-being.** In addition to benefits for communities, greater ties between farms and broader rural communities could yield benefits for farms and farmers. Farming in the U.S. can be an isolating profession, and, partly as a result, farming has the highest suicide rate of any occupation group, and the highest male suicide rate (McIntosh 2016). In addition, much of conventional farming increasingly relies on work performed from the seat of a tractor, requiring farmers to sit for long periods. Increased mechanization on a farm results in increased body mass index (BMI) for the farmer, along with associated health problems (Hunsucker 2016). A farming system that is more diverse on multiple axes can also be a system that is far more beneficial to the farmer and her household. Diverse crops may improve the health of both the farmer and the community by minimizing the need for fertilizers and pesticides, provided crops are

chosen for multiple benefits including nitrogen fixation. Diverse farm labor—by age, gender, ethnicity—may provide new ideas on the farm for how to effectively produce food and how to better connect the farm with community needs. Further, incentives for new growers to obtain land through lease or ownership could diversify farm ownership, providing similar benefits to diversified labor, and countering current inequalities of ownership, income, and food security (Brown & Getz, 2011; Green, Green, & Kleiner, 2011). Moreover, a farmer with close, personal ties to workers and others who are intimately affected by farm practices, developed through farm-community events and working side-by-side with farm labor, will be more aware of how his environmental practices will affect his laborers and neighbors. Such a consciousness can influence a farmer to decrease her pesticide use or otherwise calibrate practices that are more healthful for those on and adjacent to the farm.

One additional note: these goals can be framed by an understanding that a firmly productivist orientation to agriculture (Burton 2004) is detrimental to both human and environmental well-being. Problems of hunger are not due to inadequate production of food, but a result of poverty and inequality (Holt-Giménez et al. 2012). The world already produces adequate food for the likely population peak during this century (ibid.). Moreover, in the United States, much of our most fertile land is devoted to growing feed for cattle and for automobiles. This set of goals, then, is oriented toward an agriculture that is more flexible in the face of future climate challenges in ways that respond to varied vulnerabilities of environments, society, and economies, rather than a focus only on yield per acre. Some of the more intensive systems possible under the above goals, however, have very high productivity per acre and per energy used in the system (Ackerman-Leist 2013; Mulder and Dube 2014).

What are the synergies and trade-offs among these goals for a transformed agriculture?

Some of the synergies among these goals are suggested in their descriptions, but it is useful to lay them out explicitly. For example, increased organismal diversity, if species selection is conducted with attention to nitrogen-fixation, can decrease or eliminate the need for petrochemical fertilizers, decreasing greenhouse gas emissions (Davis 2010; Lin 2011). If species are chosen that work synergistically to attract beneficial insects or ward off pests, then crop diversity can also decrease the need for pesticides, also decreasing greenhouse gas emissions (Lin 2011). If polycultures become part of the landscape, and include perennial species, then decreased greenhouse gas emissions will occur as a result of less land-use change as its associated soil disturbance and carbon release decline (Gebhart et al. 1994; Boody et al. 2005; Liang et al. 2016). Increased crop diversity can also allow for the production of crops saleable in the local area, including fruits and vegetables. Direct-marketing of crops may allow farmers to keep more of the income from a given crop (Detre et al. 2011), as is the experience in farmers markets and community supported agriculture (CSAs) Such marketing can thus allow for increased ties to the community through local markets, including farmers markets and CSAs. Such ties also work toward decreasing farmer isolation, thereby improving farmer well-being.

Trade-offs resulting from increased organismal/crop diversity could include a decreased ease of management. As the complexity of the system increases, farmers will have less ability to manage large acreages with machines, as multiple species may require different forms of management (Lin 2011). Decreasing greenhouse gas emissions would also mean less use of large machines, both to minimize the use of fossil fuels and to decrease soil disturbance that releases carbon (Pimentel et al. 2008; Corsi et al. 2012; Baah-Acheamfour et al. 2016). Single-crop no-till systems can be less viable with decreased use of pesticides to control weeds, although incorporating cover crops into the system can help make such systems more feasible (Altieri et al. 2011). For some systems, alternative methods of weed removal involving smaller scale cultivation machinery or even hand labor will be needed. That will mean an increased need for labor, currently in short supply among farmers in this study. One solution to labor shortages could lie in new federal incentives for multifunctional agriculture, offering farmers a sufficient support to allow them to hire labor at higher rates to attract local labor. Moreover, there would be advantages to the need for more non-mechanized labor if it were performed by farmers themselves. It could decrease the propensity of farmers to increase their body mass index when too much of their labor is mechanized (Hunsucker 2016)

Decreased ease of management would not be the only tradeoff of increased diversity and increased greenhouse gas emissions. Marketing would also experience some hurdles. Farmers seeking to begin marketing a greater diversity of crops would need to seek new marketing outlets. Moreover, if decreased transportation of products was an element of cutting greenhouse gas emissions, farmers would need to seek local and regional markets. With multiple farmers competing for the same local markets, all using locally-adapted crops, there might be increased potential for competition and inability to sell when certain crops produce abundantly, as some of the small direct-to-market growers in this study have sometimes experienced. More time would also need to be spent on marketing with a more complex crop mix. Food hubs and related local food infrastructure could contribute toward easing these burdens for farmers while also making food more affordable for low-income rural residents (Horst et al. 2011; Hyden 2017).

In addition, both increasing crop diversity, especially if the increase involves polyculture, would require increased farmer knowledge. Knowledge needed would include knowledge of new crops' cultural requirements and growth patterns, as well as the plant interactions likely among a given set of crops to be grown in the same space (Jacke and Toensmeier 2005; Lin 2011). Similar learning is necessary if farmers are to focus on decreasing their greenhouse gas emissions. Knowledge of the various means through which greenhouse gases are emitted from agricultural systems, such as the conversion of nitrogenous fertilizers to the greenhouse gas nitrous oxide, are limited among farmers (Gramig, Barnard, and Prokopy 2013; Stuart, Schewe, and McDermott 2014). Farmers would need education on the ways in which they could mitigate their own emissions, so that they could choose the means that best suited their own systems. Practical techniques would need to be taught, as well. For example, techniques of animal traction would have to be learned by most wanting to adopt it (Niggli et al. 2009). The advantage of the needed learning is that farmers and communities could become more closely tied if the education occurs through social learning processes that incorporate local extension professionals as well as farmers, thus decreasing farmers' dependence on sources such as suppliers for their agricultural information.

Increasing community ties could provide synergies with the other goals. Farmers marketing in the local community would have decreased distance to markets, thus cutting their transportation greenhouse emissions. Increased ties between the community the farmer could enable the farmer to better access quality pools of labor as ongoing relationships are developed.

More diverse crop systems can help to spread labor through the year (Leopold Center for Sustainable Agriculture 2012), especially if crops are chosen to support that need, thus making it more feasible for farmers to create permanent ties with laborers who are deemed effective. The availability of more labor could make hand labor more feasible for farmers, increasing their ability to create complex, polycultural systems. Closer ties between the community and the farmer could increase transparency of the farming system, as local residents come to better understand the processes through which food is produced. That increased transparency and greater comfort of local residents with growing methods could help to facilitate local marketing by making residents better trust their local producers. Greater community ties can also decrease farmer isolation and the negative effects on mental health associated with isolation (Cornwell and Waite 2009). Further, if greater community involvement in agriculture led to the organization of food hubs and similar systems of regional food management to make use of diversified local production, it could allow farmers to make greater profit from the food they grow. Such systems could eliminate some of the middle layer of the food system of wholesalers and distributors, allowing those portions of the food dollar to go directly to the farmer. In addition, closer ties between farmers and the community could increase farmer awareness of food needs in the community, as well as of those interested in food production. Farmers might therefore become willing to participate in land-sharing with those who want to produce their own food or offer portions of their land at lower lease rates to enable local people to grow food.

These linkages between farmer and community would, however, have some trade-offs. For example, closer ties with the community could increase the risk of poor interpersonal relationships having a detrimental effect on a farmer's product marketing. For farmers who conceive of themselves as individualists and independent of their neighbors and support systems (Stock and Forney 2014), greater community ties could challenge their accustomed identities. Such tests to personal identity could cause some farmers to withdraw and cut ties to community food systems (as seen in farmers reactions to top-down systems of nature protection (Siebert, Toogood, and Knierim 2006). Further, increased complexity of farm systems, supported by increased use of local labor, would result in more labor management complexity for farmers, requiring, for example, more paperwork to establish the right of employees to work in the U.S.

Thus, these goals for a transformed agriculture are not without their pitfalls. Design of systems by farmers and other rural stakeholders would be necessary to help ensure that the systems met the needs and social context of a given rural area. Moreover, the goals meet a number of barriers in the existing agricultural context, as addressed next.

What do we know about barriers to transformative change on farms?

An understanding of the barriers and limits (Moser and Ekstrom 2010) to transformation is important to lay the groundwork that can prepare farmers and the agriculture sector more broadly for effective future change. Moser and Ekstrom (2010) define limits as "absolute;" the physical world thresholds that cannot be superseded. Barriers, on the other hand, are obstacles within human thinking and human systems that may possibly be overcome (ibid.). In identifying barriers to farm transformation, economic and social justice elements of deliberate transformation can be incorporated into a vision of agricultural transformation. Identifying barriers, in other words, assists in directing attention to the differential between farmers with extensive acreage (compared to their neighbors) and farmers with limited acreage, and between farmers with extensive financial resources and those with fewer financial resources. Farmers' networks, too, are often dissimilar, and the resources, information, and social support available in one network may be almost entirely absent in the network of a farm neighbor, even for a farmer growing similar crops. These differences produce differential barriers and widen economic as well as social gaps between farmers.

The American agricultural system provides extensive support for a specific form of agriculture. That agriculture is tied intricately to a globalized market economy from soil to seed to final product. And it is those ties that provide many of the constraints to transitioning to forms of agriculture that would limit greenhouse gas emissions, as this section lays out. Important barriers (Moser and Ekstrom 2010) to a fundamental shift of the agricultural system include arrangements of the economic, information, and technological systems supporting conventional agriculture. Farmers, in this sense, are “doubly exposed” to patterns of economic globalization and climate change (O′Brien & Leichenko, 2000) as the inputs they buy and the crops that they market are affected by global price shifts often having to do with changes in global oil supply (Baumeister and Kilian 2016) or changed market expectations in other countries (for the latter, the Brazilian insistence on the removal of U.S. subsidies for cotton is a key example (Hart 2015)). The barriers experienced by farmers, however, go beyond the economic or biophysical. The constraints provided by the changing biophysical environment, for example are shaped by understandings of how such environments have been used in the past. And many decisions made in agriculture, including those about how to usefully farm in a given set of conditions, are shaped by community expectations, by the beliefs of family, friends, neighbors, and peers (Bell 2004). Equally important barriers to transformation, however, are the beliefs and values of farmers—beliefs and values that they articulate through narratives about their farm practice. Climate change is “an inherently social process” in which both individual beliefs and values and the interactions among individuals and between individuals and institutions play important roles in determining which change is possible (Wolf, 2011, p. 29). Nonetheless, the concrete and pervasive influences of markets and policies are important constraints to agricultural transformation. I therefore begin by examining constraints in the political sphere before examining the importance of farmer beliefs and values in confining agricultural change to limited, incremental alterations.

Economic Barriers

Barriers to diversity and decreased GHG emissions. The structure of U.S. agricultural supports in forms such as direct subsidies, subsidized insurance, and price supports does little to encourage transformative change in the agricultural system. Diversifying crop systems, from increasing genetic diversity of monocultures to creating polycultures, agroforestry and mixed landscapes are forms of potentially transformative change whose benefits include disease suppression, climate change buffering, and increased production (Lin, 2011, p. 185). Yet the bulk of government agricultural support goes to a few large commodity crops (Lin 2011; Environmental Working Group 2018d) which are largely grown in monocultures. Despite substantial shifts in the 2014 Farm Bill (Orden and Zulauf 2015), commodity programs still make up as much as or more of the U.S. government subsidies that support farmers as do insurance subsidies (Environmental Working Group 2018d). Crop insurance offers the potential for moral hazard, reducing “incentive for farmers…to take action to avoid weather damages” (Repetto 2008). Moreover, crop insurance appears to have at best neutral effects on environmental externalities (Walters et al. 2012; Weber, Key, and O’Donoghue 2016), and possibly negative effects. For example, disaster and insurance payments can decrease the use of certain kinds of conservation tillage (Schoengold, Ding, and Headlee 2015), and can increase acreage of some monocropped systems (Claassen, Langpap, and Wu 2017). With little built into the Farm Bill that supports multifunctional agriculture, conventional farmers receive few government incentives to increase on-farm organismal diversity.

In addition to the lack of explicit government incentives to increase diversity, the political economy of agriculture can limit farmers' options for expanding multifunctionality in their farm systems. Mechanization makes the management of single crops more efficient than the management of multiple crops (Lin 2011). Increasing consolidation of industry means that farmers have few options for buying seeds and chemicals. In 2016, six companies—already highly consolidated entities—controlled the majority of the agricultural inputs market (Mayer 2016). With more recent consolidation, those six companies (BASF, Bayer, DuPont, Dow, Monsanto, and Syngenta) are now just four (BASF, Bayer, DowDuPont, and Syngenta, which is now owned by ChemChina) (Dow 2017; Petroff 2017; Monsanto 2018). Farmers who gain the majority of their information about seed and chemical choices from their local distributors of these products are therefore increasingly limited in sources of both information and farm inputs. Farmers growing commodity crops also have limited outlets for their produce, as with the major grain crops. In 2005, just four firms controlled 60 percent of "terminal grain handling facilities" and flour milling was similarly controlled by just four firms (Hendrickson and James 2005). Limitations on both seed options and sales options decrease the opportunities for farmers to diversify their crops even within a single crop type (e.g. wheat). The costs of newer technologies often represent substantial barriers to farmers' diversifying. Tractors and attachments specific to certain crops cost hundreds of thousands of dollars (Hawkins and Buckmaster 2015), costs of seeds have risen alongside consolidation of firms, and agri-chemical prices rise as petroleum becomes more expensive (Huang, McBride, and Vasavada 2009). Consequently, farmers may devote more resources to a single crop, steepening the barriers to diversification.

Further, political economic constraints can limit farmers' actions toward mitigating GHG emissions. For example, companies with whom farmers have payment contracts may limit farmers' incentives to decrease nitrogen fertilizer application by rewarding only high yields (Stuart, Schewe, and McDermott 2012, 2014; Stuart and Schewe 2016). Despite many farmers perceiving themselves as conservation-oriented in their approach to maintenance of land and waters (McGuire et al. 2015), economic constraints may limit their sense of control over their choices. Farmers may feel so constrained as to make what they would otherwise judge as less ethical choices (James and Hendrickson 2008). Economic constraints can thus represent significant limits to the ways in which farmers approach protection of the environment through the ways they manage their farms.

Lack of access to labor can also represent a barrier to decisions that protect the environment. Having access to labor can be a replacement for chemical inputs (Pfeffer 1992). Farmers whose networks have not previously included sources of labor may have difficulty replacing chemicals due to an inability to find sources of labor (Pfeffer 1992). An important source of labor for farmers in agricultural sectors throughout the United States is immigrants from Mexico. Tighter control of the southern border can limit the availability of labor. Limits on labor can result in decreased ability of farmers to produce and harvest certain crops, and can consequently reduce farm exports (Devadoss and Luckstead 2011). Assumptions that removal of an immigrant workforce would raise farmworker wages do not appear to have support in the literature (Clemens, Lewis, and Postel 2018). Moreover, immigrants are willing to work physically demanding jobs that U.S. natives perceive as too arduous (Zavodny 2015). Given the horticultural products that are important in farming in areas like the Southwest U.S., and the continued challenges of creating effective machinery to replace some kinds of hand labor (e.g. green chile harvest (Joukhadar, Walker, & Funk, 2018; Walker & Funk, 2014)), tightening the labor market through immigration restrictions has few, if any, useful outcomes for agricultural production. Further, when lack of labor discourages the planting of relatively drought-tolerant crops such as chile, farmers may choose crops that are less adaptive to continued drought and other climate change challenges.

Barriers to rural equity. Economic constraints may similarly prevent the improvement of rural livelihoods beyond the farm. Government support of commodities was developed to support farm households because of their lower than average income levels relative to other US households (Mishra and Sandretto 2002; Dimitri et al. 2005; Lin 2011; Mishra and Paudel 2011). But farm households now have higher average income than non-farm households (Mishra & Paudel, 2011). Direct government support, then, is oriented neither toward policies that encourage crop diversity nor toward support of poorer rural households. Instead, agricultural support payments tend to support the wealthiest farmers. According to the 2007 USDA Census of Agriculture, just 38% of farms received government payments, and just nine states had more than 50% of farms receiving payments, and six states had more than 70% of farms receiving payments—all of these in the Midwest, most in the Upper Midwest (Environmental Working Group 2018c). In New Mexico, just 15.9% of farms were receiving payments (ibid.). Moreover, 77% of commodity subsidies from 1995 to 2016 were paid to the top 10 percent of payment recipients (Environmental Working Group 2018b). Although the 2014 Farm Bill shifted payments further toward insurance subsidies and away from direct payments (Orden and Zulauf 2015), the majority of payments has continued to go to farms with the highest crop sales (Schechinger 2018).

Regulatory barriers

Another set of barriers to farm transformation lies in regulatory barriers. Barriers are not only built into farm policy and farming institutions, but also into policies affecting international trade and migration. Regulatory barriers are, for example, closely implicated in labor limitations. Federal (U.S.) decisions to limit entry at the southern border and to round up farmworkers who may be undocumented cause concerns among farmers and others working in agriculture that they will not be able to acquire the necessary labor to produce and harvest crops (Martin 2017; Wallace et al. 2017; Castillo 2018; Goodland 2018; Nassif 2018). Immigration policies have clear implications for the choices farmers can make. However, it must be acknowledged on this point that it is not immigration policy alone that has shaped immigration to the U.S. during the last decade. The 2008 financial crisis decreased immigration to the U.S., including Mexican immigration, as jobs disappeared in the U.S. (Singer and Wilson 2009; Villarreal 2014). Further, in areas of northern Mexico like the states of Chihuahua and Sonora, much of agriculture is mechanized and industrialized. Partly as a result of NAFTA policies, some forms of fruit and vegetable production have grown in these northern states even as NAFTA has contributed to declines in grain production (King 2006). In the wake of NAFTA, for example, Mexico's exports of chile grew even as U.S. production leveled off. U.S. imports of Mexican chile quadrupled between 1994 and 2004 (Economic Research Service (ERS) 2008). This has provided more opportunities for Mexicans with horticultural expertise to remain in Mexico to work rather than working in the U.S. Thus, the combination of NAFTA and immigration policies has worked together with broader changes in climate (e.g. droughts in Sonora that limited grains while encouraging certain horticultural crops) and employment opportunities to reduce the availability of labor for farmers in parts of the U.S. that had previously relied on Mexican labor. Since mechanized modes of work tend to work most efficiently in monocultural systems, a decline in available labor makes it more difficult for farmers to engage in kinds of transformative change that increase the biological diversity and therefore potentially the complexity of farm systems.

Concerns over food safety have driven some of the newest regulations that constrain farmers' decisions. The U.S. Department of Agriculture (USDA) adopted Good Agricultural Practices (GAP), in 2002, as a voluntary audit system to ensure food is safely grown, handled, and stored (Maughan et al. 2016). Then, *E. coli* outbreaks prompted the adoption of the Leafy Greens Product Handler Marketing Agreement (LGMA) in California in 2007 (University of Minnesota Extension 2018). Compulsory federal standards were adopted under the Food Safety Modernization Act (FSMA) of 2011. FSMA was designed "to establish science-based, minimum standards for the safe growing, harvesting, packing, and holding of produce on farms to minimize contamination that could cause serious adverse health consequences or death" (U.S. Food and Drug Administration (FDA) 2017). The act responds to concerns over the occurrence of foodborne illnesses that have occurred in the U.S., with the recent *E. coli* outbreak in romaine lettuce (Jacobs 2018) being just one of many. FSMA represents the first major overhaul of food safety regulations since the Great Depression (Strauss 2011). It grants the FDA broad new powers to inspect food facilities and to order recalls (ibid.). The act requires extensive management and tracking of produce to ensure that its origins can be traced in the case of food outbreaks. It also requires food manufacturers to create plans to prevent contamination (Hassanein 2011) The legislation applies not just to manufacturers, but to farmers, as well (Ribera and Knutson 2011), who must keep records that allow for the government to trace food origins in the event of a recall (Strauss 2011). Under the act, "riskiest" domestic facilities must be inspected every three years, with risk based on a specified set of fruits and vegetables that commonly cause outbreaks (Hassanein 2011; Strauss 2011).

In Congressional debates over the bill that became FSMA, actors affiliated with smaller producers, including those involved in alternative food movements, protested that the act would unfairly penalize smaller producers. Senator Tester of Montana and Senator Hagan of North Carolina therefore sponsored an amendment, dubbed the Tester amendment, to exempt smaller producers from having to meet requirements as stringent as those applied to larger producers and manufacturers (Hassanein 2011). Protestors had argued that exemption should be predicated on the lower food safety risks of smaller operations, greater social embeddedness of direct-to-market sellers, and costs of compliance that would unduly burden smaller producers (Hassanein 2011). Consequently, one requirement for not having to meet the stricter requirements is that a producer "market more than 50 percent of their product directly from the farm or from farm stands or farmer's markets" (Strauss 2011). As such, smaller growers whose horticultural produce—such as onions and chile produced in New Mexico—is *not* marketed directly to consumers must still meet the full requirements of FSMA. The requirements for growers include the Produce Rule, which requires growers to meet new standards regarding, "agricultural water;

biological soil amendments; domesticated and wild animals; employee training and health and hygiene; and equipment, tools, buildings and sanitation" (Adalja & Lichtenberg, 2018, p. 23). Farms with annual sales under $25,000 (averaged over three years) are exempt from the Produce Rule. Nonetheless, Adalja and Lichtenberg (2018) found that the new requirements are disproportionately costly for smaller farms and that the costs also tend to be higher for sustainable growers. The authors therefore contend that the Produce Rule "may pose barriers to expansion of sustainable farming" (Adalja & Lichtenberg, 2018, p. 34). By placing greater burden upon smaller growers, FSMA also adds additional hurdles to creating more equitable rural places.

Another set of regulations affecting growers is the USDA Organics Regulations. The organics regulations present a number of hurdles to farmers wishing to become organic producers, and several of the barriers are best classified as economic. For example, the three-year transition period, during which a farmer cannot market products as organic (nor earn associated price premiums) but must pay for changed input costs such as increased labor, can represent a substantial financial burden for farmers desiring to transition (Lloyd 2016). The certification process itself is also time consuming and requires additional costs in fees for inspection. The monetary cost, however, is offset by a cost share reimbursement offered by USDA (Lloyd 2016). Nonetheless the burden of obtaining certification can limit farmers transitioning to organic, especially if they lack clear market outlets for their newly certified produce. Further, the administrative burdens of certification, in terms of inspections, assessments, and paperwork appear to be linked to a decline in organic certification despite robust growth in the market for organic goods (Carter, Scott, and Mahallati 2017). The USDA organics regulations can therefore limit the spread of some sustainable practices as well as the equitable access to organic price premiums, especially because USDA organic certification is required for all organic farms with more than $5000 in annual sales (Carter, Scott, and Mahallati 2017).

The Conservation Reserve Program (CRP) contracts with farmers to plant cropland to perennial cover, often native grasses, for periods of 10 -15 years. The program aims to "re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat" (Farm Service Agency (FSA) 2018). Indeed, benefits of CRP for wildlife habitat for the lesser prairie chicken (Ripper et al. 2008) a range of other waterfowl, passerines, and other birds (King and Savidge 1995; Drum et al. 2015; Geaumont, Sedivec, and Schauer 2017; Yeiser et al. 2018) is well established. Mammalian and insect species, including key pollinators, also benefit (Vandever and Allen 2015). CRP also has benefits in reduced soil erosion, improved water quality (Stubbs 2014), flood damage reduction, and greenhouse gas mitigation (Gebhart et al. 1994; Johnson et al. 2016). By and large, then, the program appears to offer policy benefits to farmers attempting to improve the environmental quality of their land. However, barriers to farmer participation in the CRP and related conservation programs include lack of information about the programs (Esseks and Kraft 1986; Reimer and Prokopy 2014) as well as "burdensome paperwork," non-ownership of farmland (i.e. farmers who rent all their farmed land), and low payments that did not provide enough economic incentive to pull land out of cropping (Reimer and Prokopy 2014). Thus, the program has a number of advantages for increasing agricultural sustainability, but an intentional effort on the part of the USDA to reach more farmers with information, and additional consideration of whether to pay farmers more for CRP land would help to minimize barriers. Greater support of the CRP and its related programs, and expansion to additional programs that would give farmers the financial support to diversify into polycropped perennials, could further lower barriers to agricultural transformation.

Information Barriers

Lack of information or lack of diverse sources of information can play a role more broadly in limiting the degree to which farmers adopt transformative practices. Access to appropriate information can have a substantial influence on whether farmers choose to adopt best management practices, including practices ranging from nutrient management and precision agriculture to integrated pest management (IPM) and long-term conservation investments (Baumgart-Getz, Prokopy, and Floress 2012). Effective use of information can also promote climate aware decision-making by farmers (Campbell et al. 2014). However, (K. Morgan & Murdoch, 2000) contend that, “in the productivist paradigm, farmers are encouraged to have blind trust in the technical advice of the agri-chemical suppliers” (p. 168). Indeed, private firms increasingly represent a main source of information for many farmers (Wang 2014; Prokopy et al. 2015), as do private Certified Crop Advisors (Prokopy et al. 2015). Given the rapid change occurring in agribusiness in terms of available varieties of seeds and chemicals, conventional farmers can find that their suppliers and crop advisers are their best source of the detailed information they need about which varieties and chemicals will work in their systems. Yet, cooperative extension, because of its relationship with university research professionals, can offer a broader perspective on change in farming than private suppliers are likely to. Many extension educators are, for example, prepared to offer farmers information on climate change and how to best prepare for the changes expected in their region (Prokopy et al. 2015). Given the broad scope of extension’s focus, advice could go well beyond the selection of seeds, chemicals, and machinery that are common sets of advice offered by private companies. Moreover, private crop advisors and agricultural retailers generally place high trust in extension (ibid.). Since farmers who believe that climate change is occurring are more likely to support taking action to adapt and mitigate emissions (Arbuckle et al. 2013), extension educators have an important role to play in transformative change. However, given the varying beliefs of extension educators about the sources of climate change (Prokopy et al. 2015), social learning experiences (Kroma 2006) involving climate researchers, extension educators, and farmers may be necessary for information to become an important leverage point (Meadows 2009) toward transformative change. If conventional farming is to break out of a paradigm in which seed engineering is the main source of innovation (which tends to leave many environmental concerns by the wayside), one important innovation needed is in the way information is acquired and shared among conventional farmers.

Social Barriers

Aside from the more tangible ways in which the agricultural system can raise barriers to transformative change, there are also social and internal barriers to change. Whereas the previous barriers lie almost entirely in what O'Brien and Sygna (2013) define as the political sphere of transformation—those elements of a farmer's network such as policies, institutions, and markets that shape decisions from outside—some social barriers lie in what O'Brien and Sygna (2013) would define as the personal sphere. The personal sphere includes the beliefs and worldviews of a decision-maker (O'Brien & Sygna, 2013). In the social interactions of farmers and their networks, influences from the personal sphere and the political sphere may be closely intertwined. The beliefs (personal sphere) of one farmer, for example, may cross over into the political sphere in the way she influences her neighbor. That influence may, in turn, cross back into the personal sphere if her neighbor takes on her beliefs as his own. Neighbors and their beliefs about, for example, aesthetic appearance of a farm, can have a substantial influence on the practices that farmers see as acceptable to adopt or maintain (Bell 2004). Neighbors may influence beliefs about farm issues that have become associated with certain political identities, climate change being a key example of a concept that has become closely associated with political identity in the United States (Unsworth and Fielding 2014). Beliefs about climate change, in turn, may affect whether or not farmers take adaptive action (Arbuckle et al. 2013). For all farmers, “real” barriers like debt load and land availability matter, but perceptions about the possible failure of alternative systems may matter at least as much to whether farmers adopt new systems (Franzluebbers et al. 2012). The influence of peer pressure, neighbor expectations, and resultant personal beliefs can have a substantial influence in what kinds of changes farmers are willing to take in their agricultural systems.

Environment and Incrementalism as Barrier

Although, at base, the idea of climate transformation assumes that humans are transforming systems like agriculture to prepare for the impacts of climatic change, the shifts occurring in environmental systems and the incremental reactions that humans take in response may block deeper, transformational change. In the region dependent on the Ogallala aquifer, for example, decreasing water availability is likely to diminish the local economy if humans take expected measures (e.g. shifting to dryland production) to cope with the loss of water (Terrell, Johnson, and Segarra 2002). In the Rio Grande valley, as groundwater pumping makes up for water shortages from the river, excess demand on the aquifer (Samani 2012) will mean that water becomes more expensive. The cost may become prohibitive and may draw investment away from more fundamentally transforming the agricultural system along the Rio Grande. Similarly, hailstorms can significantly damage crops, but the human reaction to hail—insurance payouts—can represent a barrier to rethinking on-farm plant structure or choosing crops that would be more resistant to hail.

Conclusions

Given the diverse barriers to agricultural transformation, it is clear that deliberate transformation (O′Brien 2012) of agriculture will require multiple approaches. I therefore return to the three spheres approach (O′Brien and Sygna 2013; O′Brien 2018) for a discussion of how to move forward. As outlined in the introduction, the three spheres each address one realm of transformation: the practical (behaviors, technical changes), the political (systems and institutions), and the personal (beliefs, values, worldviews). The overlap of the three spheres also connotes the synergy among transformations in each sphere (O′Brien and Sygna 2013). Transformation, in light of the barriers to agriculture, requires change in all three spheres.

The personal sphere of transformation may, at first glance, appear to be necessary mostly for allowing farmers to change their thinking about the social barriers discussed above. Certainly, if farmers come to see the very real impact that anthropogenic climate change is having on their systems, they are more likely to take action, particularly if offered the tools to do so (Arbuckle et al. 2013). However, change in the personal sphere also affects what happens in the political and practical sphere in wider ways. For example, transformation in the personal sphere of policy makers will be necessary for alterations to future farm bills. Shifts toward multifunctional, polycultural, and perennial agriculture are necessary to support needed change to agriculture (Boody et al. 2005). New policies should more explicitly link rural well-being to agricultural livelihoods, providing farmers the supports they would need to take on complex new challenges and new sources of labor. For such changes to happen, the continued strong political supports for commodity agriculture must, at least partially, shift to more diverse forms of agriculture, which will take a substantial shift in mindsets for policy makers who create farm programs. The current siloed construction of farm bills, separating support for acquiring food from support for producing food, support for conservation from support for food production, would need to be rethought. An extended dialogue between policy makers, rural communities, those in need of food assistance, those shaping local food hubs, and rural and urban producers would be needed to ensure that changes effectively met needs of all stakeholders. In addition to a change in values and beliefs about how policy should be shaped, such a dialogue may require the creation of new institutions, such as non-profits to facilitate the conversation. Entities like New Mexico First[32] have put in some of the work to forward such conversations (New Mexico First and New Mexico State University Cooperative Extension Service 2017), but more is needed, including conversations at the national level. Although technical changes (the practical sphere of transformation) in agriculture can help to provide some of the necessary transformation, by offering assistance such as improved crop varieties and increased knowledge of complex plant interactions, the greatest changes are necessary in beliefs (personal sphere) and institutions (political sphere) that shape the current barriers to agricultural transformations. The next chapter

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[32] An unfortunate name given the current political climate, but it pre-existed recent return of the rhetoric of "America First."

addresses the need for transformation in the personal and political spheres by looking at the ways in which farmers in New Mexico experience barriers to change.

Chapter 5. Barriers to Change in the Political and Personal Spheres of Transformation in Agriculture

Introduction

Climate change is expected to have significant impacts on food production, but there is substantial scope for adaptive actions to mitigate harm to much of the food system (J. R. Porter et al. 2014). However, incremental change alone may be inadequate to prepare agricultural systems for the multifaceted social, economic, and environmental challenges that climate change is likely to impose (Park et al. 2012). The deliberate transformation of agricultural systems to meet their multiple challenges may therefore be necessary to adequately ensure future food security (Dowd et al. 2014).

Deliberate transformation (O′Brien, 2012) of systems to minimize the negative impacts of climate change encompasses more than a reactive response to current or expected climate. It incorporates an awareness of social and economic vulnerabilities and of the idea that working to reduce those vulnerabilities can diminish the challenges brought on by climate change impacts (O′Brien, 2012; Pelling, 2011). Deliberate transformation is purposeful change in pursuit of environmental sustainability, with a direct focus on climate mitigation and adaptation. It envisions structural change to institutions and processes, along with changes in beliefs and worldviews as means of attaining both environmental sustainability and social justice (Feola 2015a).

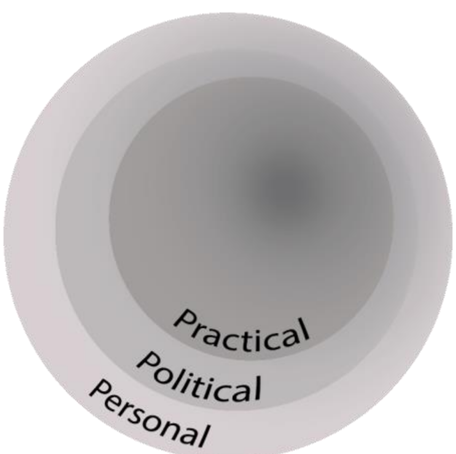

Figure 36: Representation of the three spheres of transformation. Based on O'Brien and Sygna (2013).

Processes of deliberate transformation may be better understood when framed as changes occurring across three spheres of transformation: the practical, political, and personal (O′Brien and Sygna 2013). The practical sphere includes the technical responses and behaviors "where outcomes have an observable and measurable influence on climate policy goals such as mitigation, adaptation, and sustainable development" (O′Brien & Sygna, 2013, p. 5). In the case of agricultural greenhouse gas mitigation, these might be reactions such as intentionally choosing inputs (e.g. fertilizers) that require less fossil fuel to produce. In the case of agricultural adaptation, a reaction might be choosing a set of crop varieties that is more drought-hardy than a previous set of crop varieties. An agricultural change in the practical sphere might include a deep shift[33] such as creating an integrated, perennial polycultural system that might be less vulnerable overall to shifts in both weather and markets. In calling such a shift "deep," I imply the necessity of changing multiple elements of the system. For example, a shift to perennial, polycultural systems would require farmers to incorporate knowledge of plant interactions and complex crop ecologies while also incorporating new cultural methods (e.g. a move from tractors to hand maintenance of the crops) and making connections to new market outlets.

O′Brien and Sygna's (2013) framework would suggest, however, that such a deep shift in the practical sphere would likely only result if there had been substantial changes in the political

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[33] Panda (2018) defines depth of transformation as "intensity or level of change. It can change the system components radically or superficially" (p. 8). I further define "deep" transformation in the farm context as altering multiple components of the system within a short time span. For example, a shift in cropping systems requiring new tools and a new set of knowledge would be a change in three (or more) components of a farming system. Defining transformation as changing at least two components fits well with Dowd et al.'s (2014) definition of agricultural transformation. A deep transformation might therefore change three or more. Further, ideally a deep transformation includes change in the agricultural system as a whole (e.g. political institutions, markets, worldviews of farmers and policy-makers) to better accommodate these substantial shifts at the farm level.

and personal spheres as well. As suggested by the diagram, the three spheres are embedded within one another, but the outer spheres have a greater influence on change in the system than do the spheres they contain. The political sphere, for example, “represents the systems and structures that define the constraints and possibilities under which practical transformations take place” (O’Brien & Sygna, 2013, p. 6). In agricultural systems, the political sphere can be conceived of as the agricultural network to which the farmer belongs, including the human, institutional, and non-human (e.g. crops, microbiota, biophysical environment) entities that shape a farmer’s daily life. The political sphere therefore includes agricultural support institutions (e.g. USDA, cooperative extension, state agriculture agencies), marketing entities (suppliers of inputs, buyers of products), banks, non-profit organizations, farm media, crop consultants, neighbors, and even distant farmers. Change in the political sphere can thus lower (or raise) barriers to farmers making transformative change on their farms. A decline in commodity prices may limit a farmer’s funds to undertake conservation actions on her land. On the other hand, implementation of new conservation supports within the Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) may allow a farmer to put into place new irrigation systems that use less water and that allow nutrients to be more directly targeted to plants, decreasing fertilizer use.

The deepest systems transformations, however, come from changes in the personal sphere. It is in the personal sphere that “the transformation of individual and collective beliefs, values and worldviews occur,” (an idea supported by Meadows (2009) analysis of systems change) (O’Brien & Sygna, 2013, p. 6). Clearly, it is in the overlapping of the spheres that this matters. In agriculture, for example, a farmer who begins to feel deeply troubled by the damage caused by pesticides he has used may choose to eliminate them from his system. The shift he makes in the practical sphere, in terms of his particular farm practices, may occur even despite barriers that exist in the political sphere, provided those barriers to change are not too steep. Moreover, when such change happens across a network of people, as occurred among those who first adopted organic agriculture, for example, the change can be quite powerful in that it may compel change in the political sphere in the form of new rules, new institutions, and new sources of agricultural support. The myriad changes to the USDA linked to the USDA National Organic Program, for example, in which organic certification became standardized across the country and new sources of institutional and financial support emerged, were inspired by the personal sphere transformations of those who had adopted organic farming. Meadows (2009), in her analysis of the ways in which systems function, notes that the greatest leverage for change across a system comes from changes in paradigms, and especially from the realization from those in the system that no one paradigm is the perfect model through which to understand and change the system. Paradigms, worldviews, beliefs, and values all make up the personal sphere of transformation, and together offer the potential to have the greatest leverage for transformational change. As Meadows (2009) notes, however, those who have undergone paradigm shifts often face the steepest barriers in the form of others who do not wish conventions to change. Certainly, agriculture, with its many deeply embedded institutions from farm- to federal-level, represents an area in which the political sphere (O′Brien and Sygna 2013) can offer many steep barriers to transformation, despite shifts in the personal sphere.

Transformational adaptation in agriculture has been framed in broad terms as a change in farming systems in which “the ratio between persistence and change is low; more of the system is changed than is continued as is” as measured against “background change” (Rickards and

Howden 2012, 242). The work on agricultural transformation has received the most attention from a team of researchers at CSIRO[34] in Australia, and their definitions of transformational adaptation have been developed based on both transformation as it is framed in resilience theory (Park et al. 2012) and deliberate transformation as it has been framed by O′Brien (2012) (Rickards and Howden 2012). The group's recent work, although citing both resilience and deliberate transformation, relies most on deliberate transformation as it analyzes farmers who characterize their methods as deliberate reactions to climate change and associated vulnerabilities (Dowd et al. 2014).

Rickards and Howden, (2012) further lay out three kinds of agricultural adaptations in response to climate change: incremental adaptation ("changes in practices and technologies within an existing system"), systems adaptation ("changes to an existing system such as a major change in focus between livestock and cropping, new crop types..."), and transformational adaptation (Rickards & Howden, 2012, p. 242). That conceptualization places focus on farmer choices and farming system outcomes that result from farmer choices. In surveying Australian farmers about transformation, for example, Dowd et al. (2014) asked farmers to identify the ways in which they had altered their farm management, enterprises, and land/farm size in reaction to climatic change, and linked the relative change undertaken by farmers to the kinds of information networks and social support networks upon which each farmer depended. Such a formulation goes some way toward elucidating the ways in which farmers are reacting to climate change impacts in broad strokes. However, farmers, even farmers who acknowledge

[34] Commonwealth Scientific and Industrial Research Organization. It is an independent, Australian federal government agency.

anthropogenic climate change, perceive themselves as constrained by social, environmental, and economic factors beyond climate change. These non-climatic factors constitute worries that may limit farmer actions that would help them respond to climate change (Fleming et al. 2015).

This paper will argue that many barriers to transformation (Moser and Ekstrom 2010) in agriculture lie in the political sphere of transformation (O'Brien and Sygna 2013), but that the very real barriers that farmers encounter in the political sphere can be reconstructed as still greater hurdles through the narratives that farmers use to understand them (i.e. the personal sphere). The argument will be structured as follows. A statement of the research problem is followed by a discussion of methods. Then, I address the ways in which farmers in New Mexico have experienced and narrated barriers to change. In doing so, I interpret the ways in which the barriers they have experienced represent barriers to agricultural transformation. Those barriers fall in both the political and personal spheres of transformation. I conclude by reflecting on some of what may be needed to overcome barriers to transformation in U.S. agriculture.

This chapter centers around the research problem of understanding what barriers prevent farmers in New Mexico from undertaking transformative change to their agricultural systems when faced with climate-related challenges like drought. This framing assumes that social and economic vulnerabilities are as important as weather-related vulnerabilities in the decisions that farmers make. However, it seeks to understand specifically which elements of farmers' agricultural network—from neighbors to institutions of the U.S. Department of Agriculture (USDA) to farmers' own worldviews—most shape the decisions they make. The study therefore sought to delve directly into drawing explicit connections between elements of farmers' networks and the decisions that they made.

Methods

This paper is based on interviews with 30 farmers and 44 members of agricultural networks, particularly employees of cooperative extension and university agriculture departments. Internet searches for USDA employees, cooperative extension and university departments resulted in initial contacts. These in turn led to initial farmer contacts in the study areas. The study areas included Doña Ana and Luna Counties in southern New Mexico, and Curry and Roosevelt Counties in eastern New Mexico. Southern New Mexican farmers were also identified through visits to the Farmers and Crafts Market of Las Cruces and talking to produce vendors. Most farmer contacts were identified through snowball sampling with other farmers being the prior contact. Both small, direct-to-market producers and large, commodity and produce producers were among early contacts in both study regions, leading to two loosely identifiable sub-groups in each region.

For the purposes of this paper, I analyze in-depth farmer interviews conducted with farmers in all four counties. Note that four of the farmers in the interviews were part of a joint interview with a family member with whom they jointly make farm decisions (i.e. 26 farmer interviews were completed). In their interviews, farmers recounted their history of decision-making over 10 years, or as much of 10 years as they were able. Farmers discussed the elements of their agricultural networks that influenced the changes they chose to make, and, in so doing, also highlighted the barriers they encountered to the outcomes they desired on their farms. This paper focuses on narrative analysis of farmer decisions in order to highlight the barriers farmers experience to transformative change on their farms. Farmers also discussed their farm income in

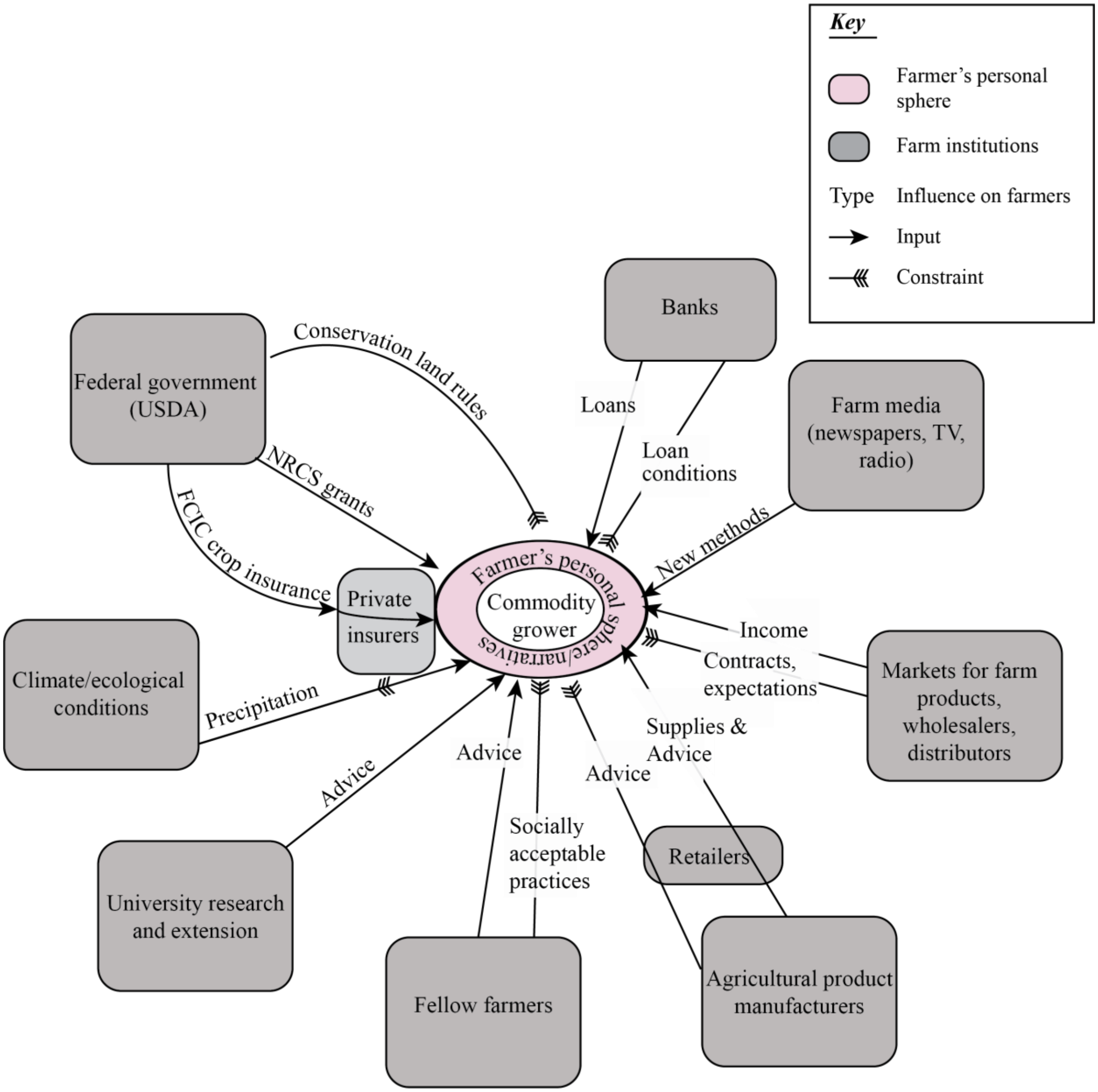

Figure 37: Conceptual diagram of some key elements of a generalized (and simplified) commodity grower's agricultural network. Note that many of the elements of the farmer's network would fall into the political sphere of transformation, but that they must be filtered through the farmer's personal sphere of worldview, values, and beliefs, represented in this case by the narratives the farmer tells about the network and its constraints or opportunities. It is worth noting, as well, that the people making up these entities are also shaped by their own personal sphere influences, and that their narratives are built partly through interaction with one another. Abbreviations: NRCS = Natural Resources Conservation Service; FCIC = Federal Crop Insurance Corporation.

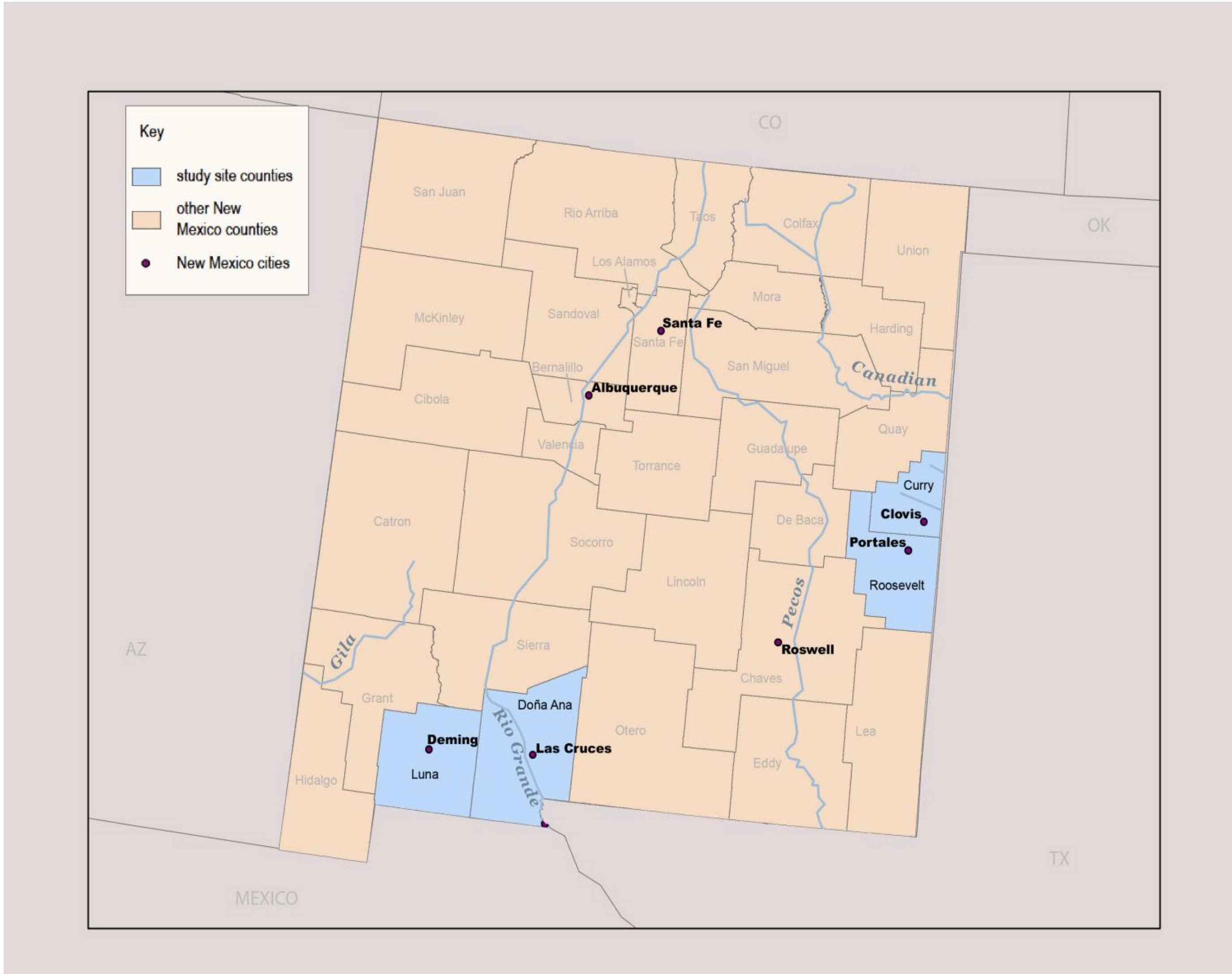

Figure 38: Study area counties include Doña Ana and Luna in southern New Mexico, and Roosevelt and Curry in Eastern New Mexico. Roosevelt and Doña Ana Counties were the original focus of the study. Due to substantial overlap in the farming communities of Luna and Doña Ana and of Roosevelt and Curry, however, it made the most sense to treat each set of counties as a larger farming community.

broad terms: I asked them to indicate whether their net income fell below markers of $50,000 and $15,000 in any given year, and they responded to the degree possible based on memory or records.

The analysis of farmer barriers is based on Lejano, Ingram, and Ingram's (2013) narrative-network analysis. I classified the influences on farmers as actors in their farm networks. I took the actors that each farmer described as an important influence on key decisions, and identified the narratives that farmers told about those network elements, including the ways in which important network elements interacted with one another. With Lejano et al. (2013), I found that the narratives farmers told of how they were influenced were far more revealing than network connections alone. Farmer narrative is therefore the focus of this analysis. Throughout, the focus of the analysis is on the ways in which given actors act as barriers or as facilitators of the goals for transformed agriculture outlined earlier in the chapter.

I also assess barriers in terms of whether they reside in the practical, political, or personal spheres of transformation (O′Brien and Sygna 2013; O′Brien 2018). As will become clear from the farmer's narratives, political sphere barriers to transformation are important, but they are strongly shaped by farmer's narratives, which lie in the personal sphere of transformation.

Barriers to Transformation

Metanarratives that encourage incremental adjustment: Water.

One set of barriers[35] to transformation in agriculture lie in the practical sphere of transformation. These barriers are created by decisions to react to climate challenges with incremental adjustments that limit future options. Water use decisions are one example of such decision-making. Water availability in Doña County has changed radically during this century. Extension agent Ron[36] describes how the situation has changed:

> When I first moved here [in the 1980s] there was a lot more water. . .Agriculture was more intense because you had plenty of water. You had all the water you wanted. The dam [reservoir] was completely full if not overflowing. So, you had regular irrigation, the water table was high. So, you had all this going on so you could plant anything you wanted and you irrigate it as much as you want to get whatever you want to do. Well, that was back in the [19]80s. Now, you know, a few years go, 2013 or so, the Elephant Butte [reservoir] got to its lowest point ever, you know, from since it was built. . . .It was down to like 3% or 5% of capacity.

Farmers, therefore, have had to make decisions that account for far less available water. The irrigation season, as a result, is also shorter, adds farm manager Camila, “I mean, the irrigating season with EBID [Elephant Butte Irrigation District], and that’s the water we get from the lakes and stuff, um, I mean, shoot, [in the past] it would start like in March and last through November or something. And [now] it’s pretty much like one month.” As water allocations have dropped from a “normal” full allocation of three acre-feet (per acre) in the 1980s and 1990s to allocations as low as 3.5 acre-inches at the lowest point of reservoir storage in 2013 (Elephant Butte

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[35] As discussed in the previous chapter, barriers are obstacles creating by human thinking and systems that may be overcome, “with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions. . .” (Moser and Eckstrom 2010, p. 22027). Barriers are opposed to limits, which are obstacles that are “absolute,” as in “physical and ecological systems in their natural state” that cannot be stretched beyond a certain point (Moser and Eckstrom 2010, p. 22026).

[36] All names are pseudonyms.

Irrigation District, 2014), farmers have drilled more and more wells to make up for the water they are not getting from the Rio Grande.

From the perspective of some in alternative agriculture, much of the thinking about water looks very short-sighted. When asked about solutions to water-shortage issues, Victoria, a grower for a non-profit organization, notes, “I think everybody’s trying to adapt in their own way. Some more than others. . . .Then there’s some pretending like there’s not a need to adjust.” Certainly, not adjusting at all would be short-sighted. With most farms having to dig new wells, however, nearly everyone is adapting in at least the sense of acquiring new sources of water. Ron, the extension agent, explains a common reaction:

> And, you know, it’s tough because a lot of the things went away, and a lot of people were irrigating only from Elephant Butte [i.e. from water the Elephant Butte Irrigation District provides from the Elephant Butte and Caballo reservoirs via the Rio Grande]. When that dried up, then there was no water to irrigate with. So, at that time, I hear a lot of people calling from pecan farms. “What do I do? I don’t have any water from Elephant Butte. How do I keep my pecans alive?” You better put in a well because they aren’t getting any water from anywhere else. Certainly isn’t raining and Elephant Butte isn’t going to give you any water. You only have one choice, to have a well, otherwise it’s all going to die. You’re going to lose all your pecan trees.

There are some alternative routes to acquiring enough water, but the main alternative, fallowing most of one’s fields and concentrating all allocated water on just one field, is not feasible for farmers making their living from the land[37], especially for those making land payments. So, the main option that most identify is digging new wells. Jeffrey, for example, explains the choices he made when acquiring new land south of his existing farmlands:

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[37] Including those growing perennial crops such as pecans.

> Really that year was 2009[38]. It's when that year happened. It just happened.
> Interviewer: When what happened?
> When we didn't get a lot of water from EBID [Elephant Butte Irrigation District]. And that year that's why we went cotton. That 400 acres of cotton and it just happened to be a dollar a pound. But we didn't get good yields. . . Because we didn't have the water. We were new to Cruces and we didn't have wells where we have them now. . . .we had to go build an infrastructure [i.e. wells] down there.

Jeffrey notes their family made an explicit choice that year to grow a less water-hungry crop (cotton), although a crop that has a long and ongoing history throughout the area. Even more drought-tolerant cotton suffered, however, and so they chose to dig wells to make up the difference in water allocation between historical allocations and drought-year allocations. From their perspective, digging wells was required if they were to continue using the new land they had obtained. Those who did not choose to dig wells, says Ron, lost their orchards to drought or sold out their land entirely.

Despite a substantial drought in the 1950s that also left Elephant Butte Reservoir depleted (Texas Water Development Board 2018), most farmers have only adjusted to drought as it arrives, and usually by drilling more wells (Michelsen et al. 2014). This incremental change—digging more wells to make up for water shortages—puts agriculture in a more difficult position in the long term. One challenge for the future is the ongoing lawsuit between Texas and New Mexico over the Mesilla Valley's use of groundwater, in which Texas contends that when New Mexico allows groundwater pumping south of Elephant Butte Reservoir (see Figure 8), it is not meeting its downstream obligations under the Rio Grande Compact (Paskus 2018b). The Mesilla

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[38] He probably was thinking of 2011, which was the first year in which water allocations dropped from close to 2 acre-feet to just 4 acre-inches. In 2006, which Jeffrey named as the first year of the drought, they were at half the "normal" allocation of 3 acre-feet, but the 2009 allocation was 2.5 acre-feet.

Valley aquifer is directly recharged by flow from the Rio Grande, so Texas claims that underground flow as part of its allocation. An equally important challenge lies in the drawdown of the aquifer as pumping increases (Paskus 2018b). For farmers who choose drilling wells as their main adaptation to declining river flow, the possibilities of either losing legal access to water or finding water too expensive to pump as levels drop are both real. Yet, with the rare exception of Victoria, the grower for a non-profit organization, no farmers suggested that they were working on alternatives to groundwater use. Even Victoria's alternatives were plans for the future: "We're going to have sections where we have desert perennials planted. And we intend to plant *nopales* [prickly pear cactus]." The metanarrative of "dig wells or the crops die" thus locks most farmers into a future that may quickly lose viability with an adverse legal decision in Texas v. New Mexico and Colorado. Even with continued legal right, expected decreases in snow cover in the mountains feeding the Rio Grande could mean increasingly, and eventually, inviably expensive groundwater pumping as the aquifer loses its source of annual recharge.

A similar metanarrative is present among those who farm the region of eastern New Mexico that depends on the Ogallala aquifer. Farmers here, however, do more directly acknowledge water shortage as a significant problem. Eastern New Mexico lies over the far western edge of the southern Ogallala, and it is a shallow section of the aquifer. Ed, a farmer in Roosevelt County, says, "Our water's getting shorter and shorter." Ed adds:

> Right now, our water level is a little over 100 feet down at the bottom of our wells. And most of the wells around here are about 125 or 130 feet. So, we've got about 20 feet of water left in most of our wells. It's gone down basically a hundred foot in the last 70 years. So, you can figure how much 20 feet's going to last, 20 feet or less. There's a lot of places out there, they're not irrigating anymore because the water level's gone down that much.

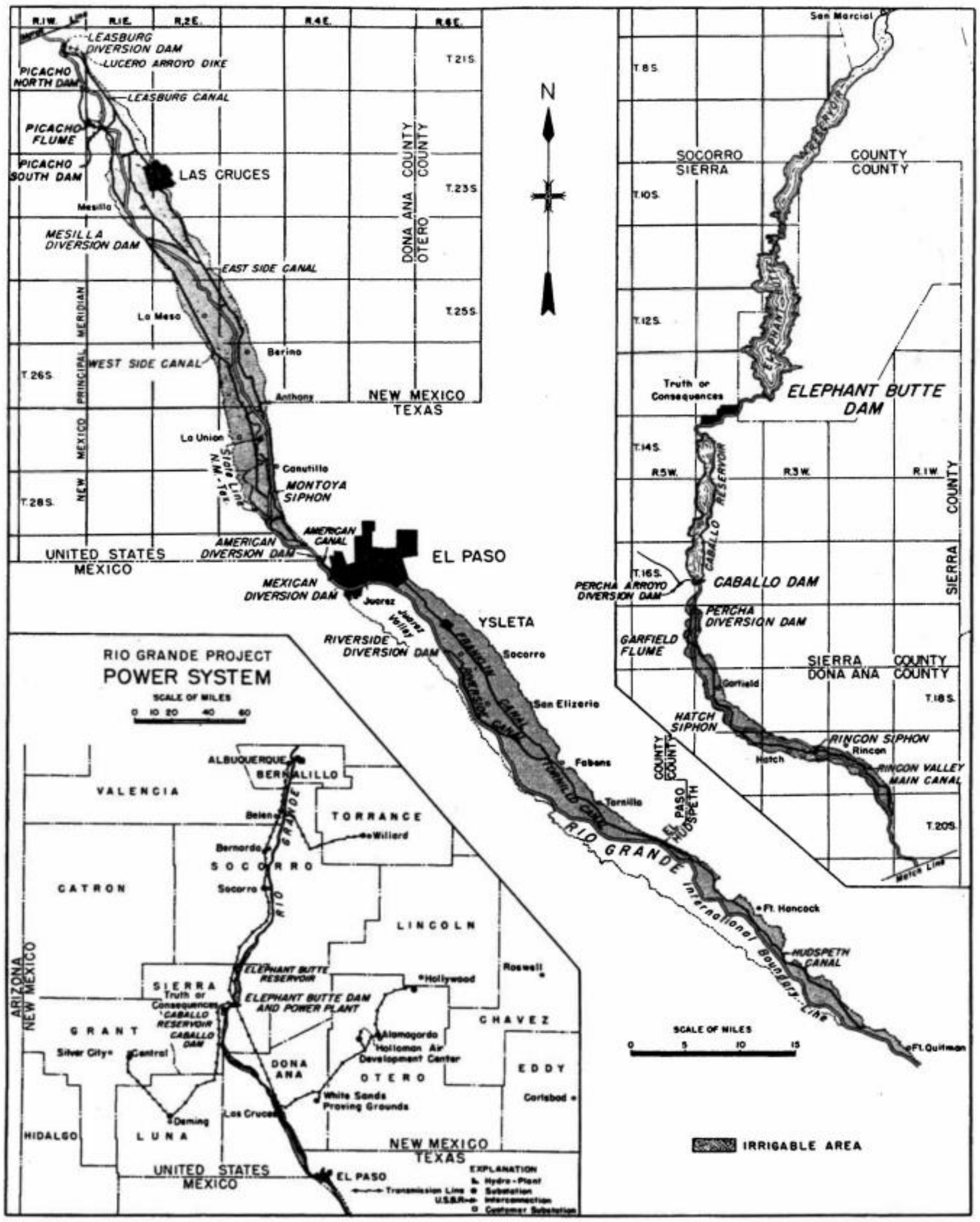

Figure 1 - Elephant Butte Reservoir location map.

Figure 39: Locator map for Elephant Butte Dam and Reservoir. The map in the bottom left gives an overview of the river as it crosses southern New Mexico counties. Note the dam in Sierra County, north of Doña Ana County. The middle map offers more detail of the irrigation canals ("ditches" or "acequias") starting just north of Las Cruces. The right-hand map gives a sketch of the major dams and reservoirs. All water south of Elephant Butte Dam belongs to Texas under the Rio Grande Compact. Source: Bureau of Reclamation, Elephant Butte Reservoir 1999 Reservoir Survey Collins & Ferrari 2000.

Randall, when asked about the water future for Roosevelt County, and whether people will be able to continue irrigated farming, bluntly says, “no.” He tempers this assessment by adding, “It’s going to be spotty. There’s always going to be water in places, but the quality of it is not going to be good enough to grow like I am now with certain crops.” He continues, “Oh no, we’re in a horrible drought, yes. Look at all the dead trees in the country. That is just lack of water.” Clancy, a dryland farmer, notes of the irrigated farmers in Roosevelt County that, “they’re out of water.” The metanarrative around water availability in the county, then, is quite clear in saying that water for irrigation is rapidly running out.

Nonetheless, the attitudes about irrigation among some farmers are much the same as those in the Elephant Butte Irrigation District. An alfalfa farmer in Roosevelt County, for example, Ed says he adjusted to drought conditions in 2012 by, “well, just irrigating all the time I guess.” Michael, too, noted that his irrigated “wheat grain and grain sorghum, they suffered during that time because, I mean, you know you just couldn’t keep it wet,” but he irrigated as much as he could to keep them going. Irrigated farmers are often determined to keep

watering the crops even as they are aware that the water is poor quality for their crops. Ed says:

> You don’t drink this water now, I mean, it’s terrible. And, you know, the 60s, well, like I said, the [19]70s, the water was getting salty enough because our water table was going down that we had to quit growing peanuts because it got too salty. And the, basically, it just keeps getting saltier and alfalfa’s not really a salt tolerant crop.

Randall echoes both concerns about quality and quantity, while still saying that he is using as much irrigation water as necessary for water-intensive alfalfa:

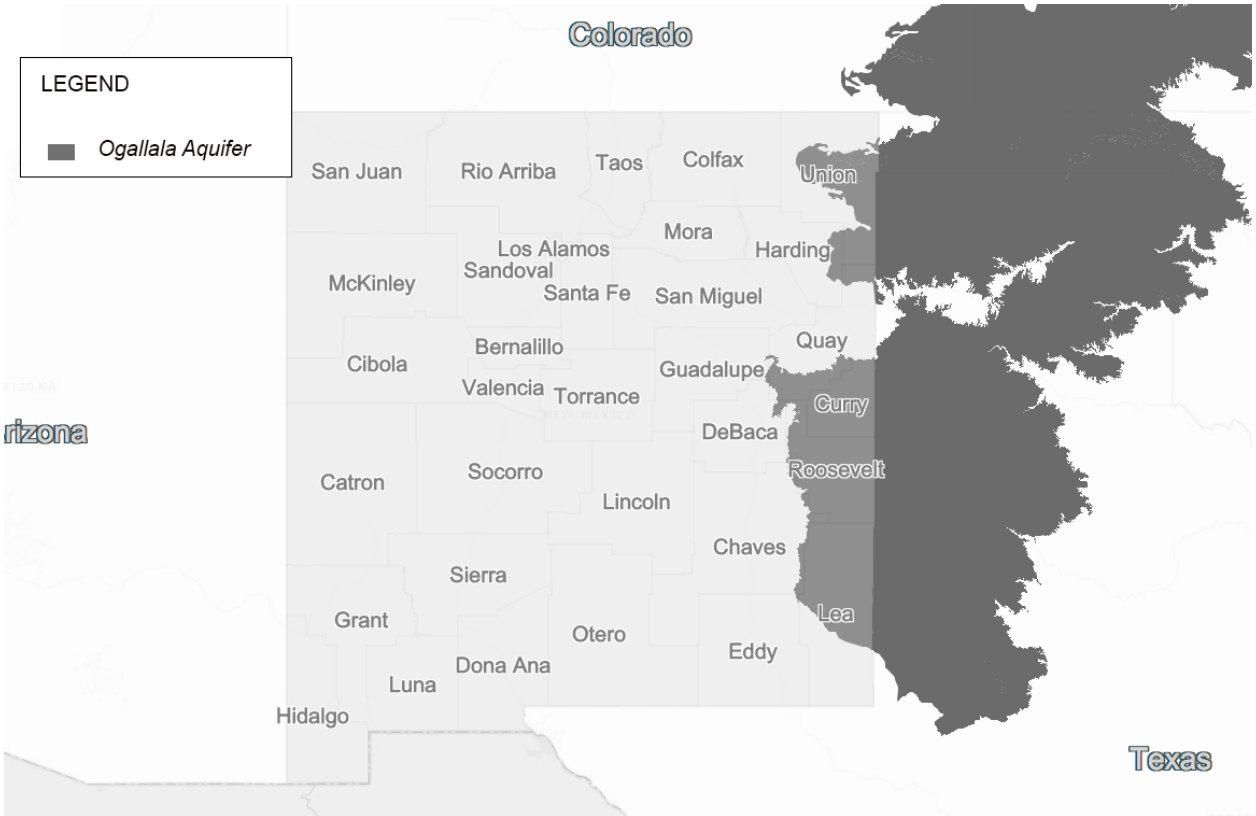

Figure 40: New Mexico Counties over the Ogallala aquifer. County and state data from U.S. Census Bureau (U.S. DoC 2007). Ogallala data from USGS Groundwater Resources Program.

> We're having to pump lots of water, our water—pumping out lots of water, it isn't going to make a lot of hay because there are a lot of minerals and salt in the water, the hay don't like it.

The options that most of the irrigated farmers see as available to them are simply to keep growing as long as they can using their sub-optimal water. In narrative terms, water shortage (and water quality decline) as foe is to be fought simply by acknowledging its presence but continuing to pump water knowing that the foe is bound to win in the end. That is not to say that there are no efforts at conservation. Randall and John, for example, both talk about changing the heads on their sprinklers. Over time, they have placed the leads on the heads closer together so that they will work with lower pressure, and now heads move just above or even on the ground instead of sprinkling from high in the air as center pivots used to. The stringing of hoses to put sprinkler heads close to the ground result in much more water going to the crop rather than being lost to evaporation. But those changes are largely out of necessity in dealing with the decreased water available to them from wells and increased evaporation with higher temperatures--with some support for changes to sprinkler systems coming from grants from the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP).

So, there are incremental measures to attempt to eke the last of the water out of many of the irrigation wells that remain. However, the metanarrative comes across similarly to that in Doña Ana County, where there is a use-it-or-lose-it philosophy. Farmers see little point in minimizing their use of irrigation because the tiny amounts offered by aquifer recharge each year would not sustain any of the commonly irrigated crops with which they are familiar. There is little, if any, counternarrative among those who irrigate about means of changing their farming systems to leave more water in the ground in the long-term—aside from simply abandoning irrigated farming, which is being felt as a forced, not a deliberate, transformation of the system. There is no conversation about a form of deliberate transformation that would radically alter farming to allow aquifer recharge even while maintaining some form of production. As drought makes dryland farming increasingly challenging, the county is being pushed toward an undesired (by farmers, at least) move away from any form of cropping. The sense of having few options persists even though, as Ed says, “If we don’t restrict our water use, in about ten to fifteen years we’re going to be out of water, and I don’t doubt it.”

Why does it persist, this metanarrative that encourages irrigated farmers to keep using what they have while they have it? One girder supporting its persistence is the fact that irrigated crops grown in the area are higher-value crops than the dryland crops. For example, prior to 2016, Randall says that (irrigated) alfalfa in Roosevelt County could gross $1,000/acre, and net around $500. State agriculture statistics for 2016, however, have (mostly dryland) wheat grossing just $72 per acre. So, the smaller areas of land used by irrigated growers can offer a good income, whereas dryland growers must use many more acres to make their production worthwhile. John, for example, says that his irrigated system has allowed him to have income above $50,000 consistently for the ten years we discussed. Frank, on the other hand, says that his dryland income is often a "wash," with income and expenses coming out nearly equal, although only "about three" of the ten years under discussion saw the household's net income fall below $50,000, and it likely never fell below poverty level of $15,000. So, the consistency and potential for profit contribute to farmers holding on to the narrative of needing to use the water regardless of consequence.

In addition, farmer identity, prior investments, and the difficulty of conceiving a system that would use water at a rechargeable rate make the use-it-or-lose-it metanarrative persist. Farmers identify closely with the crops they grow. John, for example, is heavily involved with the state organization for one of his main crops and sees that work as a key part of his identity. Moreover, major shifts in crops require major reinvestments in machinery. John mentions his specialty harvester, "I paid $320,000 for this machine, so I can't afford not to be using it." Shifting styles of production and associated machinery is an expensive endeavor and takes commitment to using a given piece of expensive machinery in the long-term. Shifting systems would mean major new financial investments in machinery, as well as substantial time investments in finding new marketing outlets and knowledge about the new crops. Thus, radical alternatives, along the lines of the desert permaculture that has been attempted in Jordan (MacKintosh 2014), are difficult to envision[39]. Given these barriers, the persistence of the irrigated farmer's narrative, in which there are no real alternatives to growing crops like alfalfa and chile except to give up irrigation altogether, makes sense.

Metanarratives that encourage incremental adjustment: Pests

Similar metanarratives surround decisions about dealing with a new pest challenge. The sugarcane aphid (*Melanaphis sacchari*) arrived in the U.S. in 2013, and rapidly spread to areas growing sorghum (Bowling et al. 2016). It hit Roosevelt and Curry Counties in 2015, and rapidly drove sorghum (milo) yields downward. Clancy describes the impacts:

> And these destroyed our grain sorghum. It's going to make it prohibitive for us to grow grain sorghum, and that's been one of our major crops. They've just come in here, and the price to spray and all of that stuff—it's just cost prohibitive to grow grain sorghum now.

Asked what he will do, Clancy says he will replace all of his sorghum with corn. Michael's experience with decreased sorghum yield was severe:

> And the first year I had some of it—made a real good model crop in spite of it all. I was just, there's no big deal, you know. So, the next year, which was this year, they showed

[39] Such projects might be able to use more water for establishment and then just rainfall for maintenance, using water collection strategies like swales, as the project in Jordan does. Such uses of irrigation water could operate as a fuller acknowledgement of the losses in the aquifer and produce high-value yet low-water using crops. However, since the area experiences winter freezes, crop varieties would need to be chosen that were both winter hardy and highly drought tolerant. Newer varieties of pomegranate could be one example of such selections.

> up, same thing, late in the season. Don't worry about it, you know. Well, I mean, they just exploded, and finally got to the point, I said, "You know, if I was going to spray them, I should've already done it." This is after the fact I really would be wasting my money. . . So, I like to just let them go ahead and have what they wanted of it. Cut our yield down from nine thousand to about three thousand.

Michael leaned toward the same solution, growing corn in place of milo:

> I don't know if I want to grow milo again or not. That's got this problem—if these buggers are going to be around here. Because, you know, it's apparent that we're going to have to spend a bunch of money to deal with them, and there's not much money in it. So, corn, for instance, which would have to be late in the year. If you get a good crop can be quite a bit better than the milo anyway. So, takes a lot more water, but we just plant fewer acres. . . . Like I say, I haven't done it yet; I'm not sure I will. But I'm considering it because of that new insect.

Like Michael and Clancy, Christopher experienced substantial losses in the first year of the sugarcane aphid, having decided not to spray: "I think our crop would have been twice as big had I spent the money [to spray pesticide]." He looked on his decision not to spray as "a big mistake," but was not yet sure what his action for the next year would be. Despite substantial losses from the pest, the only options identified by any of the farmers experiencing the losses were insecticides and changing crops[40]. Moreover, the crop to which they were considering changing is a substantially greedier water user, even with increasing efforts to breed more drought-tolerant varieties of corn. None of the farmers expressed any awareness of options to increase in-field plant diversity, nor even integrated pest management (IPM), as a potential

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[40] These decisions would be classified as incremental changes. The framework for identifying incremental versus transformational change is discussed in chapter 6. In brief, however, a crop change is incremental if it does not require other substantial shifts in the form of substantial new machinery investments, identification of new market outlets, or new methods. A shift from milo to corn in the context of these two counties does not involve substantial changes in any of the above, partly because corn is a crop with which there is already extensive experience in the counties.

alternative. The reasons for some of this lack of awareness are clear: sorghum polyculture has not been a focus of U.S.-based agronomic research, despite its common occurrence elsewhere in the world (Altieri 2009; Ghosh et al. 2009). The lack of IPM awareness is not as easy to explain, given the long history of IPM for sorghum pests (Harris 2001) and some already developed IPM methods for sugarcane aphid despite its newness to the U.S. (Bowling et al. 2016). So, despite research in the U.S. on IPM and internationally on sorghum polycultures, counternarratives of how to conduct large-scale agriculture do not appear to exist in regard to pest management in sorghum. In addition, much of the decision-making about both pests and water shortages occurred in the practical sphere, and left farmers locked into incremental alternatives that could limit future transformation. Some of the reasons for the limited scope of the metanarratives around agricultural change in reaction to influences like water shortages and pests are further explored in the following sections.

Barriers in the Political Sphere: Policy

The political sphere of transformation includes “systems and structures”—institutions, rules, markets—that shape the transformations that can occur in the practical sphere (O′Brien & Sygna, 2013, p. 6). In the United States, the farm bill passed approximately every five years and the U.S. Department of Agriculture that administers the bill’s programs have substantial influence over farming in both creating rules that determine farmers’ choices and offering financial incentives (or disincentives) to make certain choices. The barriers and supports through which the farm bill and the USDA produce options for farmers are real, but farmer narratives about them can also further inhibit or inspire change in agriculture.

Farm subsidies

One important means through which the USDA regulates farming is through its insurance and subsidy programs. With the Agricultural Act of 2014 (a.k.a. the 2014 U.S. Farm Bill), a subsidy system that largely paid farmers directly was significantly revised to encourage farmers to instead participate in farm insurance programs (Orden and Zulauf 2015). Nonetheless, payment programs continued, as well, some of which pay farmers based on historical crop acreage rather than current production (Morgan, Gaul, & Cohen, 2006; Orden & Zulauf, 2015). With farm insurance programs subsidized through the USDA's Risk Management Agency (which managed $102 billion of insurance liability in 2015) (Risk Management Agency 2016), insurance represents another important source of federal support to farmers. Yet, it is largely the largest and wealthiest producers who receive the bulk of support from both insurance subsidies and more direct forms of support (Environmental Working Group 2018b). Among the conventional growers in this study who receive insurance or subsidies, most minimized the importance of government support to their overall revenue, and usually characterized it in their accounting of income as being at most one or two percent of the revenue for any given crop. Farmers often express conflict about their relationship with government support. Chuck, for example, says that he never bought crop insurance until, "…they started requiring that you buy crop insurance in order to qualify for government programs." He adds:

> I probably insured some milo, too. You know, like I said, whatever I had to do in order to—government programs in this country are something that is just kind of a necessary evil. You know, uh, we all think in the back of our head that we really think we would all be better off if we didn't have any of 'em, but at the same time, we don't want to take the risk if we can help it, because they do help us sometimes.

Danny, aware that "you can go online [to the Environmental Working Group's (EWG) Farm Subsidy Database] and look up anybody in the country that receives a subsidy," claims:

> So, when you hear of complaining [about] the farmer, all he does is he's getting that government money, this and that, well, the farmer doesn't want it. He wants the markets to work, capitalism to work. But the government realizes they do that then it's going to affect [food prices]. To go the farmer: pennies. And if it's the other way around, you're paying through the nose on food.

Danny, a young farmer working alongside his father, has a less tempered view of subsidies. Since his father still leads the farm, he may have had less awareness of their impact on farm finances—he did not receive his first subsidy payments until after the interview according to the EWG database. Nonetheless, his strongly averse framing of subsidies, as an enemy to the effective functioning of farm markets, often underlay the metanarrative of subsidy discussions with conventional farmers. Frank expresses a similar perspective, but sees the situation as having changed over time:

> I started farming 30 years ago. I knew guys that farmed off the government with direct payments and different guaranteed this and that. And that's all they farmed for. They didn't even farm to make a crop. They could make enough living off what the government paid because it didn't cost them nothing—farming. You can't do that [now].
> Interviewer: Since you have to plant just to get insurance?
> Yeah, yeah, even when you do that, but you just got to make it, you can't—you can't live off the government, it just doesn't pay enough. And it just ruins everything. It ruins the markets anyway. I mean, they're subsidizing corn. I mean we have one of the biggest numbers of corn farmers ever because we farm for the government, not what the market wants us to do.

Interesting in this metanarrative is the mythical other. The farmer who lived off the government was never the speaker. And that inherent otherizing demonizes government, or at least government support, in the narrative.

Yet, the conflict is striking. Some of the farmers speaking strongly against government support (as Chuck's narrative suggests) are the very farmers receiving it in fairly large amounts, even if it represents a minor element of income when a farmer is grossing $1 million. Frank, for example, was paid nearly three quarters of a million dollars over 20 years (Environmental Working Group 2018a). In chunks of one to three tens of thousands of dollars per year, it does seem a drop in the bucket relative to whole farm revenue. But it is easy to see where farmers' uneasiness with farm support comes from. First, it represents far more government support than other private households receive. For a comparison with other private individuals, we can look to the mortgage interest deduction as one of the largest subsidies granted to households. First, the mortgage interest deduction, like farm subsidies, most benefits those with already higher incomes (Frostenson 2017). However, even top earners saved an average of just $5,021 on their 2012 tax bills because of the mortgage interest deduction (Randazzo and Stansel 2013). Thus, the mortgage interest deduction is a significantly smaller benefit to households than are commodity, disaster, and conservation subsidies for a farm household like Frank's. The comparison may not be entirely fair. After all, farms are businesses, and other private households (generally speaking) are not. But farmers see themselves receiving substantial government benefits out of line with what any of their non-farming neighbors might receive.

Of course, the metanarrative of the evils of government support does not derive solely, or perhaps even primarily, from this sort of explicit, local comparison. From conservative think tanks (Mitchell 2014) to popular media (Beck 2010), narratives of smaller government as better government are common. Such narratives often include discussion of government payouts and their negative effects. Such broader societal narratives appear to have been drawn into the subsidy metanarrative of conventional farmers.

While it appears that the metanarrative recounting the damage of subsidies does not limit farmers' use of subsidies, the metanarrative may be having subtler and simultaneously more far-reaching effects. For example, those retelling a narrative of the damage of subsidies may be more likely to vote for those who tell a similar narrative, thus limiting future subsidies. More importantly, from the perspective of agricultural transformation, repeating such a metanarrative limits the likelihood of farmers advocating for more and different subsidies that might change the focus of government support. Subsidies for multifunctional agriculture, for example, could require a substantial restructuring of farm programs, but could also still require substantial payments to farmers and rural communities—payments that do not fit with the metanarrative about the evils of subsidies. People might accept the payments, but, if convinced by the "evils of subsidies" metanarrative, would not be likely to advocate for them.

Subsidies and narratives about them are thus doubly damaging to the goals of transformational agriculture. The existing subsidies continue to focus most heavily on the production of single commodities, limiting support for multifunctional agriculture. And the metanarrative of the damage of subsidies works to erode farmer (and rural) support for the kinds of transformational change that could rebuild rural communities and better prepare agriculture for future challenges.

The Food Safety Modernization Act

Although the USDA has long been the primary federal entity with which farmers have interacted, the Food and Drug Administration (FDA) also has jurisdiction over food in regard to food safety. With the passage of the Food Safety Modernization Act (FSMA) of 2011, the FDA came to play a much larger role in farm operations for farmers who grow any form of produce. From some farmers' perspectives, the FSMA produced new tracking and paperwork requirements. For others, however, those who were already certified under Good Agricultural Practices (GAP) or Safe Quality Food (SQF) (a higher standard than GAP), complying with the FSMA was a minor change. Camila describes the situation of the large farm operation for which she is the business manager:

> It's kinda like a law now that you have to—it's not voluntary. It's more of a law; if you're packing vegetables, you have to have some type of food safety program in your company, so. . . we've been doing it for ten years, and we try to stay up to date on everything. And, you have food safety a part of your program and it just really helps you manage your farm better if you take it to heart, you know?

Camila sees the system as benefitting the business:

> It has helped us become more organized. . .. You know, you need to keep track of chemical inventories. . . keep those neat and organized. You know, it's helping us out for the GAP side of it because we're SQF certified. . .. That's a good thing. As far as here in the shed, we're always trying to improve and upgrade and stay in compliance. . .. Once you're in it and you have your program established, maintaining it is, you know, it takes time, but it's not a headache.

Camila's narrative reflects a vision of the world that brings Foucault's governmentality to mind (Foucault 1994). She seems quite comfortable with the idea that the operation she runs must be entirely legible to regulatory forces. So much so, in fact, that she sees the requirement for legibility as helpful to the operation to maintain its own organizational systems. It is important to note here that she is working for an operation large enough to hire her as full-time business manager—and large enough to have run a large, enclosed packing shed for well over a decade.

The size of the operation becomes important, I learned, when smaller growers are factored in. As previously discussed, the FSMA included an amendment intended to protect smaller growers, but it does nothing to shield small growers who sell none of their produce directly to consumers. Jim is one such grower. After the passage of the FSMA, he was inspected, and a rat-chewed box was found among those he was preparing to ship. Because the FDA was not yet enforcing the law, he agreed to work with the New Mexico Department of Agriculture (NMDA) on improving his operation to ensure compliance. However, for some reason he never discovered, the FDA had his facility raided, and assigned a substantial fine that amounted to a lost year of business. Jim's relatively small business had a traditional open shed, in which workers packing produce were protected from the sun but were exposed to winds to keep them cool. Kasey and Pearl also discussed how the new law would require the enclosure of sheds. Both Jim and Kasey and Pearl felt that the enclosure of sheds was a step backward for workers. Pearl describes her frustration:

> I had the prettiest chile peeling place, and then all is green, then with the air going through it, real nice and everything. Food and Drug shut it down, closed it down. . . It's too hot working in there. All closed up and stainless steel and then just that little air conditioner in the back where we are—no air. Back in the packing area you can't have nothing like dust or anything blowing. They want no air movement, but yet you're dying in there and then you get to working with hot, hot chile and everybody is dying [from the hot chile fumes]—it's like a coffin. And that makes it—I mean, that's not sanitary.

For small growers like Jim and Pearl, then, the standards can result in poor outcomes for workers because they cannot afford the systems that make enclosed sheds feasible. In terms of paperwork, too, the system can become a steep hurdle for smaller farms, according to Jim, "Now they require you to do this, you do it, you know? You basically have to hire one or two people to do all your paperwork." He feels that the paperwork requirements are "too much of a burden for a smaller operation."

Regardless of the size of the operation, the requirements of the FSMA compel attention and money to be focused on paperwork and tracking. The goals of the act cannot be argued with—food related disease sickens 48 million people and causes 3,000 deaths per year in the United States (Centers for Disease Control and Prevention 2016). But the burdens on smaller growers mean an increased viability of larger farm operations over smaller farms, contributing to a further degeneration of rural communities as more farmers are forced to find off-farm work and fewer remain in key roles in rural communities. The Act therefore contributes to making farming a more isolating profession, as well as potentially drawing resources away from the in-field transformation of farms.

Conservation and Agroecological Programs

Farm bills, including the 2014 Farm Bill, have included substantial support for programs supporting multifunctional goals. The goals of the bill often look much less than multifunctional, as goals are siloed from one another—commodity programs from conservation programs from rural development programs. There are, nonetheless, important supports for elements of multifunctional agriculture built into the bills and their administration by the USDA.

The Conservation Reserve Program (CRP) and related programs such as the Grassland Reserve Program (GRP) and the Farmable Wetlands Program are all designed to keep land out of cropped production. All are meant to create or keep perennial cover, and often cover of native species. As both Roosevelt and Curry Counties were important sources of Dust Bowl erosion (NRCS n.d.), and continue to have croplands classified as highly erodible (NRCS New Mexico 2013; Portales Field Office Local Work Group 2014), the CRP and GRP have both been important ways to limit wind erosion by taking land out of production. Frank and his wife Minnie, however, note that the program shrank the local farm population:

> Minnie: You know, we've never used CRP like, "Okay, I'm going to go down and get a job with every acre I have [in CRP]." Which is why farmers—that's why there's nobody left. . ..
> Frank: 'Til the Russian[41] came and broke it all back out [into farmland], yeah. . .. At that time, my dad's generation, they were all in their 60's and 70's when [CRP] first came out. It just gave them opportunity to retire. No kids could farm, but he, it gave him a guaranteed income. So, he just put it in . . .
> Minnie: And then that took a lot of cash share crop from some of the other farmers. . .. 'Cause you had, you know, that was their landlord, so they may not have enough acres. So, a lot of those guys then had to go to town and get a job.
> Frank: We lost about half of what we were farming [in the county] during the first CRP and lost business big.

They note that the $50 per-acre rent paid by the government at the advent of the CRP (in 1985) has declined to about $29[42]. Frank adds, "Which is good, because we'd have every acre in the county in CRP if it wasn't [low rent]." Conservation Reserve Program land is often viewed as what to do with land upon retirement, as with Randall's father-in-law, "He's got all his land paid

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[41] "The Russian" was a somewhat mysterious character to whom several of my informants referred, but none knew much about. In trying to track down more information about him by asking for useful people for sources, I kept running into dead ends of people who did not return my calls or those who ended up knowing nothing except that they had heard of him or other outsiders acquiring large acreages in the county.

[42] As of 2018, rental rates had declined still further, to $20 per acre in Curry County and $23 per acre in Roosevelt County. Payments for Grassland Reserve were just $4 and $2, respectively (Farm Service Agency, 2018). For comparison, Frank noted that at the time of the interview, he was renting dryland cropland at $400 an acre. The cost had been driven up the outside investors' purchases.

for, [and] in CRP." Chuck considers himself retired and, "I've been basically all CRP the last three years." Clancy, nearing retirement, says, "We've done lots of CRP land. . .. everything that we farm now is rented land. All of our land that we own is CRP." Few of these farmers expect their children to enter farming, and many already have children well-started in professions far from Roosevelt and Curry Counties. So, turning the land into CRP land means less maintenance and ongoing income for them for as long as they continue to own the land. As far as erosion in concerned, the arrangement seems wise. CRP, however, is not a permanent arrangement. And land in the area under CRP for 10 or 20 years recovers very little of its quality (Idowu and Kircher 2014). So, the end of contracts could mean a quick return to highly erodible cropland, as Frank and Minnie mentioned. "The Russian," another buyer from Chicago, and a local individual who "built dairies for a living" each invested in tens of thousands of acres in the area. These land investors bought the land and were "breaking it all out" [i.e. converting it back to cropland], hiring locals to do the farm work, but reaping any profits for themselves. In sum, the CRP has environmental benefits as long as it remains in CRP contracts, but the system has hastened the consolidation of land and the loss of farmers from the area.

A longer-term view of the region—an area long grazed by bison and other ungulates before European settlement—might consider CRP as a way to reproduce past grazing lands. The 10-15 year contracts are a hurdle in this regard, but potentially negotiable if there was political will behind a change. With the current system, however, farmers are not permitted to graze CRP except in emergency situations as during the height of the drought in 2011-2012. Rather than relying solely in CRP, then, Michael chose to use cost-sharing programs (e.g. USDA's EQIP) to put his land back in grass for his retirement. "It's not CRP," Michael says:

> . . .but the government will cost-share the cost of the seed and put it in, but they don't make annual payments like they do CRP. But you get to use your grass immediately any time you want to turn cattle on it, you know? It's yours, free to use, you know?

Thus, CRP land does not provide adequate flexibility to treat the land as agricultural land (i.e. ranchland), not does it pay enough to completely replace cropland. A rethinking of CRP land for dryland regions, with a thoughtful incorporation of grazing into the system, could be one means of transforming agriculture at the heart of the Dust Bowl region to be closer to the pre-existing ecosystems. The question of rural employment, however, would still arise, as dryland ranching is an extensive rather than intensive use of the land.

Like the conservation programs, the USDA National Organic Program (NOP) offers the potential for extensive agroecological benefits[43]. However, it, too, raises some barriers that can make it difficult for growers to participate in the program. Jim relates the difficulties he had in organic production, despite a strong commitment to it:

> We've had a lot of alfalfa that we—up until a couple of years ago, I couldn't find organic seed. So, we would plant raw seed and can't—just about all the seed you can find now is coated, which isn't allowed in organic. So, I planted some bad varieties that didn't yield, so we had to stop, you know. We've been looking for better varieties. . .. You know, being organic now, these companies around here aren't really—it's, organic is kind of new. . .. I call a lot of seed people to see what they have available, not very many. Now, they're starting to get where they can get some organic varieties in. . . . I've used to get some seed out of company in Utah, and I tried some seed—the alfalfa seed, mainly—They're like in Iowa or something like that, they sent me samples. Well, I tried some seeds from them but they didn't, you know, and that's what I was talking about, I already

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[43] Although the power of certification alone to produce extensive agroecological benefits has certainly come under question (Guthman, 2004a, 2004b).

> had fields that didn't yield, and you know, seeds that aren't compatible because I tried to use organic seeds and the company mainly they had some raw seed but it wasn't organic.

Jim's narrative covers a lot of ground. The USDA NOP regulations include requirements for seed. It must be uncoated. So, lacking local suppliers of organic seed, Jim was trying to mail order seed from other parts of the country where organic production is more established. But alfalfa from more northerly parts of the country does not do well in the Chihuahua Desert (Randall explained, for example, how dormancy matters in alfalfa, and so seed selection depends partly on freeze dates). So, lacking local organic sources, Jim experienced repeated failures in his hay crops. Jim's narrative, therefore, expresses both a barrier raised by USDA certification and a barrier raised by lack of a local, organic seed salesperson. For a farmer less committed to 100% organic production, the repeated alfalfa crop failures would likely have led to abandonment of organic certification.

In fact, it is the gaps in farmers' narratives that raise the most significant point about organic growing in southern and eastern New Mexico. Very few farmers mentioned the USDA NOP at all as any sort of influence on their decisions. Even among the smaller, direct-to-market growers, organic production was rarely mentioned. Lisa, for example, mentions it only to say, "We're not organic. And we don't claim to be totally chemical free. But for the most part, no, we don't use chemicals." Fred's narrative goes some way toward explaining that lacuna, at least in eastern New Mexico:

> I was [organic] for two years and I just—it makes no price difference. People wouldn't pay any more for it at the farmers' market here, and I spent so much time doing paperwork. And I like farming instead of doing paperwork. I decided we're not doing this no more . . .. As a a matter of fact, when I first—we started in 2006 was the first year we started selling at the farmers' market—And 2006 we decided we were gonna get certified

> organic, so it took a year. And the first year we sold everything good. And the second year we put up signs saying certified organic and everything, and people were scared of it. They were going, oh, you'll get diseases and all kinds of stuff from it because—and I had to educate a lot of people in this area.

The price premium possible with organic certification is the major financial incentive behind organic production, and ideally helps to outweigh additional costs involved in hand-weeding, paperwork, and similar additional burdens associated with organic production (Lloyd 2016). Yet for farmers in Curry and Roosevelt Counties, not only was the price premium not available, but a penalty in the form of lost revenue was imposed for a time. It is possible that in the minds of consumers there, organics had become associated with the food safety hazards to which FSMA was meant to react. Regardless of why "organic" was framed as a danger in customers' narratives, however, it suggests that alternative forms of agriculture may face consumer barriers in this part of the country, potentially hindering some forms of agricultural transformation.

Extension

Extension programs in the United States have long worked on a model of transferring knowledge from universities to farmers through local extension agents. (Lubell, Niles, and Hoffman 2014). But with a proliferation of other ways for farmers to access information, including the fact that farmers themselves are more highly educated than in the past, scholars suggest that new modalities for extension are necessary (ibid.). For farmers in the four counties in this study, federal, university, and research extension often played very limited roles. Federal extension in the form of the Natural Resources Conservation Service and Farm Service Agency were seen as being sources of funding for projects like replacing sprinkler heads—projects that aid in water conservation being a key intervention on the Ogallala Aquifer—but were rarely seen as sources of advice in other ways. They do act as regulators, as when they require farmers to maintain their insurance policies if they are to receive any federal assistance, but for important changes to their systems, farmers did not tend to name federal extension as a source of advice.

University extension, in concert with county-level agents, represent another means of disseminating information to farmers. Here again, however, few farmers named any ties to extension as an important source of advice for their farm systems. Although private-sector crop consultants often act as informal disseminators of university extension advice (personal communication, Kucharick, 2018), only a few farmers noted any dependence on crop consultants for advice. John, for example, says that he has found his crop consultant useful for advising him on changing planting times as local temperatures change. Henry is the only farmer who mentioned substantial interaction with university extension. His work on a computer program to better time his flood irrigation of his pecans was based on work conducted at New Mexico State University and in consultation with those who developed the program. By and large, however, farmers usually mentioned gaining their information from sources aside from extension. No farmer that I talked to mentioned interaction with county extension as a significant source of advice on their operation. Certainly, in New Mexico, at least, it does not appear that extension is a significant source of transformative information. Its very lack of influence constitutes a barrier to agricultural transformation in that without it farmers may tend to lean on sources of information like their input suppliers, whose advice may be tainted by their own companies' prejudices toward profit-making technical innovation over a more fundamental rethinking of agricultural production.

Farm Organizations

Two of the crops most strongly identified as New Mexican crops in recent years are chile and pecans. Both have trade organizations that advocate for their farmers. In the case of pecans, none of my potential entrees into the circle of the most powerful pecan growers (e.g. the Salopek family) panned out, so I was not able to talk to those who run the growers' organization, New Mexico Pecan Growers. The single set of goals articulated on their website is, "…to accomplish legal recognition of the water needs for New Mexico's pecan orchards in state court and administrative settings" (New Mexico Pecan Growers n.d.). Like pecan growing itself, then, the goals of the pecan association run counter to a transformation that prepares for a lower-water future.

As for chile, one of my informants was a central leadership figure in the New Mexico Chile Association. The goals of the Chile Association are more diverse, including promotion and market expansion of chile as product internationally, leading scientific and engineering innovation for the industry, and advocating for legislative and regulatory outcomes that support chile growers' priorities (New Mexico Chile Association n.d.). Because of its focus on a single crop, however, and its need to be concerned with strong competition from other countries, the association is doing little to further transformation. One grower I talked to, John, has himself engaged in transformative practices, however, as he has worked to create a chile system that better survives low-water and high-wind conditions. The growers association, as a whole, though is not strongly focused on such practices.

Thus, although there are farmer advocacy organizations that are important in New Mexico, they are not sources of transformational ideas or information.

Barriers in the Political Sphere: Markets

The Labor Market

Barriers resulting from policy often intertwine with barriers resulting from markets, as Jim's example of organic seed provision suggests. One way in which policy and markets have been closely intertwined in raising barriers to farmer access to labor. Labor can be a key element to agricultural transformations, as Mateo's experience with weed control in organic farming suggests. He stopped using herbicides entirely, and so needed to rely on hand labor to remove weeds. He was fortunate in his choice of labor contractor, he said, because "most of the people [he hires] are locals." For most farmers, however, as, John states, "Labor's getting so tight, we're trying to find a mechanized solution to every problem we can. Because we can count on mechanization. We can't count on labor." For growers like John and Jim, who grow green and red chile, hand labor is necessary for harvesting green chile, for which no mechanized solution has yet been fully developed.

The reasons for the labor shortage are complex, and farmers have multiple narratives regarding its explanations. Changes in Mexican immigration, however, provide one of the most significant explanations. Jim notes, "You know, [farmers] have trouble getting people even from Mexico." Although farmer narratives often pointed to other causes, the decrease in immigration after the 2008 financial crisis, combined with 1) strict limitations on Mexican immigration as the American economy recovered and 2) the increasing availability of agricultural work in northern

Mexico have meant that less agricultural labor is available (King 2006; Singer and Wilson 2009; Villarreal 2014; Wallace et al. 2017).

Farmers narratives about labor shortages point to other combined economic and policy barriers in agriculture. Jim describes his favorite farmhand[44] as being a great worker but notes that the hand is limited in the number of hours he can work. Since he receives Medicaid for his family, working too many hours would result in the loss of medical care—which is far more valuable to his family than the extra hours would be. From Jim's perspective, the continuing dysfunction of the American healthcare system is one major reason for labor shortages. John's explanation is similar, although with a different political twist:

> When I have work, I can't find one of those souls [laborers] anywhere. You know, the safety net in this country is very good. You know, they talk about the poor and how they get mistreated, but the safety net is very good in this country. If you don't eat in this country, it's your own fault. . .. But, the safety net's good and, you know, there's people willing to work that are hard to find, and they are much more expensive than they used to be. [later in the conversation, he adds] So, the dairies have most of the labor already scarfed up. Which is kind of funny. I have a lady that puts the hoe crews together for me. She's a great lady, she has some of my green chile. . .. She takes her kids and they go hoeing in the summer to make money for school clothes and this that and the other. Which is what a lot of people used to do. You don't see that often anymore.

Robert, too, connects with this metanarrative of too little work and too much offered by the government:

> But all the labor is—the labor force is getting older and older because, like, kids our age don't want to go out and pick chile. They don't want to go work hard. And so, which is like especially, when the government gives the people everything, then no one has the desire to do anything. It's like, "why would I got work hard and make the same as what I make sitting on my butt not doing anything, collecting unemployment?" You know what I mean?

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[44] Jim did not want to be recorded discussing this, so this description relies on my notes.

The metanarrative of the conservative farmer on labor, like that on subsidies, is a narrative advocating smaller government. Even John, who acknowledges that his own regulatory requirements have gone up steeply as immigration laws have been more strictly enforced[45] does not suggest that lower immigration may itself be the problem with acquiring labor. Therefore, as is the case with subsidies, farmers' narratives may themselves provide a barrier to transformative change. If too few farmers advocate for change to immigration systems, and against policies supporting the health and welfare of their workers, the links of such issues to agriculture may not become adequately clear. Transformations in diversity and in rural community that would benefit from additional labor are therefore less likely to happen.

Markets for Agricultural Products

Some of the same forces changing the labor market are affecting the market for agricultural products in both southern and eastern New Mexico. As labor availability has declined north of the border, products from south of the border have been gaining an edge among New Mexican buyers. Jeffrey and Danny say that their hay sales have been affected:

> We were doing silage, but the dealer's gotten to where they weren't paying and [were] changing their contracts. I mean, Mexico has come in and, I mean, hay went from $300 to $125. So, we've really backed out of the hay deal.

Pearl, too, says she has seen prices affected by Mexico's entry into area markets:

> And there's no reason for us to plant. We can't—they won't buy from us because we have to get a certain price from our product or we go out of business. So, we just quit growing. It's like, hey, you probably seen tons of bales of hay around. You know why? Because they can't sell it. They're, they're bringing it in from Mexico.

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[45] "So, I've went to the e-verify. I do everything to do the legal system. And now the paperwork. I've got a notebook in here this deep of paperwork having to do with people."

Robert also has seen that the dairies are “starting to buy a lot of feed from Mexico.” The chile market, too, seems increasingly dominated by Mexican imports. Robert mentions having taken a trip with his broker to look at the broker’s work with a chile operation in Mexico. Robert says, “Jalapeños are now all grown in Mexico.” Jeffrey notes that his local chile processor, “wouldn’t even take [our red chile] this year,” and adds, “Mexico is really pushing hard on the red.” Jim says, “I’ve got some friends that process chile, and they get organic from Mexico.” Pearl sees NAFTA as a key to the problems of growers in southern New Mexico, noting that she no longer grows chile because of competition with Mexico. While some of the assessment by farmers of the relationship between NAFTA and their market losses may be overblown (Pearl calls NAFTA “the ruination of the nation”), the U.S. has been importing substantially more chile than in the past. Foreign imports of chile (from Mexico and elsewhere) represent about 80 percent of U.S. chile consumption (Hawkes 2012).

At the same time as New Mexican chile, alfalfa and other hay crops have lost ground to Mexico and other foreign producers, pecans have taken an increasingly prominent role in production in both southern and eastern New Mexico[46]. Indeed, pecans are increasingly seen as important fallback in the case of market failures for other crops. Jeffrey explains the role they have on his farm:

> We invested in [pecan] trees many years ago, and that’s what really saved us.
> Interviewer: Just having the pecans to kind of back things up?
> Yeah, yeah. It’s, you know, on a ten-year average. Once they come into production they should net more than any crop in New Mexico.

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[46] Eastern New Mexico in this case, however, largely means Chaves County, home of Roswell, the Pecos River, and, of course, an abundance of off-world aliens.

Not only have pecans been extremely profitable (Swinford and Pkwy 2011), but they are well insured compared to other major crops in Doña Ana County, which are often insured only with hail insurance or catastrophic insurance. With pecan crop losses, Jeffrey says, the insurance, "guarantee[s] you 75% of what you would have made." One of the influences causing pecans to be highly profitable is the export of pecans to China[47] (Andrew 2017).

To those growing pecans in southern New Mexico, pecans have looked like the force that would save them from increasing market encroachment from Mexican and other foreign produce markets. (Of course, that attitude may change if Chinese tariffs are left in place). The problem with the loss of production of crops like chile in favor of increased pecan production is the significant difference in their water use. Alfalfa, too, is a significant water user. In considering the future of farms along the Rio Grande, water is an increasingly important consideration. Alfalfa and pecans require six acre-feet of water through a growing season. Other common crops in the area, like chile and onion, take four acre-feet, and cotton can take just two acre-feet. The university pecan professor suggests that these differences in water use are unimportant (personal communication 2016). He suggests that farmers should consider dollars per acre-foot as their prime measure, which puts pecans well ahead of the other crops (for now). Yet, the narrative of pecan as savior is resulting in a Mesilla Valley increasingly covered in a water hungry crop, even as upstream water shortages look increasingly severe (Paskus 2018b). The landscape reflects the most common metanarrative among farmers along the Rio Grande south of Elephant Butte Dam:

[47] If the U.S.-Chinese trade war continues, however, this may change rapidly. China has assigned pecans a 47% import tariff (Pecan Report, 2018).

profit is more important than ecology. This is not to assign blame: this economistic metanarrative runs through a great many natural resources decisions in the United States, including discussions of payments for ecosystem services. But recognition of that metanarrative draws attention to the need for the telling of other stories about how most farming in the United States can look.

Conclusion: Change in the Political and Personal Spheres

For the most part, farmers discussing their barriers to change focused on particular sets of legislation, international trade policies, or changes in markets. This relatively narrow vision is reflected on the website of the current administration's Interagency Task Force on Agriculture and Rural Prosperity. The first interactive element of the website is a large graphic and link that ask rural people to identify specific regulations that are harming them (USDA 2018). Zach, however, pointed out that the very mode of agricultural decision-making in the political sphere of the United States needs to change. Rather than focus on specific pieces of legislation, he argues:

> I'd like to see it like another third-party company where I could see, you know, and their data is transferred to our lawmakers as boiled down and simple. Because, you know, I talk to Representative Conaway, the head of the House Ag Committee in Washington, D.C., and he says, you know, I can sit down and decipher numbers. . . but when you take someone from the inner city of Chicago and they're voting on some—they have no clue what they're voting on. And he says, "So, if we could boil down a system where they can sit there and say, this is good, this is bad, this is what we need to look at," you know. It frees up their time plus employs more people, you know, and I would have not problem paying a small fee for it, you know.

The problem Zach is highlighting is the complexity of agricultural problems. As this paper has argued, legislation that may be of benefit to a broad group of farmers (and consumers) may not benefit smaller growers. Market shifts that provide substantial profit may push agricultural production along a path with only a short-term ecological future. And the barriers that keep farmers moving toward a future of monocropped, annual commodities are also the barriers that are preventing the rebuilding of strong rural communities. But each barrier has complex ramifications for different kinds of farmers in different contexts. Zach believes that an organization that can communicate more directly with farmers and can better distill agricultural information for federal-level decision-makers, would go a long way toward making the problems more transparent and the solutions more obvious. He may be right.

In addition to change in the legislative context, however, changes in farmers' narratives about barriers will have to change for transformative change to occur in U.S. agriculture. Farmers construct additional barriers to change when their narratives dismiss the usefulness or potential of farm support programs. When their narratives do not include diverse options for the crops they are already growing (e.g. polycultures of their existing crops), they limit their means of dealing with the increase in pests expected with continued climate change. When they dismiss the ways in which government support is vital for the healthcare and food needs of their laborers, they provide stronger constraints to systems that work more effectively with trusted laborers available in adequate numbers.

This last barrier, in which farmers dismiss the importance of government support, boxes farmers in from a variety of transformative options. Support for a less restrictive Medicaid, or for truly universal health insurance without income limitations, would make labor more available to farmer—laborers on Medicaid currently have to restrict their farm work to part-time. Support for a broader-based farm bill that more effectively supported local food hubs and associated sales outlets, farm visits, and diverse forms of on-farm innovation would allow farmers to decrease their social isolation and increase their market options for a variety of crops. Support for more open immigration practices might open an additional avenue to more labor availability, provided the incentives for working in New Mexico are high enough to again draw more Mexican labor across the border. In short, the conservative rhetoric that farmers appear to have drawn from popular media often contributes to their raising barriers to their own success.

An agriculture prepared for future climate change includes agroecosystems with a diversity of species and a diversity of ideas. This paper has laid out the political, economic, and narrative barriers to such change. These barriers lie not only in the political sphere of transformation, but in the personal sphere. The production of change requires both a rethinking of our current agricultural institutions—both agencies and laws—as well as a move toward producing narratives of what a richer rural future can look like. The change in the personal sphere of worldviews and beliefs may represent the greater change, but understanding farmer narratives takes us closer to understanding how agricultural narratives could change.

Chapter 6. Farmers' Narratives of Change: The Potential for Transformation Across the Three Spheres

"Pelling (2010) describes a central challenge for systems analysis: placing the system itself as the object of observation. He notes that the resilience of a system is often maintained by focusing on the proximate causes of undesirable outcomes, rather than the root causes of vulnerability that lie in the social, cultural, economic and political spheres." (O'Brien and Sygna 2013)

Introduction

Agricultural systems are necessarily complex. Placing an entire agricultural system under observation, even within a circumscribed geographic area, to demonstrate the root causes of its vulnerabilities seems a steep challenge. Yet a great many aspects of agricultural systems are already closely studied, from agricultural economics (Cohen and Siegelman 2010; Feng and Babcock 2010; Coble and Barnett 2012) to farmer identity (Burton 2004; Gray and Gibson 2013; McGuire et al. 2015). Understanding agricultural systems is therefore more of a question of making sense of how elements of a farm system link together. From the perspective of understanding what happens on the farm and why, what creates a set of beliefs in the farmer and what kinds of decisions and landscapes result from those beliefs, a fairly broad sketch of the system can be created in talking to the farmer and asking her how those decisions might be made. In outlining those decisions, a farmer will tell stories that explain the influences that helped to shape the decisions. In those stories, those narratives, the farmer will describe, analyze, and illustrate much about the farm system's function from his perspective. In those narratives, I argue, one can begin to discern not only the constraints that prevent change on the farm, but how a farmer weighs those constraints. As importantly, from the perspective of considering adaptation to climate change, one can detect the elements of a farmer's network that she considers important in changing her farm operation, regardless of the real or perceived constraints that influence her decisions.

In this chapter I will argue that analysis of the narratives of farmers who have made transformative management decisions offers insight into the particular ways in which transformative decisions are made. Specifically, I will argue 1) that it is through changes in the personal sphere of transformation (O′Brien & Sygna, 2013) that farmers are most likely to make sweeping changes to their farm operations, 2) that changes in the personal sphere emerge from multiple entry points, including both crises and positive changes in the farmer's network, but that 3) possessing or acquiring certain kinds of support through the agricultural network are important for sustaining a transformation in the practical sphere, and finally that 4) a worldview in which a farmer strongly values elements of his network for non-market, non-capitalist (i.e. diverse economies à la Gibson-Graham (2006) reasons is more likely to support transformation.

To build this argument, I begin by defining transformation both as it has been understood as deliberate transformation (O′Brien, 2012), and as it has been defined elsewhere in the literature on climate change in agriculture and the sustainable agriculture literature. I then walk through relevant literature on how agricultural research has understood who farmers are, how they innovate, and the ways in which they may adopt others' innovations. Next, I introduce the diverse economies framework (Gibson-Graham 2006, 2014) as a way of identifying elements of farmers' narratives that suggest how they may have been encouraged or inspired to transform their systems. Then I offer a sketch of each of the farms that I identify as having undergone transformation based on a definition that relies heavily on Dowd et al (2014). Finally, I conduct a narrative-network analysis (Lejano, Ingram, and Ingram 2013) of interviews with the farmers who have transformed their systems so that I may identify the elements of their narratives that allow them to make transformative decisions in spite of the constraints otherwise associated with their networks.

Transformational Adaptation

Current plans to decrease global CO_2 emissions are insufficient to meet a 2ºC limit on planetary warming (Rogelj et al. 2016; Peters et al. 2017). Even with a set of goals that meets the 2ºC limit, the scale of change already experienced and expected to continue requires substantial efforts to adapt to change (Field et al. 2014). Much of the literature on adaptation has focused on what Bassett and Fogelman termed “adjustment adaptation” and does not address the “roots of vulnerability” (Bassett & Fogelman, 2013, p. 42). O’Brien suggests that deliberate transformation represents an alternative approach to adaptation that address the social and economic roots of vulnerability (O′Brien, 2012). O’Brien cautions that deliberate transformation has multiple histories and meanings, and encourages researchers to develop “the capacity to become critically aware of one’s own assumptions (and those of others),” but to push, nonetheless toward new and innovative ways of thinking about both research and global change (O′Brien, 2011, p. 673). It is important to note here that deliberate transformation is envisioned as transformation “along pathways towards greater justice, equity, and long-term resilience” (O’Brien 2011, p. 672). This vision of transformation is directly counter to what Folke et al.

(2010) define as forced transformation: “an imposed transformation of a social-ecological system that is not introduced deliberately by the actors” (p. 22).

Feola (2015) identifies eight strands of literature that address “societal transformation in response to global environmental change” (p.380). The literature emerges from traditions including resilience theory (Walker et al. 2004; Folke et al. 2010), social metabolism (Fischer-Kowalski and Rotmans 2009), transition theory (Grin, Rotmans, and Schot 2010) and human security (Pelling 2011). Some of the strands explicitly value “desirable” outcomes of transformation such as sustainability, while other strands are not normative, thus encompassing potentially undesirable outcomes of transformation. Deliberate transformation is one of the former, and resilience theory/regime shift (for example) is one of the latter (Feola 2015b). Progressive transformation (Feola 2015b) also explicitly values the sustainable outcomes of transformation (Pelling 2011). Pelling and O’Brien both advocate an approach that identifies root causes of social and economic vulnerability, and that identifies climate as only one among the factors that shape overall vulnerability (O′Brien, Eriksen, Schjolden, & Nygaard, 2004; Pelling, 2011). As they focus on root causes, both advocate a transformation that reacts to vulnerability as “framed as an outcome of wider social processes shaping how people see themselves and others, their relationship with the environment and role in political processes” (Pelling 2011). Values (e.g. human rights, meeting “basic needs” (Pelling 2011)), worldviews (O′Brien and Selboe 2015) and power (O′Brien 2015) are consequently integral elements of the transformation that Pelling and O’Brien advocate.

O'Brien frames transformation as occurring "across three embedded and interacting spheres" (O′Brien & Sygna 2013). Building on Sharma (2007), the concept of the three spheres is a synthesis of four other approaches to climate transformation, including not just those emerging from socioecological traditions and related approaches addressed by Feola (2015), but also psychological literatures on behavior change as well as its critiques (e.g. Shove 2010; O′Brien and Sygna 2013). The three spheres are intended to provide a conceptual means of considering the ways in which the realms of the personal, political and practical interact with one another, as well as where interventions in a system may be most effective for producing transformations to sustainability. The personal sphere represents goals, beliefs, values, and worldviews. The political sphere is the realm of influence of systems and institutions. The practical sphere is where "outcomes have an observable and measurable influence on climate policy goals such as mitigation, adaptation, or sustainable development" (O′Brien & Sygna, 2013, p. 5). The practical sphere, then, is the area in which technical solutions are applied and on which much of climate policy has focused (O′Brien & Sygna, 2013).

Why the three spheres approach? All three spheres shape the choices farmers make. They are intentionally nested and overlapping, suggesting the ways in which transformation in one sphere can effect change in the other spheres. Separating the influences on decision-makers by sphere creates an opportunity to identify the particular dynamics at play in any decision or set of decisions, and to clarify which sphere's influences may have the greatest leverage for change. According to O′Brien (2018), "the relative size of the spheres corresponds to the potential leverage of an intervention" (p. 157), as depicted in Figure 41. Interventions in the low-leverage practical sphere alone can have negative repercussions that may result in long-term maladaptation. For example, farmers who choose water-hungry perennial crops because of their current profitability may be making it more difficult to adopt crops more appropriate to a water-poor context during future droughts. So, attempts to influence behaviors or to offer new technical solutions—interventions in the practical sphere—are the least likely to have broad influence toward causing transformative change. On the other hand, changes in the personal sphere, in the core notions people have of themselves, of their world, and of their interactions, are the most likely to create broader change and have the potential for transforming systems, but the greatest change results when such changes reverberate through interactions across all three spheres (O'Brien, 2018; O'Brien & Sygna, 2013). Within the personal sphere, and closely related to worldviews, are paradigms. Paradigm shifts and moving beyond a reliance on dominant paradigms, around which institutions and technologies have developed, represent the highest leverage to the system (Meadows 2009). Meadows (2009), following Kuhn (1996), asserts that we have the tools to make such fundamental change happen. That by "pointing out the anomalies and failures in the old paradigm" and confidently asserting the power of the new, we can create

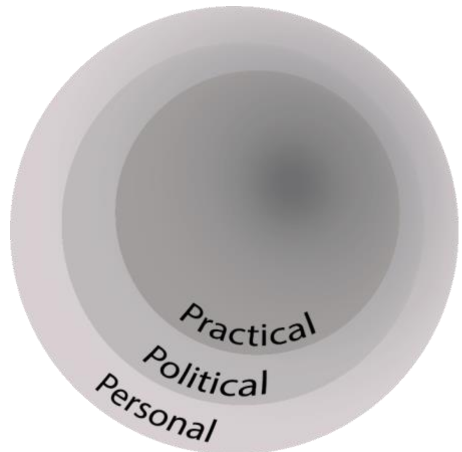

Figure 41: Representation of the three spheres of transformation. Based on O'Brien and Sygna (2013). The personal sphere corresponds to goals, values, beliefs, and worldviews; the political to systems and institutions; and the practical to "technical and behavioral interventions" (p. 155).

needed paradigm shifts that will have transformative effects throughout the system (Meadows 2009).

Defining Transformations in an Agricultural Context

Agriculture is at once one of the greatest sources of environmental change, and is also itself profoundly affected by greenhouse gas emissions (Foley et al. 2005; J. R. Porter et al. 2014). Consequently, change in agricultural systems is among the most important shifts necessary for mitigation of carbon emissions, and it is also vital for continued food security (Foley et al. 2005; Tilman et al. 2011; J. R. Porter et al. 2014). As in much of the climate adaptation literature, however, the focus in agricultural adaptation to climate risks is often on technical change (Stokes and Howden 2010), change that O′Brien (2018) would term as taking place in the lower-leverage practical sphere and that Bassett and Fogelman see as reinforcing the status quo (Bassett & Fogelman 2013). As in other realms of climate adaptation, therefore, transformation is beginning to emerge as an important alternative approach.

In agriculture, transformation has been defined as one of three levels of change, ranging from incremental to systems adaptation to transformation (Howden, Crimp, and Nelson 2009 in Rickards and Howden 2012)[48]. In this view, incremental adaptation, or adaptation in which “the ideal ‘ratio’ of what remains relatively constant to what is deliberately changed is high,” is a form of change that may limit future alternatives in the face of increasing climatic change

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[48] The definitions of this group of researchers with Australia’s CSIRO have derived from both resilience theory (Park et al. 2012) and from O’Brien’s (2012) deliberate transformation (Rickards and Howden 2012). Recent work, although citing both resilience and deliberate transformation, examines farmers deliberate decisions to improve their systems in the face of climate change, and thus falls most clearly under O’Brien’s (2012) definition of deliberate transformation.

(Rickards & Howden, 2012, p. 242). Rickards and Howden (2012) further differentiate systems adaptation from transformational adaptation, placing within systems adaptation those changes that are major changes to an existing system. Transformational adaptation, then, is change in which more of the system is changed than is retained (Rickards and Howden 2012). Rickards & Howden (2012) further differentiate transformational adaptation by its depth of change (profound), generality of change (general or intangible), spatial scale (whole system), effect on the system (relatively profound), and permanence (difficult to reverse).

There are important resonances between transformational adaptation in agriculture and related areas of research, including climate smart agriculture (Lipper et al. 2014; Long, Blok, and Coninx 2016) and sustainable agriculture (Kroma 2006; Velten et al. 2015). Climate smart agriculture, for example, includes a focus on helping the most vulnerable, including smallholder producers, providing equitable access to needed inputs, and increasing access to information (Campbell et al. 2014; Lipper et al. 2014; Long, Blok, and Coninx 2016). All three of these (less explicit) goals of climate smart agriculture coordinate with the underlying goals of transformational adaptation to address the deep social and economic vulnerabilities that are exacerbated by climate change. Climate smart agriculture, however, relies strongly on three goals: 1) productivity of agriculture and incomes, 2) increased resilience to climate impacts, and 3) greenhouse gas mitigation (Rosenstock et al. 2016). Goals 1 and 3 are explicitly oriented toward technical change, and all three goals are often interpreted as requiring top-down governance measures (e.g. Lipper et al., 2014). Much work on climate smart agriculture, therefore, does not leave room for the deep personal change inherent in O’Brien and Sygna's

(2013) three spheres approach, nor does it fundamentally question the agricultural status quo as does transformational adaptation.

Sustainable agriculture, as a less recent concept than climate smart agriculture (and one tied to the increasingly contentious word sustainable (Tregidga, Milne, and Kearins 2018)), has been variously interpreted over its nearly 40 year history. Kroma's (2006 based on Pretty, 2001 and Röling & Wagemaker, 1998) principles of sustainable agriculture include minimizing non-local inputs, diversification, “broad-based participation of diverse social actors,” “local experimentation and innovation,” and the recognition of people’s capacities to learn (p. 8). These values resonate strongly with a three spheres approach in their accommodation of interventions in the practical (inputs, diversified species), political (participation, experimentation including new technology), and personal (individual learning and change). Analysis by Velten et al. (2015) concludes that across a range of literatures including engineering and natural sciences, agricultural sciences, interdisciplinary sciences, economics, humanities, and social and political sciences, the definitions of sustainable agriculture vary widely. Velten et al. (2015) group the literatures into five perspectives on sustainable agriculture and conclude that there are some areas of substantial overlap between them. Nonetheless, a key difference is a “utilitarian view” of the term in the natural and engineering sciences, a view that tends to emphasize productivist goals, as compared to an approach in the “practitioner-oriented literature” that focuses more on change in social issues of agriculture. Ultimately, Velten et al. (2015) contend, elements of all conceptions of sustainable agriculture are useful to effective agricultural change, a view which perhaps most closely approximates Meadows (2009) view of the greatest leverage for change coming from abandoning attachment to any one paradigm.

All three conceptions of goals for change in agriculture—transformational adaptation, climate smart agriculture, and sustainable agriculture—share important elements to their definitions (see Table 2). An underlying or explicit assumption of all three is that the future of agriculture must include arrangements that support ecosystem and farmer livelihood goals in ways that much of current agriculture does not—in neither the Global North nor South. Where transformational adaptation and the more practitioner-oriented sustainability depart from most climate smart agriculture and the more natural-science focused sustainability, however, is in their placement of the farmer as a key locus of change in agriculture. The farmer as change agent, as decision-maker, as shaper of the landscape—the farmer is the piece of the network through which the rest of the change in the system is filtered. The focus of climate smart agriculture and related sustainability frameworks is to offer technical solutions and government policy that tend to place the farmer as receiver rather than shaper of change. In contrast, it is in seeing the farmer as central locus of change that the three spheres approach becomes most pertinent. The potential for transformative adaptation depends on how daily activity on the farm, in farming institutions, and in the farmer's mindset come together.

Social Learning vs. Technology Transfer. One counter to the technology-transfer orientation of much of the agricultural change literature comes through the literature on social learning. In the United States, farmer education has long been linked to agricultural extension

Table 7. Relationships between key agricultural change literatures

	Deliberate transformation (in agriculture)	**Climate smart agriculture**	**Sustainable agriculture**
Objectives	1) "Often carried out with the intention of achieving a particular goal" 2) "[N]ot about social engineering or designing the future, but rather about recognizing that some fundamental shifts are necessary to enable desirable futures to emerge" (O'Brien 2012). 3) "[A]ddress the long-standing ecological, social and economic vulnerabilities that climate change exposes, such as soil degradation, biodiveristy losses, dependence on declining soil reserves, low financial equity, and an aging farmer population" (Rickards and Howden 2012)	1) "sustainable increases of agricultural productivity and incomes;" 2) "adaptation and building of resilience to climate change impacts;" 3) "reduction of greenhouse gas emissions" (Long et al. 2016).	1) Few external or non-renewable inputs; 2) Diversification, healthy plant-livestock interactions; 3) Broad social participation; 4) Local innovation; 5) Recognition and support for local learning and experimentation by farmers and others (Kroma 2006).
Origins	Builds on both resilience theory (Folke at al. 2010) and deliberate transformation (O'Brien 2012)	Developed by the Food and Agriculture Organization (FAO) as a "unified approach to address climate change challenges" (FAO 2018)	As "sustainable" agriculture developed in 1980s with work from Rodale Institute (Edwards 1990), but with extensive ties to the organic agriculture tradition going back to Sir Albert Howard in the UK prior to 1940 (Heckman 2006)
Ties to deliberate transformation	(see above); Tends to place the farmer in the role of key decision-maker and agent of transformation, in accordance with the imperative that people shift to "viewing themselves as subjects or agents of change who are capable of contributing to systemic transformations" rather than being framed by external actors as "'objects to be changed'" (O'Brien 2018, p. 157)	Focuses on building adaptive capacity to climate change (Campbell et al. 2014), but no explicit focus on transformation nor on centering the farmer as key decision-maker.	Often centers farmers as key agents of change in the practitioner-oriented literature, although not necessarily in the natural-science-oriented literature (Velten et al. 2015). Not necessarily any direct focus on climate change.

services like Cooperative Extension (Lubell, Niles, and Hoffman 2014). The extension model assumes that researchers create new ideas and pass them, via extension, to farmers (Carr and Wilkinson 2005). Although models preceding the early 20th century development of extension were based on farmer autonomy and democratic models of learning (McConnell 1969), the technology transfer model of extension has long been the norm in the United States. As alternative agricultural networks have developed alongside organic farming, however, they have increased their reliance on models that tend to emphasize collaborative learning with fellow farmers as well as experts (Kroma 2006; Jordan and Warner 2010). Therefore, other models of learning both within (Warner 2008; Lubell, Niles, and Hoffman 2014) and beyond extension have become more common in some geographical areas and types of farming.

Social learning is a central piece of much agricultural learning innovation. In agriculture, social learning takes place among groups of farmers and other stakeholders who construct their knowledge collaboratively over time, often in a network intentionally formed to include a given set of participants. According to Kroma (2006), the practice "challenges the understanding of farmers as merely passive recipients of knowledge and technology and demonstrates instead their capacities to learn and collaborate actively in their own learning" (p. 12). When conducted jointly by farmers and researchers, it provides opportunities for researchers to better understand the value of alternatives to the farming systems that are produced out of existing land-grant university models (Nerbonne and Lentz 2003). Effective social learning "requires conscious design and facilitation" (Kroma 2006). Moreover, in a review of the literature on social learning in natural resources management, Cundill and Rodela (2012) contend that "sustained interaction" and "on-going deliberation" are necessary and can yield improved decision-making capacities among participants. Some definitions of social learning frame it as a far broader and more casual process of training, but recent work (Nykvist 2014; de Kraker 2017) suggests the importance of carefully co-constructed processes. De Kraker (2017), despite some caution about the broad applicability of the process to natural resources management scenarios, suggests the possibility that new technologies may make change through social learning increasingly possible across large geographic areas.

Social learning, then, offers at least one appropriate tool for undertaking change in agriculture across personal and practical spheres. Farmers—as well as researchers and extension professionals—may learn not only new agricultural methods, but also change their mindsets about agricultural problems and solutions as their decision-making capacities develop. Social learning among farmers does not necessarily have great utility for change in the political sphere, however. Or, at least, farmer-originated changes in the institutions and structures that have a strong impact on farming decisions would require the engagement of individuals in those institutions and structures in a process of social learning alongside farmers. However, the focus of this paper is not the political sphere, but the importance of change in the personal sphere and its ramifications throughout a system. To make sense of when and why personal sphere change matters, though, I first address some of the factors that block change, including factors in the political sphere.

Barriers to Transformation. With Moser and Ekstrom (2010), I define barriers to transformation as obstacles that are embedded within human systems and mentalities, but do not have absolute thresholds in natural systems beyond which "existing activities, land uses, ecosystems, species, sustenance or system states cannot be maintained" (p. 22026). The latter

Moser and Ekstrom (2010) refer to as limits. Because barriers emerge from human rules, institutions, and worldviews, they have the potential to undergo change. However, transformative change may originate from shadow networks, informal groups that may not have to deal directly with formal regulation (Olsson et al. 2006; Pelling et al. 2008) as with the early development of organic agriculture (Padel 2001). Consequently, some barriers to adaptation may lie in deeply ingrained cultural practices or well-established institutions with which proponents of adaptation must contend when scaling up an approach (Moser & Ekstrom, 2010; O′Brien, 2012). Moser and Ekstrom (2010) provide a framework for analyzing the barriers to transformation at each stage of an adaptation process: understanding the problem, planning options based on the understanding developed, and managing the implementation and evaluation of the adaptation. Key potential barriers may lie in leadership of the process, resources available for adaptation, quality of information and communication, and *values and beliefs* (Moser and Ekstrom 2010). The last is worth emphasizing because it underlines the potential for elements in the personal sphere of transformation to be both deep barriers to transformation as well as the most powerful source of transformation. As Meadows (2009) underlines, leverage in paradigms (or goals, values, beliefs and worldviews in the three spheres framework (O′Brien and Sygna 2013)) can have profound effects for change, but “the higher the leverage point, the more the system will resist changing it” (p. 165). A “high” leverage point is framed as on that has substantial potential to transform a system. Understanding the occurrence and effects of personal sphere transformations in farm systems can therefore provide insights into how the farming system might be more broadly transformed.

Paths to Innovation: Farmer Innovation

Farmers, like the rest of us, are all part of networks. They participate in networks of sales and marketing; of production, input, and use of fertilizers, pesticides, and machinery; of neighbors who support, critique, or question their methods; of information acquisition and dispersal; of family both on and off the farm; of the animals, plants, fungi, and microorganisms with which they work every day. The particular networks that farmers choose to participate in—and see themselves as able to participate in—strongly shape the way that farmers think about farming and about themselves (Bell 2004). In other words, networks can shape farmers' paradigms and worldviews (e.g. through social learning, Kroma 2006). Just as importantly, farmers' worldviews shape their decisions to participate in particular networks.

Worldviews are shaped by diverse cultural influences, and often intricately tied to notions of identity and place. The fear of loss of specific places and values that define one's culture may represent barriers to adaptation (Adger et al. 2009a). Strong attachment to place and to one's identity as a farmer may facilitate incremental on-farm change, but preclude transformative change (Marshall et al. 2012). Farmer identity may be strongly tied to a particular story of the land being worked and the farmer's success at grappling with nature to shape it to a particular vision (Burton 2004)—a vision that may not focus on agroecological or multifunctional goals (Burton and Wilson 2006). Moreover, a view of oneself and one's family as dependent on a farm livelihood may encourage farmers to believe that their current models of farming should not be altered (Neumann et al. 2007). Farmer views of self and farm can be intentionally shifted, however, by activating elements of farmers' identities (e.g. conservation identity) through intentional interaction with other farmers (McGuire et al. 2015).

Farmer Innovation. In literature on the Global South, farmer innovation plays a major role in understanding when and how change occurs in agriculture systems (e.g. Dolinska & d'Aquino, 2016; Jagoret, Michel-Dounias, Snoeck, Ngnogué, & Malézieux, 2012; Röling, 2009; Tambo & Wünscher, 2015; Waters-Bayer et al., 2015). In literature on the Global North, including the United States, there is less focus on farmer innovation than on the ways in which farmers adopt innovations from beyond their farms. Work done on farmer innovation in the Global North often focuses on alternative forms of agriculture, including organics (e.g. Kroma, 2006; Shelton & Tracy, 2016; Warner, 2008). This suggests that there may be inadequate understanding of the ways in which conventional farmers in the U.S. innovate, and also suggests how pervasive the perception may be among both conventional farmers and researchers that agricultural innovation originates off-farm. Morgan and Murdoch (2000), for example, see knowledge in conventional agricultural systems being distributed to input suppliers and frame conventional farmers largely as receivers of knowledge produced elsewhere. Organic farmers, on the other hand, relearn how to farm in ways that reflect local knowledge of ecosystem processes (Morgan and Murdoch 2000).

In examples from Australia, farmer innovation was found to flourish in an environment where farmers both felt a need for change and felt that they had the space to experiment within their own systems. Farmers were able to create solutions that fit the particular characteristics of their farms and machinery better than solutions created completely off-farm. Farmer-driven networks were thus perceived to be more successful at fostering innovation than more traditional extension networks (Bellotti and Rochecouste 2014). In U.S.-based organic farming, extension has sometimes been perceived as fundamentally unhelpful in organic growing because the traditional extension model requires extension educators to define the problems to be solved. Organic farmers find they can better innovate when allowed to define their problems and seek assistance in finding solutions (Kroma 2006). Even with challenges that have, in the 20th and 21st centuries, been conceived of as highly technical, farmer involvement in fostering innovation can increase the applicability of final outcomes. With plant breeding, for example, direct farmer participation in breeding and selection can create varieties that better fit the farm system (Shelton and Tracy 2016). Systems that acknowledge farmer agency and ability in agricultural change provide greater opportunity for farm-appropriate change to occur.

Innovation theory suggests that innovators “are better educated than later adopters and tend to have more social contacts outside their local community” (Padel 2001). Indeed, innovative farmers make more use of information from extended networks (Diederen et al. 2003). Recent work on deliberate transformation in agriculture has found that transformative farmers also tend to rely most on extended information networks, and much less on local social networks, than do their peers (Dowd et al. 2014), suggesting that there may be substantial overlap between the categories of farmers as innovators and as early climate transformers. Innovators tend to be involved with the creation of new processes or products, rather than merely adopters of what has been created elsewhere (Diederen et al. 2003).

Farmer Adoption. When innovations are developed elsewhere than on one’s own farm, what encourages farmers to adopt those innovations? A range of factors have been proposed, and a number of those factors have varying degrees of support. In a review of reasons for adoption of best management practices for reducing non-point source pollution from farms, factors affecting adoption included access to credible information, subsidies supporting choices made, an orientation toward environmental protection, and the ability to profit from a given practice (Liu, Bruins, and Heberling 2018). In choosing to adopt “pro-environmental agricultural practices,” farmers’ values, beliefs and norms are important (Price and Leviston 2014). Values, beliefs and norms may be influenced by farmers’ development of new skills, as through formal agricultural training, as such education can provide the farmer with a great sense of control over opportunities and a more positive sense of self (Price and Leviston 2014). Decisions to adopt new methods are also influenced by farmers’ network connections. Belonging to a formal network focused on a specific problem may alter both perceptions of the gravity of environmental problems and encourage conservation-oriented behaviors among farmers (Pape and Prokopy 2017). Farmers are more likely to adopt new ideas and systems when trusted persons are the source of the information shared (Manson et al. 2016). So, literature on farmer adoption includes a sense that 1) the personal sphere (perceptions, beliefs, values) matters to the decisions that farmers make and 2) networks (i.e. the political sphere), especially formal networks, can have a strong influence on shaping a farmer’s outlooks, decisions and behaviors.

Paths to innovation: sources of innovation for deeper change

In shaping her decisions about farming, a farmer relies on diverse influences, some of which may not be consciously articulated. Those influences, and the beliefs that are formed from them, come together for farmers into sets of stories through which a farmer makes sense of the agricultural surroundings (environment, neighbors, input options, family, institutional parameters). In other words, each farmer identifies with a set of narratives about farming as it functions in the geographic and network locations within which they work. And it is the narratives that farmers tell about their networks, about their work, that most strongly shape the decisions that farmers make. The real constraints of farm networks are not negligible (Lin 2011; Long, Blok, and Coninx 2016). Farmers face markets that shift rapidly or that favor crops that are ecologically ill-fitted to their systems, increasing regulatory requirements that call for farmers to spend limited farm income on hiring new administrators to fulfill paperwork requirements, and increasingly volatile weather. Nonetheless, different farmers formulate different narratives about those constraints. Those who build opportunity into their narratives, including an acknowledgement of the importance of diverse economies (Gibson-Graham 2006) in a farm system, create deeper and often transformative change in their farm systems. These shifted narratives emerge from a transformation in the farmer's personal sphere.

The diverse economies framework is a "new economic ontology" intended to "contribute to novel economic performances" (Gibson-Graham, 2008, p. 615). In working to reshape our understandings of economies and what could count as economic activities, Gibson-Graham (2006) laid out a framework of activities ranging from contemporary market-based understandings (economy as: market, wage, capitalist) to the alternative (alternative market, alternative paid, alternative capitalist) to those that we have typically placed outside of market dynamics (nonmarket, unpaid, noncapitalist) (p. 71). In building on post-structuralist and feminist ontologies, the framework makes room in economic thinking for (for example) the unpaid labor of women working in their own homes, volunteer work, gift-giving, gleaning, and—yes—feudal and slave labor, that otherwise disappear from view in our society's usual framings of what makes up a capitalist economy (Gibson-Graham 2006; St. Martin, Roelvink, and Gibson-Graham 2015). The scheme thus conceives of non-market or alternative market activities differently than does a Marxist structural approach. Instead of being in opposition or alterity to the capitalist economy, these elements of the diverse economy are instead systems of their own, worthy of independent recognition, and offering an opportunity to conceive of a world separate from the capitalist system[49] (Gibson-Graham 2006).

Why should the diverse economies framework be applicable to conventional farming? (It is probably clear why it might apply to alternative farming systems (Cameron 2015)). Conventional farming appears so deeply embedded in capitalist processes, in market-based dynamics. But the diversity of practices in farming includes activities that support couples, households, communities, and landscapes in ways that are not always linked to market-based or capital-based transactions. I argue that farmers whose farm and household practices engage in substantial ways in diverse economies are more likely to transform their farming systems. Through transformations in the personal sphere, farmers come to see engagement in diverse economies as a key element of their farming operations, and that engagement contributes to bringing about practical, on-farm transformation.

Literature summary and research questions. This chapter centers around the question of how farmers can undertake deliberate transformation on their farms, despite the barriers they face. Deliberate transformation in agriculture has often relied on the tenets of deliberate transformation as outlined by O'Brien (2012). Those tenets include an intentional, focus on change that better prepares farmers for a climate change-influenced future. O'Brien (2012),

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[49] The diverse economies framework is meant to intentionally avoid placing the non-capitalist/non-market activities it highlights in a subaltern position to capitalism. That is because it seeks to better value those activities as separate and important systems: "What is intriguing, however, is that 'marginal' economic practices and forms of enterprise are actually more prevalent, and account for more hours worked and/or more value produced, than the capitalist sector. Most of them are globally extensive, and potentially have more impact on social well-being than capitalism does – though the latter claim is speculative. . ." (Gibson-Graham 2008, p. 617)

Pelling (2011) and O'Brien and Sygna (2013) also underline the importance of addressing the social and economic vulnerabilities that are more strongly exposed as a result of climate change. O'Brien and Sygna (2013) suggest that we may better understand such vulnerabilities through the three spheres approach. I have pointed to the ways in which farmer innovation and adoption can reshape such vulnerabilities, as well ways of thinking that may lead farmers toward deliberate transformation of their farming system.

The remainder of the paper focuses on two research questions: 1) How are the three spheres of transformation important in shaping the changes that farmers make on their farms? 2) Does the personal sphere of transformation have a strong leverage to shape other spheres of transformation for farmers? To address these questions, I first lay out my methods. I then address the question of whether deliberate transformation can occur when farmers do not accept the fact of anthropogenic climate change. Next, I give a brief overview of the farmer population studied. Finally, I address what transformation looks like on the farm, and how farmer narratives (the personal sphere) shape transformative outcomes.

Methods

This paper is based on interviews conducted with 30 farmers and 44 participants in agricultural networks (extension professionals, professors, members of farming-oriented NGOs) between 2012 and 2016, with the majority of farmer interviews in 2015-2016. I conducted 26 farmer interviews. Four additional interview participants were part of an interview with another farmer and participated as family members and fellow decision-makers of the farmer who was my original contact in those cases. These four additional farmers are combined with their family members in the summary statistics about farms. Farmers in the study all farm in one of four New

Mexico counties: Doña Ana, Luna, Roosevelt, or Curry. Initial contact with farmers was made through multiple entry contacts obtained through internet searches of universities and cooperative extension, and snowballed from those initial contacts. Initial contact points included extension agents, professors, and growers who attend the Las Cruces farmer's market. These multiple starting points allowed for the diverse set of growers seen in the results.

The information analyzed in this paper comes from in-depth, semi-structured farmer interviews. In interviews, I worked with farmers to reconstruct as much of a 10-year history of on-farm decision-making as a given farmer was able. Based on those interviews and, in most cases, guided farm tours, I analyzed whether each farmer had made transformative choices on his or her farm. A starting point for that determination was made based on CSIRO researchers Rickards and Howden's (2012) characterization of transformative change as being a change in which the ratio of persistence to change is low; i.e. more changes than persists. More specifically, I relied on the further refinement of that system in the CSIRO group's Dowd et al. (2014) to assist me in identifying potential categories of change. Based on Dowd et al. (2014), categories of potential change I identified from interviews included: 1) change in the structure and management of an operation; 2) changing the mix of enterprises that make up a farm business; 3) starting a new enterprise, 4) leasing or buying land to farm in other regions, 5) changing the size of the farm, or 6) exiting farming. Change in one of these categories constitutes systems change and change in two or more constitutes transformative change. Conversion of a crop to organic production, for example, I counted as starting a new enterprise, because of the necessity for connecting with new suppliers, changing labor practices and/or machinery needs, and forging new market outlets for the product.

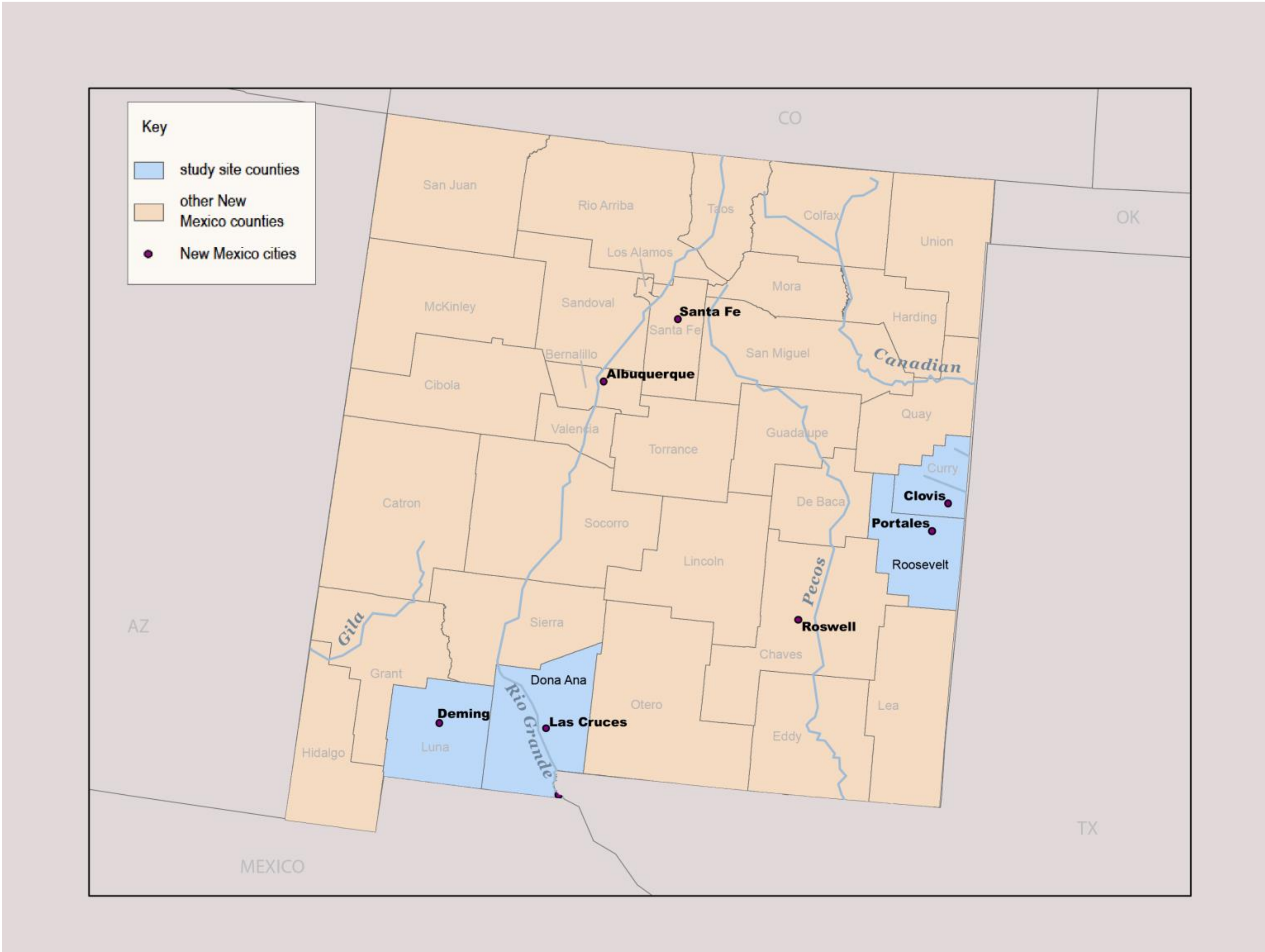

Figure 42: Study area counties are identified in blue. County seats are identified in bold next to magenta dots.

In addition to identifying transformative farmers, I further analyzed the interviews based on Lejano et al.'s (2013) concept of narrative-networks. In the ten- (or fewer) year histories outlined by farmers, I identified major sources of influence on decisions, classifying these sources of influence as actants in the farmer's network, along with the farmer her or himself. However, with Lejano et al. (2013), I found that the greatest explanatory power for farmer decisions came from the narratives they told about those networks, rather than merely the network connections themselves.

Finally, although this study is explicitly examining farmer reactions to climate change, I avoided asking about climate change outright. From preliminary research, I was well aware that many farmers saw anthropogenic climate change as part of a certain worldview to which few of them subscribe. To avoid shutting down conversation, I asked instead about how farmers dealt with specific weather impacts that have worsened in the Southwest (e.g. drought), and that are expected to be further exacerbated with future climate change. In framing those questions, however, I asked about specific weather impacts, such as drought, snowstorms, and hailstorms, rather than framing them as part of climate change. For the most part, the major impact I asked about was drought. In discussions of weather and its effects on their operations, however, farmers often spontaneously brought up climate change. The results on perspectives on climate change therefore emerge from this organic discussion.

A Nagging Question

One central question in this study has been whether deliberate transformation (O′Brien, 2012) is occurring. Farmers largely acknowledge substantial changes in the weather, but those who refer to climate change frame it as part of "60-year cycles" that they see as the usual pattern of the

Southwest. None of the farmers with whom I spoke acknowledged anthropogenic climate change as a part of their worldview. With that reality in mind, can I argue that deliberate transformation is occurring? I argue that, yes, deliberate transformation is occurring. Farmers directly speak to their reactions to drought, hailstorms, strong winds, and winter storms. These events are expected to become increasingly challenging with climate change, and already appear to include greater extremes than seen in the historical record (see Chapter 2 for details on measured climate change). Further, since an important element of the deliberate transformations/three spheres approach to climate change transformation is understanding the multivariate vulnerability of those adapting, I argue that the other forces to which farmers are reacting (policy, markets, neighbors, etc.) are as important to a definition of deliberate transformation as are their reactions to climate impacts.

Farmer Population

Table 8. Categories of farmer adaptation among study farmers

	Conventional large-scale Farmer	**Organic large-scale farmer**	**Market Gardener (none certified organic)**	**Non-profit market gardener**
Incremental adapter	12			
Systems adapter	2	1	3	
Voluntary Transformational adapter	2	2	1	2

The group of farmers with whom I talked was diverse. It included conventional small-grain growers; feed growers (cattle and horse); chile, onion and alfalfa growers; organic cotton growers; small, diverse market growers; and two farmers who conduct non-profit growing, one for a 501(c)(3) non-profit corporation and the other as a passionate hobbyist. Each grower's operation was in some way distinct from the others in terms of crop mix grown and inclusion or lack of livestock. This high diversity is typical of the two growing areas (southern New Mexico and eastern New Mexico), since both are areas with relatively long growing seasons and access to a diversity of markets. Nonetheless, there are some general commonalities in each region of the state. Roosevelt and Curry Counties tend to grow predominately dryland crops, especially small grains like winter wheat, and some feed crops like sorghum hay. Grazing cattle on wheat fields is fairly common. The few irrigated crops are also often feed grown for dairies, such as alfalfa. Doña Ana and Luna Counties, where essentially all fields are irrigated, are focusing increasingly on growing pecans. The two counties have, in the recent past, grown mixes of alfalfa, onion, lettuce, cabbage, and chile, with some frequent additions like corn and small grains. A number of farmers still rely on these crop mixes while moving increasing acreage into perennial pecans.

What Does Transformation Look Like on the Farm?

Despite the overall diversity of operations among the farmers I interviewed, there were several farmers who stood out as making radically unusual choices relative to their peers. The most radical choices tended to come from farmers who, in describing their work, highlighted the importance of relationships that included more-than-capitalist-market factors. These relationships, in other words, are better captured by the diverse economies framework (Gibson-Graham 2006) than by a perspective that assumes that farmers' decisions are strictly based on market factors. In the proceeding sections, I analyze farmer narratives to understand why they made their decisions. First, however, I examine what transformation looks like on the farm.

The cases that are most useful to analyze through the lens of transformation are those taking place on farms that are otherwise very much part of a conventional farming paradigm. Organic farmers of any size, as well as market gardeners, I would contend, are necessarily connected in some way to alternative farm networks. They have been involved in changing the paradigm of farming *within* those alternative networks, but much of the change has not been taken up into the conventional farming paradigm that covers by far the majority of agricultural acres in the United States. It is useful, therefore, to understand how and why transformation does take place on conventional farms where alternative agricultural networks are far from given. I begin, then, with the two cases of transformation on conventional farms before examining transformation on large-scale organic farms, a direct-to-market farm, and two non-profit farms.

Two conventional farmers have made transformational change on their farms. There are substantial differences between the two. Before 2000, John[50] grew peanuts for a large part of his farm income, and then converted to chile grown in strip-tilled wheat. The chile then became this largest farm income source. In converting to chile in strip-tilled wheat, he decreased soil erosion and water use in his system. One other major change undertaken by John was in direct reaction to the combination of drought and declining yields from wells. Alfalfa was long an important element of his crop mix, making up 25 percent of the space in his fields. As water availability declined, he took half of a circle[51] out of alfalfa production for each of four years until he was not growing alfalfa at all. Both of these enterprise shifts have meant a substantial adjustment in the operation. Strip tillage, in particular, required new investments in machinery and required a new approach to growing, as wheat and chile now occupied the same field space. In addition to changes to his system so far, John is planning to transform his landscape completely as he moves

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[50] All farmer names are pseudonyms. To help preserve confidentiality, farm details (e.g. mixes of crops, location details) are included only as directly relevant to the question of transformation.

[51] A circle being the space in a field irrigated with a center-pivot sprinkler system. One "circle" in this sense usually occupies the largest possible circle that can be drawn on a quarter section (160 acres). The area irrigated is about 130 acres. This arrangement leaves the corners of the square unirrigated, and is the typical, although not only, arrangement of center-pivot irrigation systems.

toward retirement in the next few years. To begin, he plans to enroll several fields in the Ogallala Aquifer Initiative. The initiative would require him to continue to farm the land, but without any irrigation. Before he completely retires, he plans to convert all his fields to native grass and sell the water rights to a community that needs more water.

The other transformative adapter among the conventional farmers is a farmer who in many ways fits the mold of innovator in the innovation/adoption literature (Läpple, Renwick, and Thorne 2015) in being young, educated, married, and having a relatively large operation. Zach has shifted the location of his farm over one hundred miles. He has shrunk the land area of his operation from over 4000 acres to just over 1000 acres. His discussion of the shift did not frame the land transactions as an obstacle, but rather a path to better production:

> And I don't want to be 1000 acres. You know, at one time I was almost 4000 acres. And I'm learning, you know, how do we get bigger and how do we grow. It's not about, you know, the farm size. It's about the quality of produce you can actually, you know, grow and it’s about the market you can supply.

He has taken on multiple new enterprises, ranging from becoming a buyer and distributor of beans to working to open a community farm store to creating a greenhouse system inspired by another innovator in the region. He has undertaken a management reorganization of his operation to offer greater autonomy to his staff. In that reorganization, he has ensured that multiple members of his staff are trained to lead each of his enterprises, and that they get training to work in multiple enterprises. He is creating a highly skilled staff, rather than attempting to “micromanage” every area of his operation. He is renovating a farm enterprise he bought, and which, under previous management, caused significant environmental and economic problems within the small community of which it is a part. He intends this enterprise to produce vegetables that will, in part, go to feed the children in local school districts.

The two other large-scale transformative farmers, Mateo and Jim, are among the few running fully organic operations[52] in the counties studied. They are closely tied to one another, with the first to convert to organic offering extensive advice and marketing connections to the second, and on an on-going basis. Both grow cotton and alfalfa for their main source of farm income, along with some pecans and a few other crops that fill out their acreages (e.g. chile, small grains). Their conversions to organic production required new machinery and labor arrangements, as they moved from chemical-based to mechanical removal of weeds. Their marketing arrangements changed radically, as finding markets for their organic crops has meant shifting from selling to local buyers to selling to entities as far away as Montana and Japan. The lack of organic seed sources, particularly for alfalfa, have been obstacles, as most organic alfalfa is grown in very different climates than that of the high desert, and so certified organic seed has usually proved entirely unsuitable for their use.

The transformative market gardener is in many ways an outlier. Galen does not necessarily fit the mold of the innovator (not being especially young, well-off, or with a large operation), but his style of farming is highly innovative relative to any of his neighbors. He was the first farmer in the region to undertake a greenhouse hydroponic system, and the system involved a complete conversion of the land that he took over to create it, from a fairly typical outdoor, conventional system to mostly indoor production of crops that are otherwise often

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[52] USDA statistics, for example, counted 16 farms with organic acreage in Doña Ana County in the 2012 agricultural census (USDA NASS 2012), but in talking to farmers and extension professionals, no one seemed aware of any farmers whose entire operations were fully organic except for the two I interviewed. Sampling bias may play a role here, but I did talk to others who had experimented with a field or crop under organic certification and, usually, gave it up because of the administrative hurdles.

challenging to grow in the Chihuahuan Desert, including beefsteak and heirloom tomatoes, strawberries, and lettuce. His hydroponic system has lower water needs than an equivalent outdoor system, although it may require more energy inputs (Barbosa et al. 2015). He is constantly experimenting with his system, crop varieties, and pest control mechanisms.

Finally, the two non-profit growers are quite different from one another. Victoria is one of the founders of an agriculturally-focused 501(c)(3) organization that works to bring healthy food and food information to the low-income residents of the southern part of Doña Ana County, as well as working on local and regional food policy. Their farm system is much as would be expected of a market garden elsewhere in the country—reflective of the two lead farmers' experience in the UC Santa Cruz farmer training program—but unusual in southern New Mexico. The system is transformative in that its farm is not only meant for production and fund-raising for the non-profit, but also to train young, local farmers. Programs target local high school students, many of whom are Latin@, as well as young adults. Given the lack of adequate attention to non-white growers by the USDA (Cambio Center and Center for Rural Affairs 2011; Bryan and Stateside Staff 2017), as well as the rising age of U.S. agricultural producers (USDA 2012), training of new, young, Latin@ farmers has the potential to be a transformative force, especially in a county with a very high Latin@ population (U.S. Census Bureau 2017). The goals of the farm itself are also potentially transformative, as future plans include planting desert crops like mesquite and prickly pear and rebuilding the cultural acceptance of their food value.

The other non-profit grower is a hobbyist, but I choose to include him in this analysis because of the degree to which he is working to innovate while also attempting to build food knowledge and alternative agricultural networks in the area. Reed grows bioponically, a technique similar to aquaponics, but instead of fish being a required element of the nutrient system for the plants, fish are optional. Bioponics does not use "manufactured petro-chemicals" (Bioponica 2018). He uses agricultural waste for growing media and grows both annual and perennial crops. He collaborated for a time with the farm enterprise attached to the local food co-op in attempting to build an effective aquaponics system. He is also the driving force behind the local seed saving initiative that is partly focused on breeding food crops to be better adapted to the climate of the Chihuahuan Desert, and partly focused on increasing local participation in growing food. All of the seed saving work takes place in an informal and non-market-based system, with free exchange of seeds and plants taking place one or more times each year.

Narratives of Agency: Toward Transformation through Characterization

To explore what has produced the shifts each of these farmers has undertaken, I turn to narrative analysis, or narrative-network analysis, as employed by Ingram, Ingram, and Lejano (2014) and Lejano et al. (2013). Each farmer constitutes part of a network that, if taking a farm-centric view, can be seen as converging on the farm and the decisions made on the landscape that shape lives of the humans, plants and livestock on the farm. Such networks include both elements that are consciously constructed (e.g. choices of suppliers, and sources of advice) and some elements that occur by chance (e.g. weather, available market outlets), but, in actor-network terms, most actants that belong to the network result from conscious choices made by the farmer. The "shared stories" that develop through networks allow for clearer identification of "key sources of motivation for participants to take, or not to take, action" (Ingram et al., 2014, p. 987). As such, narrative analysis offers a deeper view of the networks themselves than does analysis of network structure (Lejano, Ingram, and Ingram 2013; Ingram, Ingram, and Lejano 2014). It also offers an opportunity to see the multifaceted nature of farmer decision-making through a perspective that views farmers through more than the "narrow notions of technocratic rationality"

(Fischer, 1990 in Ingram et al., 2014) that often pervade the views conventional farmers have of themselves and their systems.

To explore the motivations for transformation among farmers, I examine the ways that transformative farmers characterize themselves and other actants in their farm networks, the narratives (stories) that farmers tell about their personal sphere transformations (O'Brien & Sygna, 2013) and how those have shaped the practical sphere (ibid.) of farm life, the unexpected twists in farmers' stories, and what can be read in what farmers leave unsaid. As Ingram et al. (2014) argue that this form of analysis offers perspective on the resilience and vulnerability of a network, I argue that it offers insight into the transformative potential of networks and their processes of creating personal transformations.

Characterization of Self. Within the diversity of growing, marketing, and management schemes practiced by the farmers in the study, there are several cross-cutting commonalities among a few groups of farmers. One is that, to some degree, each of the farmers frames her- or himself as a highly independent person. However, those who make more transformative decisions on their farms tend to frame themselves as different even from other farmers. Mateo, for example, says of himself, "I'm just a regular farmer I guess…compared to everyone else…except I'm a little bit different." Or as Zach puts it, "I don't know, it's one of those things, I'm a dreamer and I'm like, all right [try it out]." These two see themselves as outliers and innovators in the farming community. Mateo sets himself apart from his neighbors while also joking about the difficulty of the methods that he has chosen:

> So, I haven't had any problems going organic…I think some of my fellow farmers, they kid me, "Well, [Mateo], what are you going to do for weed control?" Because that's your biggest problem…And I said, "Well, I use that new organic herbicide called azadon." And there is, what it is is, uh, *el azadon*, the hoe—it's a hoe in Spanish.

Mateo's joke about hoe-as-herbicide highlights the firm yet gentle way he sets himself apart from his neighbors. He is self-deprecating, freely admitting that he's chosen a very "expensive and cost-prohibitive" way to go about managing weeds, suggesting that his neighbors see his choice as "crazy." Yet at the same time his joke gently points out that there are other means of controlling pests than those chemical means that have become widely accepted among all of his neighbors. He is clearly different in his methods but recognizes the importance of continuing to foster good relations with his neighbors by mildly making fun of both himself and them at the same time. Galen similarly emphasizes his simultaneous difference and humility, “And then very few people did it the way I did it by myself, you know. And that’s…made me more humble [sic] and just, and makes you think a little harder, I think.” In regard to his own decisions in the greenhouse, he says, “So, I’m trying to figure out what to grow in here. I don’t know what to grow.” Galen, like Mateo, is a farmer of long experience, but continues to frame himself as a person always learning, always experimenting.

Of the for-profit farmers, Galen, Zach, and Mateo stand out as the most prone to experimentation, and most comfortable with beliefs about themselves as different from their neighbors while still considering neighborly relations and fellow farmers’ practices as important. Zach, for example, makes it clear that his ties to conventional agriculture are central to his choices, “I am a proponent for production agriculture.” Yet, their choices on their operations have created farms that are, or were for some time, unique among their agricultural neighbors.

Stories of transformation. The farmers who have transformed their systems have stories of personal change that shapes the narrative of their farms. Most of these stories have to do with changes in the personal sphere (O’Brien & Sygna, 2013), particularly for the farmers whose farms have undergone the greatest transformation, but changes in the personal sphere are often directly linked to changes in the practical and political spheres. One farmer[53] has a story of the chronic illness that overtook him, that he attributes to pesticide exposure. He came to see organic methods as the best for his health and his family’s health, and converted his farm on that basis. He says that even as a conventional grower, “we didn’t use a

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[53] Since this farmer asked for additional assurances about the confidentiality of this part of his story, I am not using his pseudonym so as to avoid tying him to other aspects of his farm. It was not clear if he was concerned about making accusations against the pesticide company or perhaps making his disability known.

lot of chemicals," but he notes that the conversion to organic was, at times "depressing because my fields are a lot weedier you know." Mateo has a similar story:

> Interviewer: What made you make the decision to go that way?
> Farmer: Oh, it was—back then when my first—my son—was born and while sitting in the barn with the barn full of poison, you know, herbicides, insecticides, and I thought… and then conventional farming was in the dumps… You know, we weren't making any money. You'd go a whole year and end up just kissing your sister, you know, that's no fun. So, when, about that time Buhler Mills from Switzerland came by looking for an organic grower. And I thought, well, you know, it might be worth a try. So, we started out with 25 acres.

The farmer's story of change here is multifaceted, but what he mentions first, as if most important, is his instinct to protect the new life coming into his family. The personal sphere transformation, of coming to see the tools of conventional farming as "poison" and a danger to his family was a key spark to the direction of his farm from that moment forward. At the same time, however, the market elements of his network played an integral role in his decision-making. With minimal or no profits from conventional sales, organic production seemed a worthwhile risk to take, especially when a buyer of organic products was specifically searching out producers with whom to contract. Further this farmer's continued conversion of his entire operation to organic came about not only through his permanent change in beliefs about the holistic welfare of his family and farm, but also through a path dependency created by the USDA organics regulations:

> Farmer: So, I converted the whole farm to-- you have to clean your equipment if you're farming any transitional or conventional land, and then jump back to your organic. You have to clean your equipment and that was a problem. So, we just-- I took-- we took the plunge, we're all organic. Now, I farm 1200 acres and it's all certified organic.
> Interviewer: Wow, OK. With the cleaning equipment problem, I've heard people mention that but I'm always trying to picture what that actually means, is that like getting in with soap and water and scrubbing everything down?
> Farmer: Or pressure washer…. You know, you have to take time out to clean it up. And we did that for a year and that got old real [sic] quick. So eventually, that's-- And then the whole farm became organic, so I didn't have that problem anymore.

Thus a conversion that began from concern about the new life coming into his family was fostered by market forces, and encouraged to spread by a single piece of regulation that had significant effects across the farmer’s operation in the practical sphere—that made one behavior a hurdle and another set of behaviors, therefore, more feasible.

Market gardener Galen’s story of transformation merges with his faith. As a bishop in the Church of Jesus Christ of Latter-Day Saints, his faith and his farming are intertwined. His farming style is highly experimental, and his faith helps to inform why he farms. His first two experiences in farming reflect the main themes of his farming style and the inspiration for his farming. His first experience was as a college student, a “greeny” farmer, working for another farmer. In that position, he taught himself about drip irrigation systems and set up the entire system from scratch, using the early internet to help him to look up answers to questions he could not figure out on his own. His second experience, just after college, highlights the importance of the church in his farming experience:

> So and then from there I moved—graduated from college—and went and got a job in Oregon. It was actually the elder’s church. It was like 3,000 acres' farm and they hired me because they needed a foreman, working foreman. And they worked me hard.

In launching into his own greenhouse-based farm, Galen continued to experiment as he had in his very first farming job. But the financial needs of launching a greenhouse was on a scale beyond what a farm laborer could afford. So, the church was again important in making his hydroponic experiment possible:

> We have an, a good friend that's a member of our church who kind of—one of our customers… we could of done it ourselves this greenhouse. All we had to do we just had to borrow $20,000 for the greenhouse. But it cost 40,000, you know, so we basically funded half of it ourselves. And then he offered the other half. We could have done it by, you know, credit [inaudible] done it before of credit cards and stuff and we paid it back pretty fast, but... And we did try to get a bank loan, but they said no. So, I said fine. I did it anyway. I don't care. I don't have to have your help by golly. Anyway, so. I sometimes it's a stubborn streak. If I decide to do something I do it whether I have money or not.

So, the church as a network was important to Galen’s ability to engage in the experimentation he has undertaken in his hydroponic greenhouse. Galen’s role in the church is central to his self-definition as well as his network. According to one of his employees, he has hired members of the church for farm labor, and also proselytizes to employees who are not part of the church, even inviting a new employee to church events and ensuring that he met more members of the church. But, it is as a farmer that he gains credibility in the community, reinforcing his role in the church. Throughout his interview, Galen reflected on particular successes, as well as his ongoing experiences, so that despite his ongoing uncertainty about his experimentation, his skill as a vegetable grower comes across. That skill as a farmer is one means of contributing to the church of which he is a bishop. One of the ways the Mormon Church supports its members is through ensuring the welfare of all, including through bishop's storehouses, which are much like other food pantries. In bishop's pantries, however, "Bishops ask those who receive assistance to work for the help they receive in whatever way they can. These work assignments provide them with an opportunity to give back in a meaningful way" (What is a bishops' storehouse? 2018). According to his employee, one such arrangement existed on the farm at the time the employee was working there. The combination of working for his church community and building his skill and reputation as a farmer have shaped Galen's goals and focus in his operation.

The transformation story of the highly transformative conventional grower, Zach, emerges from his youth. He began farming at sixteen after convincing his father to let him take on some of the farm operations, and he and his father started a farm partnership a few years later. His transformation story begins with a conflict with his father:

> Me and my dad had a big fallout my freshman year of college. And it was about this time right before Christmas and I said, you know what, screw it. I'm done. I don't want to do this anymore. I don't want to fight with you. I don't want to ruin our relationship. So, I quit. And he's like, you can't just walk away. I'm like, I'm out, I'm done. So, I loaded my truck with all my cold winter gear I had. My brother Ross was living in Denver, outside of Denver, up in the hills of Silverthorne. He was working for an equipment company and they needed a guy just to change oil on equipment. So, I went out and worked four tens up there changing oil in the middle of the winter and so was a ski bum. I just skied. And I saved up enough money to leave there. I was there till mid-January and then I just worked my way through Colorado, to Utah, and then up in Montana, and I almost didn't come from Montana.

This early choice to walk away from everything to do with farming has shaped his attitude toward farming ever since:

> …and that's a funny thing. I always do -- I'm like, if everything goes south, if I lose everything, you'll never see me again. Like once the bank takes it all, I'll go work for a dairy or something, make enough money to get a camper and I'll be a village hippie in the mountains somewhere.

This constant background idea that he could simply leave farming has left Zach with an openness to experimentation with his operation, since he is operating from an assumption that failure is always an option. That openness has led him to membership in the US Farmers and Ranchers Alliance[54], which he has used as an opportunity to understand how farmers elsewhere in the country work and to begin to open his own farm operation to public view through posting details of his practices on social media, particularly Instagram. He feels that the "unbelievable group of growers" he has met through the Alliance and making his farm practices transparent on social media have both been positive influences on his farm and himself. So, Zach's changes in the personal sphere, in operating from a worldview where failure and change are part of farming, have also led to changes in his networks that have, in turn, led to further change in his beliefs about his farm and his actions on the farm.

Farmers who experience transformation of their ideas about self and farm also tend to have multiple influences within their networks that support transformation, and that they themselves view as supporting their work and livelihood. One important support for many transformational farmers is their spouses. Some of that support comes in the form of direct financial support, as in John's case, as his wife is "payroll manager for our local hospital. And it does two things, it gives us secure partial income, and it gets us health insurance." Incrementally changing farmers may diminish the importance of such forms of support out of a desire to emphasize the centrality of farm income to the household, as with Jeffrey, whose wife is a teacher, "We don't use my wife's [income]. My wife uses it as she sees fit, but all she does is buy little groceries, clothes." The "little" she does is framed as unimportant, as if her input removed from the household would not matter. Transformative farmers, on the other hand, tend to

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[54] Credible sources (Lappé 2011; Moskin 2011; Pollan 2016) suggest that the US Farmers and Ranchers Alliance is, in origins and funding, a greenwashing campaign by the large agricultural corporations (e.g. Monsanto) and agricultural marketing boards (e.g. American Egg Board, National Pork Board). Although the direct effects on Zach's decisions seem to be broadly positive, the fact that it results from corporate influence is important to note, as it may be that education programs may be oriented more toward teaching farmers greenwashing techniques than to creating real openness in farm operations.

characterize their wife's inputs as key. Zach says, "So, my wife is in charge of the farm to market store as far as getting it set up, and I think that will probably be our best venture so far." He sees his wife as the boss of an enterprise, and views it as one of the best pieces of work his operation has engaged in. Similarly, Mateo boasts about his wife's skill as a horsewoman, having recently won the All-American Futurity, a race in Ruidoso, NM, through which she won more than a million dollars. He is proud of her, "[Jessy], come here. I want to brag on you." And he also acknowledges the usefulness of her money, "Well, we use that money really right fast on the farm." (At the same time, he also emphasizes the common farmer relationship with the federal tax system, as he adds, "Well, we had to, otherwise Uncle Sam was going to take it all away." Finding ways to spend more money on the farm is a common means of reducing a farm's tax burden.) Spouses of transformative farmers thus tend to be framed as important actants in their networks.

Transformative farmers also often characterize other on-farm members of their networks as playing important roles. John, for example, notes the key role his son has played on his farm, discussing, for example, the machines his son helped to build and the fencing he designed and built. Because of the "water situation"—drought and a declining Ogallala aquifer—on his farm, however, John has pushed his son away from the farm, insisting that he depend instead on his engineering degree for work. Mateo's father, similarly, was important to his operation and to his transformation—despite the fact that his father doubted the wisdom of going organic. His father, "showed me how to soup up a cultivator to get really close." The cultivator is a replacement for herbicides in the organic system, so to his father it was a step backward, but he still helped Mateo to make his transition happen. It is not only family that is important in transformations, however. Zach, talking about the reorganization of farm management he undertook, says:

> And it's been great for us to find out who our leaders are that were already working for us. You know, [Miguel], we started tearing those barns down, I don't even remember when… and I was down here micromanaging them and they got about a quarter of it done in about three weeks. And then I turned him loose with it. And they're almost done with the first house and that was only a week.

Zach emphasizes the importance of recognizing the existing leadership abilities and possibilities among his staff in making his transformation more feasible, reducing his workload. He notes that since the management reorganization rather than receiving calls every five minutes, “my phone rings once every 15 minutes now.” He is able to step back and think more about the larger picture of his operation.

The supplier and market elements of transformative networks also contribute to making transformation possible. Mateo’s ties with Buhler Mills first enabled his organic conversion, and his determination to become fully organic has since led him to connect to organic cotton buyers in Japan and organic wheat buyers in Montana. Thus, his convictions combined with the market benefits he began to realize have reinforced Mateo’s farm transformation. Similarly, John’s connections to those in the chile business helped enable him to convert his farm from water-hungry peanuts to the lower-water-use system of strip-tilled chile and wheat: “Yes, that’s how I got started. I got a contract from [a chile color extraction company] and then my green chile thing just came along beside and because of that. And, of course, I got involved with the Chile Association.” Zach’s market connections are various, as he grows a wide variety of crops, but one example of a connection helping him to innovate is an organization researching the potential of cottonseed for fish food. He is growing a variety of cotton with “no gossypol and no toxin” for the mill and is working with them to research how it can best be grown and processed for feed. In thinking innovatively about their network possibilities, transformative farmers are able to build on their personal sphere transformations and successively change their ideas about what kinds of connections constitute the network of a successful farm.

Metanarrative and the Diverse Economies Framework. The transformative farmers in this study tend to be able to articulate narratives of changed outlooks and changed farm practices. Their narratives tend to stand out, however, from a farming metanarrative that insists that markets are the primary moving force of everything that happens in agriculture. Jeffrey, for example, when asked about the reasons for decisions and outcomes on the farm repeatedly said simply, “Demand and supply. Supply and demand." This said as if there were no further explanation needed. Farmers often talked about abandoning a crop as the price falls and starting a new crop as the price rises. This metanarrative reflects the pervasive influence of an economistic understanding of the way that agriculture functions, and one that runs through the stories of even market gardeners. But the farmers who attempt deeper transformations to their farming systems tend to talk more about other foci. Zach introduced a social and safety event every Friday morning. The event is important to the operation, he says, because:

> You know, we don't pay our guys a lot of money. You know, we don't have a lot of money to pay them. And they work harder than probably anybody else in the world. And so, it's important to keep the family aspect to let them know that as we grow, they grow.

He adds, "And it's a good session for the guys to hash out if they got a problem with somebody else." So, while the breakfast does directly serve the needs of the operation by improving employee relations, safety, and retention ("I have not fired anybody [in nine months], you know?"), it is also oriented toward supporting the individuals involved in the organization. As the management reorganization supports their professional development, the breakfast supports them as people with emotions and disagreements. The breakfast serves the market economy but is better placed in the diverse economies framework. It is a form of gift to the employees in support of their well-being. Similarly, the relationship between the two organic growers is rich with free gifts of skills, connections and information about necessary inputs that are hard to find for organic farming in the Chihuahuan Desert. Jim describes his connections to Mateo:

> [When selling cotton to Japan], it mostly goes through that friend of mine, and that's where I get the seed from, and I just kind of tag along, and it kind of—you know, it was a great benefit, for me at least, I guess. He kind of handled it, and there's a lady in California that brokers it…. Yeah, yeah, he has helped me a bunch. I'm very grateful to him, too.

Mateo acts as seed and sales connection for all of Jim's organic cotton. Mateo preceded Jim in the business and had already significantly developed his own network of suppliers and markets. His assistance to Jim, however, is not market-based, but friendship-based. This contribution of skills and network connections fits far more clearly in a diverse economies framework than in a strict capitalist market framework (or in opposition to one), because although the farmers benefit (separately) economically, the greater benefit seems to be in the friendship and support they have built up between each other. Their valuation is of the relationship, the skills, and the connections. And the valuation of connections is not merely market-based, as Mateo himself illustrates:

> We went to Japan. They invited us to go over there and so went with them. And it was amazing, because in Japan, you know, they're more environmentally conscious than we are here because they've had to live among themselves for hundreds of years…. And this guy, a Japanese spinner, he—Mr. Kondo—he's famous for, he can build, he can spin thread that's hollow on the inside and makes it more absorbent.

Mateo assesses his relationship with those to whom he sells his cotton more in the richness of his learning experience and his sense of being exposed to greater environmental awareness than he is used to at home. So, although the reason for the connection may have originally been market-based, the relationship now reflects a rich set of non-market transactions of cultural understanding, environmental awareness, and exposure to others' skills. The valuation of other humans, their skills and relationships, tends to be especially high among transformative farmers.

These twists in the metanarrative that highlight the importance of diverse economies are not just in relationships with people, but relationships with nature, as well. Severe pest infestations are one example in which transformative farmers demonstrated a different valuation of nature. When a cotton boll pest became a significant problem in southern New Mexico, for example, Mateo's fields were excluded from the spraying program because of his organic certification. "And… I never got sprayed. And I think I benefitted so much more from the program because my fields were sort of a refuge for a lot of the beneficial insects." Employing the language of integrated pest management, Mateo sees his fields as richer in organisms because of his determination to keep them pesticide-free. Victoria is coming to see farming in the desert as a question of adapting the humans to what works in the desert—"it's adapting to what we grow"—as much as encouraging the growth of "traditional fruits and vegetables like beets, carrots, that sort of thing." That adaptation is something that the organization intentionally fosters through cooking lessons and with kids and "historically looking at how [desert perennials] used be considered, like, nourishing." So, in essence, Victoria is seeing humans as part of nature and understanding them as in need of change as much as or more than the farm system may need change. Looking to nature for guidance is also built into Reed's attitude about building aquaponics or bioponics systems:

> You go to wild places and [organisms] have [healthy systems] already. You go up here in the Gila and you find a stream, and, you know, you're going to find lots of healthy creatures living together. We almost need to, like, chop that out and build our own, you know, add the pump… sunshine to pump that water. Have that same mix of stuff in there.

Reed's metaphor for copying the natural system (chop it out) suggests a wholesale adoption of all the elements of the wild stream system with humans working just to keep the system running. The imitation or even adoption of nature becomes the model for agriculture here. For large-scale conventional growers, however, even when they transform much of what happens on their farms, the focus still tends to center around human-created systems. Signs of their valuation of nature come nonetheless through particular decisions they make, as with John's movement into strip tillage: "Conventional equipment won't manage that residue. It balls up…. You have to have specialized equipment to manage the residue." His adoption of that "specialized equipment" is allowing more organisms, especially soil organisms, to remain in his system. And he says that it "makes a world of difference" and he is "thoroughly convinced that it's the ideal way to farm in the arid desert."

In their valuations of nature as in their valuations of other humans in their networks, transformative farmers frame them as important influences, with their closest network connections being framed as helpers, guides and teachers.

Conclusions

Among the key characteristics of farmers who made deliberate transformative decisions on their farms was that their narratives about their farm networks and actions on their farms reflect a belief in the importance of other-than-market influences in making farm decisions. The diverse economies framework (Gibson-Graham 2006; St. Martin, Roelvink, and Gibson-Graham 2015) offers a means of seeing the narrative-network elements that offer farmers opportunities to transform their systems. These farmers (with the exception of the hobbyist farmer) do not ignore market forces, but they recognize the ways in which systems of care (de la Bellacasa 2011) matter as much to useful on-farm outcomes as do the strictly monetary transactions around which farms are so often assumed to be structured. Actants within these farmers' networks become matters of care (de la Bellacasa 2011) to them as the farmers acknowledge the importance of more-than-market considerations.

Now, although substantial transformations were undertaken on the farms I am classifying as having undertaken deliberate transformation, it is important to come back to the fact that the worldviews of by far the majority of the farmers in this study do not accommodate anthropogenic climate change[55]. Still, they are, in some of their decisions, clearly reacting to environmental change. John reacted to drought and aquifer drawdown, for example, and Galen's greenhouses are partly a reaction to rising windspeeds in the region. Nonetheless, permanent change, a permanently different climatic future, was not part of the decision-making process of any farmers but those outside of conventional farming (mainly Victoria and Reed). Much of the deliberate transformation happening included transformations toward sustainability: decreasing pesticide use, developing crops that could serve as both fiber and fuel on the same amount of land currently producing fiber, decreasing water use, recycling nutrients, shortening the distances between schools and their food sources, decreasing erosion. Does it matter that these decisions were not made in direct reaction to anthropogenic climate change? No, in the immediate sense it does not matter. The transformations toward sustainability are and will improve both the food

[55] Instead, many of them spoke of 60-year cycles of climate change in the Southwest, in which drought occurs every 60 years. Despite a search of both academic literature and the internet more broadly, I was not able to find the source of this myth.

security of the region and broader environmental health. However, if such changes can be made without the threat of future environmental change, perhaps even more pervasive change might come about with climate change in mind. Perceptions of vulnerability to climate change influence the kinds of decisions people make (Wolf 2011). Perhaps if farmers were offered narratives of positive futures (Veland et al. 2018) based on changes they might make in their systems such changes would become more likely. Adger et al. (2009) suggest that our attachments to specific places and cultures represent a barrier to climate change. That "disruptive impacts on…cultural identify, knowledge, and traditions belie successful transitions" (Adger et al., 2009, p. 349). Overcoming those barriers may require finding stories of climate change futures that fit within or close to the current worldviews of conventional farmers, who so strongly influence our landscapes and the environmental impact of our broader society.

Chapter 7. Conclusion

This chapter summarizes the main empirical arguments made in the dissertation as well as its theoretical contributions. This chapter also offers recommendations of institutional and educational means to move agricultural systems toward transformational adaptation in anticipation of future climate change.

Summary of Main Arguments

The central objective of this project was to determine the circumstances that contribute to producing deliberate transformation in agricultural systems challenged by the kinds of weather extremes that are expected to become increasingly common in the future. Specifically, the study addressed: 1) whether and how the historical record and local ecology offer examples useful to a future with lower water availability and higher temperatures, 2) the barriers to transformative change inherent in both the political sphere (systems and institutions) and the personal sphere (narratives that shape beliefs, values, and worldviews) of farmers and agricultural systems, 3) the narrative-networks that spur and sustain transformation for certain farmers despite the barriers to transformation. The main findings of the dissertation are as follows.

(1) The drylands ecologies of the Great Plains and the northern Chihuahuan Desert include a diversity of edible plants. Past uses of both native plants and of diverse agroecological systems represent potential elements of future models of agriculture.

The High Plains and the Chihuahuan Desert are both challenging environments. High temperature differentials, both on a daily and an annual basis, mean that plants must be able to survive both heat and chill. Annual precipitation totals are low and highly variable. Evapotranspiration is high in the dry air that results from being located in rain shadows.

Nonetheless, a variety of plant and animal life survives and thrives in both ecosystems. Before European arrival, these areas also supported human cultures that, in many cases, made their livelihoods from the native species of the region. Even for those that added crop plants from elsewhere in the Americas (corn, beans, squash), native species, including animals like turkeys and plants from *Acacia* to *Yucca* species, were still central elements of their food stocks (Martin et al. 1956; Sánchez, Spude, and Gómez 2013). Although some of these species have not been domesticated, there are already those working to grow out and test the continued viability of desert crops—like Gary Nabhan-founded Native Seeds/SEARCH and affiliated farmers, many of whom are Native American growers (Garber 2018). Further, projects to rebuild large-scale agroecosystems based on native species are envisioned for regions like the Great Plains (Nabhan and Kindscher 2006).

After European settlement, systems that were at least partly subsistence-based were still common, even after the arrival of the railroad. Agricultural systems included diverse home gardens (Burroughs, Padon, and Grove 1975; Measday and Measday 1982; Ackerly et al. 1992) and a variety of livestock for home-scale production (USDA n.d.; Ashabranner 1989). The arrival of the railroad, however, did begin to bring a substantial orientation to export to distant markets[56] (Ackerly et al. 1992). As irrigation water, transportation, and the consequent potential for profits began increasingly to influence southern and eastern New Mexico, large proportions of counties' land became devoted to single crops, such as cotton (USDA n.d.; Carleton 2017). Although such changes did not eliminate crop diversity—crops like chile, for example, continued

[56] Some orientation toward export markets may have existed in prehistoric southern New Mexico, given the regional interconnections clear in items like turquoise and parrot feathers found far from their places of origin, but little of this trade would have been of agricultural staples (Childs 2008).

to be produced mainly for local consumption through the early 1970s (Carleton 2017)—they did reduce it. And, as agricultural extensionists warned in the period between the two World Wars (Carleton 2017), such changes necessitate more chemical inputs, a need only partially reduced when crops like alfalfa are still included in a rotation. Consequently, the shifts in the agricultural system have resulted in greater vulnerabilities to pests and dependence on distant suppliers.

The declines in crops continued during the period that some of my informants were able to discuss (in broad terms, at least), from 1995 to 2015. During this period cultivation of not just diverse vegetable and fruit crops, but even staples like cotton and corn grain declined (see chapter 3). The changes in this period resulted from exposure to an another vulnerability beyond those of dependence on distant suppliers and pests. International market change, and growing competition, were important factors in changing the crops farmers grew. Toward the end of the period, however, drought also began to be an increasingly important factor in eliminating a number of crops as choices, including corn grain and wheat grain.

So, what do these declines, especially declines in crop diversity, mean for New Mexico? Are they a signal of adaptation (even if inadvertent) to climate change? Of the increasing incorporation of New Mexico into the global market system? I would contend that both are elements of the adjustment occuring here. But I would add that the changes are incremental and reactive rather than anticipatory. Agriculture as a whole appears to be responding year by year in relatively small shifts away from crops, often as drought drives losses and consequent reductions in acreage, with little in replacement but heavy water users like dairies and pecans. The modification of New Mexican agriculture is, then, on whole, one that is decreasing adaptive capacity to future climate change (as large capital investments are made in high water-users) and, through limiting crop diversity, also limiting potential to adapt to future market shifts. Pecans are an example of this precarity. Not only do they demand more water per acre than most other crops traditionally grown in the region, but the majority of their export is to a single market—China. With the tariffs imposed by the current administration, the profits from pecans come under threat as China imposes counter-tariffs. Pecans have thus brought a temporary economic boon, but at the cost of present and future agricultural viability.

Past models of locally adapted crops and diverse mixes that provide adaptability to new market and ecological conditions thus offer the potential for better alternatives to the current system. The American model of 160-acre homesteads of largely imported crops was not sustainable for most, but other systems based on similar diversity may be. For the High Plains, Nabhan and Kindscher (2006), advocate a return to bison grazing with what they expect would lead to increased diversity of grass and forb species. For the desert, Nabhan suggests intercropping, shade plants, and the human-powered labor that can introduce methods of increase soil-moisture capacity like artificial basins (Nabhan 2013). Many of the models for a more climate-adapted agricultural future lie somehow in past systems—although not all useful systems will necessarily derive from the local area. The complex forest gardens of places like Nigeria and Central America (Kumar and Nair 2004; Wiersum 2004; Belcher et al. 2005), for example, can provide inspiration even for agriculture in a drier place. Their high ecological function, risk spreading, and diversification of income sources (Belcher et al. 2005), for example, may not fit current modes of market-based agriculture, but do provide the potential to deal well with future weather volatility and decreased external inputs. In addition, prehistoric Mogollon systems of water management, that dealt most with available surface water rather than drawing on limited groundwater (Pool 2013), offer possibilities of managing with existing water sources rather than drawing down groundwater sources. Permaculture designers are bringing together ideas of traditional surface water management with forest garden systems in other desert places such as Jordan (MacKintosh 2014). Although little research has been conducted on permaculture systems (Ferguson and Lovell 2014), there have been some promising results both ecologically and financially on a system in France (Guégan and Leger 2015; Morel, San Cristobal, and Léger 2018).

In short, there are models to be derived from New Mexico's past, its ecology, and from agricultural systems past and present around the world, that offer ideas for how to proceed with the state's agricultural future. Such changes, however, will likely require a move away from understanding agriculture as a form of industrialized production. Understandings of and narratives about agriculture will have to change if transformational adaptation is to occur. Given the droughts of prehistory and current climatic predictions for the region, substantial anticipatory change is needed for the region's agriculture to survive and thrive.

Such changes will best be shaped by substantial involvement from those who know farming best, including especially the farmers themselves. I recommend, however, four goals from which to begin the discussion. First, I call for an increase in organismal diversity. Increased diversity, especially in carefully planned polycultural systems, can provide the potential to decrease the need for inputs from distant suppliers, increase flexibility when the system changes (e.g. during drought or as temperatures rise), minimize pest problems, and offer a system that requires consistent labor investment year-round, as was all discussed in chapter 4[57]. Polycultural systems

[57] And as was once called for by extension agents (Carleton 2017).

in the style of forest-gardens that are being tried in Jordan also offer systems with increased drought resistance by providing diverse kinds of drought-tolerant cover that increase the moisture-holding capacity of soils and the system as a whole (MacKintosh 2014).Moreover, an increase in diversity of crops, livestock, and even people (in terms of age, ethnic background, rural-urban origins) can offer a source of new ideas and innovation within the agricultural system, ideas that can work more explicitly toward goals like diminishing vulnerability to drought. These changes can work in tandem with the three other goals. Second, the systems should reduce their greenhouse gas emissions. By working to mitigate climate change, agriculture can help minimize its own future challenges. By minimizing industrial fertility inputs and decreasing pest problems, diverse systems can work rapidly toward this goal. In addition, increased human diversity can offer means of increasing ties between rural communities and agriculture, ties that have broken down as farmers have left the profession and as rural communities become increasingly dependent on service economics. This increased linkage represents the third goal. Revitalizing agricultural systems by tightening their links with the broader community can happen in part by a greater focus on crops that people can eat locally rather than crops exported around the world. Consistent labor needs can also increase the permanent communities built up around farms. Finally, agricultural systems must become better oriented to support farmers. Farmer mental and physical health has declined as a result of isolation and tractor-focused lifestyles. A return to collaborative hand work could help to address problems of high suicide rates and poor physical health among farmers, while also rebuilding community. As stated above, however, such changes will require new narratives about what constitutes American agriculture.

(2) Barriers to transformative agricultural change often lie in the political sphere of transformation, but the personal sphere of transformation in the form of narratives about those barriers can further decrease the potential for transformation.

Barriers to a changed agriculture for the region lie in the realm of current narratives about agriculture, as well as in very real institutional arrangements that largely support a highly industrialized agriculture. Markets and policy together currently shape substantial barriers to transformative change. Farm subsidies, including crop insurance, have had a strong focus on commodity crops, not diverse or polycultural systems. The Food Safety Modernization Act (FSMA) has provided new barriers to smaller growers, further incentivizing a long-standing "get big or get out" mentality that has continued to pervade agriculture long after Earl Butz left his role as Secretary of Agriculture. Conservation programs like the Conservation Reserve Program encourage the loss of more farmers as they remove land from production. The National Organic Program provides small but real barriers to those growing in areas where the value of organic food is not recognized. To this laundry list of policy barriers can be added market barriers, shaped in their turn by policy. The loss of access to Mexican labor has multiple origins: financial crisis in the United States making Mexico more attractive for work, changes in immigration policy, and increasing opportunities to work in Mexican agriculture. The impacts of the loss, though, include a decreased ability of farmers in the region to engage in agriculture requiring hand labor. Finally, market competition with Mexico and other foreign countries has made the production of iconic and staple New Mexican crops like chile and alfalfa increasingly challenging for farmers. Thus, farmers are left with fewer and fewer options, losing more and more of the existing diversity in the farm system. Thus, the barriers in policy and markets are working against the goals of transformed agriculture laid out in the previous section. As more farmers leave the system, and lands are bought out by foreign investors, rural communities lose more of their source of cohesion and economic sustenance. The remaining farmers are left more isolated and less able to engage in neighbor networks that would allow them to innovate.

It is not only the market and policy barriers that stand in the way of innovation, however, but also the narratives that farmers shape about their own barriers. Some farmers frame all of their decision-making, for example, as the result of the economic conditions in which they find themselves. Jeffrey, for example, when asked about crop decisions constructed most of his choices as being about “supply and demand, demand and supply.” By conceiving markets and their influence on his choices in this way, Jeffrey made them seem an uncontrollable anonymous force, rather than the outcomes of decisions of his fellow farmers. Farmers’ purely economic narrative framing of their decisions often seemed to leave them with a sense of inevitable but unruly change over which they have no influence. With little sense of agency, a farmer is unlikely to undertake substantial innovation to a system.

A set of economic policy narratives about government subsidies are also common among farmers. One of these metanarratives involves the subsidies available to farmers themselves. Many dislike the direct payment systems (more common before the last farm bill) as well as the government subsidies of crop insurance. Even as they take the money, they feel that government should not be “choosing winners and losers” or that they wish they could be assured of making a living every year without debt and without government payments. The attitude makes their support for new or changed forms of government support for farming less likely, thus making it more difficult to find support in the agricultural community for funds that would support multifunctional agricultural goals of a kind in line with deliberate transformation.

A related metanarrative is about laborers and other rural people. Some farmers feel that the government safety net is too generous and therefore prevents people from working the kinds of jobs they, the farmers, have to offer. So, a government program that, for example, would provide salary support for agricultural labor or would not set limits on the income a person can earn while on Medicaid, might not find support among those farmers. Despite the usefulness of such programs to the farmers and rural communities, these farmers would likely frame such programs as part of the excess of government aid and therefore lobby against them. Narratives of government excess, so common in some popular media, work against government aid that would be beneficial for rural revival—in the style of the New Deal.

If farmers continue to follow market signals and engage in incremental change, the trends of change so far suggest that a fundamental decline in agriculture will occur in the state. Such a decline will have important cultural and economic effects on the state. Many of the icons of New Mexican culture are directly tied to its agricultural past and present, including especially the food culture, which is so closely tied to chile and the many products and dishes made with it. At least as importantly, farm culture, centered around farms and farmers, was long the focal point of rural areas, and is losing its place as the number of farmers declines in places like the High Plains. Dairy has increasingly become farming's economic powerhouse in New Mexico, but it is highly dependent on water, both for irrigation of feed crops and for watering the cattle themselves. Pecans too are highly water-dependent. Thus, the economic mainstays of current farming are placed to drive farming away from adequate adaptation to future drought. If farmers continue to rely on their personal narratives in which market forces reign, individualism is an automatic good, and government aid is sketched as the bugaboo, farm entrepreneurialism will be pushed toward maladaptive choices.

So, telling new stories of the role of the economy, of community as a value over individualism, and of the beneficial role of government would be one element of moving toward transformation. Telling new stories about the role of agriculture in society, as much more than an economic cog, is needed to transform thinking about the place agriculture can occupy in rural lives.

(3) Transformational adaptation has happened on the farm level when farmers' beliefs and worldviews, together with effective network connections, allow farmers to consider more-than-market narratives about key goals for their farms.

Despite all of the barriers to agricultural transformation, some farmers find ways to substantially shift their farm systems. The means to such change lies in the kinds of narratives transformative farmers tell about themselves, their life and farming experiences, and the connections made in such narratives to agricultural goals that are not solely economic. The narratives of transformative farmers emphasize the importance of care (Puig de la Bellacasa 2015) and of elements of diverse economies (Gibson-Graham 2006). Relationships that go beyond the strictly economic (market- or wage-based) are a fundamental element of the way that these transformative farmers see their systems. They express the importance of family support through financial, emotional, and technical labor. They emphasize the importance of other farmers as partners and supports to the decisions that they make. Those for whom labor makes up a large and ongoing part of their operations see their employees as people with diverse skills, abilities, and needs. They may frame them both as a key part of their operations and as one of the goals of their operations—in other words, the support of ever-better technical and social skills among employees becomes a goal of the farm. The broader goals of the farm among these farmers are also often focused on community well-being beyond the fence lines of the farm. Supporting better food for schools, adequate support for low-income members of the community, or simply better social relations with international buyers constitute some of the goals for these transformative growers.

The farmers in the study who transformed their system also do see themselves as innovators, and a little different from their peers. Their ideas of difference are founded on both the way that they carry out their farming and on their personal stories of transformation. From coming to see the use of chemicals as a real, tangible hazard to family, to coming to see oneself as a farmer always ready to leave the farm behind and therefore free to experiment, particular personal experiences have shaped who these farmers are and how they see their way forward in agriculture.

But that is not to say that, despite their seeming uniqueness, their experiences are irreproducible. All have been shaped by new elements of their agricultural networks. Some have reshaped their networks in order to maintain the transformations they wished for their farms. Others have sought out new networks so that they might glean ideas for innovation from other farmers both in the state and well beyond its borders. Regardless of why and how, the exposure to networks outside of the county, the state, and even the country, have helped to shape the possibilities that these farmers saw as feasible in their systems. Those extended networks have also offered support—as suppliers, markets, and social and inspirational sources—not necessarily available from their geographically proximate network members. The extension of network connections thus offers potential for making more transformation possible (see Recommendations, below).

Theoretical Contributions

(1) For studies of agricultural change in conventional systems

More research has come to focus on the role of the farmer in conventional American (U.S.) systems. The role of farmer identity (Burton 2004; Marshall et al. 2012) and the adoption of new ideas (Price and Leviston 2014; Pape and Prokopy 2017) have received some focus, for example. For conventional American systems, however, transformational adaptation has not been the focus of study, despite the many intersecting stressors likely to result from continued climate change. For agriculture of the Global North more generally, this project offers a new perspective by examining farmer reactions through the lens of the three spheres of transformation. It draws explicit links between the decisions that farmers have made and the narratives that shape their decisions, highlighting how strongly the personal sphere of transformation matters in the models that farmers envision and ultimately carry out for their farm systems. As the evidence from these New Mexican systems suggests that most farmers are making incremental change, and that their decision may be locking them into future maladaptation, transformative adaptation is a needed perspective for such agricultural systems. Moreover, the three spheres perspective, offers a means of seeing the ways in which interior mental and emotional processes combine with broader systemic influences to shape when and how transformation happens. It thus offers a way of understanding how societal institutions (e.g. USDA, the Farm Bill) intersect with individual understandings of change. It thus offers a means to suggesting how transformational change can be fostered.

(2) For political ecology

Although political ecological literature has not formed the bulk of background literature for this work, it forms the essential backbone of the project. One sense in which this is true is methodologically. Methods for the project were built on network political ecology (Birkenholtz 2012), with the key motivation being to tie local decision-making to broader patterns of institutions and change. By sketching out how farmer choices were based upon influences from far afield, as well as much more local and individual influences, the project scaled up the lessons from separate farms to county, state, and national implications. The project thus builds on the tradition of bringing political ecological thinking to bear on questions of resource management in the Global North (Walker 2003; Robbins 2006; Galt 2013). The question of farmer agency, of the degree to which farmers were able to make decisions within the constraints of the larger agricultural system, links directly to the notions of power and heterogeneity of resource access among farmers that are common in political ecology. Galt (2013) has called for an increased focus on “the margins” in a political ecology of food systems of the Global North. He includes in that call a focus on alternative food networks (AFNs) as well as on the distribution of surplus value. I argue that a political ecological focus on conventional agriculture can highlight the ways that AFNs can and cannot ultimately reshape the larger agricultural system. Finally, the motivations for the forms of deliberate transformation advocated by Pelling (2011) and O’Brien (2012) come from political ecological understandings of the multifaceted sources of climate vulnerability. In making clear the ways in which conventional farmers may be vulnerable to social and economic forces as well as the biophysical effects of climate change, I further underscore the ties between transformation and political ecology. In so doing, I suggest that the "margins" of agriculture sometimes lie at the heart of the accepted agricultural paradigm, in conventional farmers constantly striving to maintain a model that is crisscrossed with vulnerabilities for their livelihoods and ecologies.

(3) For deliberate transformation

The project contributes to work on deliberate transformation by bringing its focus to agriculture in the United States. There is an extensive literature on agricultural change in the U.S., including climate change in agriculture. Deliberate transformation differs, however, with its intentional concentration on change across the social, economic, and biophysical vulnerabilities experienced in a system. In addition, by bringing the three spheres approach to an understanding of agricultural systems, the project highlighted the ways in which the (personal sphere) narratives about agriculture told by farmers intersect with the influences of the larger agricultural system to determine agricultural outcomes.

The three spheres of transformation approach provided a means of identifying the key sources of transformation on farms, especially by permitting focused attention on how farmer worldviews and values shape the approaches they take to their farms. Farmers whose values have shifted to an increased valuing of their employees as people, to offering greater significance to environmental health, and to building richer, to believing in the importance of more interconnected communities, are those who have undertaken farm change.

In turn, I have contributed to the three spheres approach. 1) Methodologically, I have highlighted the usefulness of narrative in understanding how personal sphere transformative decisions may be shaped and how they, in turn, shape the landscape that decision-makers manage. 2) I have illustrated how a focus on the personal sphere can reveal the means through which transformative change can run counter to the dominant political paradigm of agriculture. 3) I have clarified the ways in which distant networks of information contribute to the creation and maintenance of a transformed personal sphere and the far-reaching effects of that change. In engaging with the three spheres of transformation, I am helping to point to the importance of understanding that global social and economic change will not occur through technical change or institutional improvement alone, but must come through the transformations of how each of us perceive the world.

In defense of the persistence of New Mexican agriculture

In speaking with people from outside the state, and even a few in the state, I have several times encountered the question: Why should agriculture in New Mexico persist? Given the climatic conditions and predictions, why not just let it fade away?

In brief: culture matters. Adger et al. (2009b) contend that culture is one of four social "limits"[58] to climate adaptation. In clinging to a given culture and its associations with a given landscape, a society may be reluctant to undergo intentional change for fear of losing key elements of its culture. Place attachment "contributes to individual and community well-being and quality of life," and "individuals with a strong attachment to their community are often unwilling to migrate to maintain their income levels because they are reluctant to leave behind their social and emotional support groups and adapt to a new community" (Adger et al. 2012, p.

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[58] Adger et al's (2009) "limits" closely resemble Moser and Eckstrom's (2010) barriers.

113). Moreover, resource-dependent communities often benefit from their place-attachment when adapting, as it “motivate[s] individuals to identify novel solutions and create a sustainable future” (Marshall et al. 2012, p. 3). Forced relocation can diminish the capability of individuals to adapt, as can a forced change in occupation (Marshall et al. 2012).

There are several lessons in this literature for New Mexican agriculture: 1) people with strong roots in the state are likely to remain in place even if substantial climate shifts occur—as reinforced both by the persistence of the Pueblo peoples in the region and by a recent High Country News article on remaining in Santa Fe during severe drought (Carswell 2018)); 2) maladaptation to climate shifts may continue to occur if adaptation is posited in a way that is perceived as a threat to culture, which has important implications for how to shape narratives about potential transformation; 3) people with strong roots in New Mexico and New Mexican agriculture will be the most likely to work hard to produce transformations that are effective for both their climatic conditions and their culture—if given the tools and narratives to do so; 4) most knowledge and skill about agriculture would be lost in a forced migration, as farmers would be demotivated to adapt, and even perhaps demotivated to continue as farmers—in addition to their likely inability to reinvest in farming if their loss of New Mexican land is due to substantial abandonment, because it would offer little financial support to their departure.

So, culture matters in adaptation, and if people are to continue in New Mexico, then New Mexican agriculture will likely continue as well. And should it? Well, given a future in which humans will need to rely less on fossil fuels, and our inability so far to scale up a feasible alternative to petroleum for transporting most of our food, local food production will be important for food security. The costs of food transport could rise if petroleum use is phased out without sufficient development of alternatives, and that could reshape the ability of people in New Mexico to access food (one of four elements of food security defined by the Food and Agriculture Organization) as prices steepen (Schmidhuber and Tubiello 2007). Maintaining local production will also be important as the variable impacts of climate change affect the stability of food supplies (ibid.). Even though it can be difficult to see food security as an issue in the context of the Global North, where many of us have no difficulty accessing food, there are substantial food security issues for large numbers of people in the U.S. Nearly 16% of New Mexicans are classified as food insecure (New Mexico Department of Health 2018), meaning they live in homes without consistent access to food. Non-profit organizations in the state are working to address hunger partly through providing direct access to healthful food as they allow residents to grow their own food in community gardens, or to access fresh produce from non-profit-funded, low-cost market trucks ("Mobile Markets"). Such trucks serve areas where there are few or no grocery stores (i.e. food deserts), in both urban and rural areas. Thus, there are non-profit systems already in place working to reformulate the food system to ensure that all people have access to food. Ensuring the availability of food for such systems in a low-carbon-emission world, however, is partly a question of growing fresh food wherever possible. Food grown close by, especially food grown specifically with the goal of feeding people who need it, may reduce vulnerabilities to international food system volatilities likely with continued climate change—as long as there is some water to grow it.

Should people continue to grow food in New Mexico? In stepping back from the system, attempting to take a "passionless" view of agriculture in such a dry climate, one might say no. But the reality is that people will remain as long as they can, and food production will continue in some form as long as people and water remain. This is an emotional, cultural, complex reality. But it is also a means to reducing climate emissions by making places livable without constant extensive, carbon-expensive transportation connections.

Recommendations

Recommendations for future research

My research looked closely at farmer thinking and decision-making, but was not able to address questions like the following: 1) How has the geographic distribution of types of cropland changed over time in each of the counties? 2) Can networks intentionally fostered to create change that looks to the climatic future contribute to the transformation of farmer worldviews and the goals of farms and of the larger farming system? 3) How does farmer training contribute to the transformation of agriculture? 4) What specific sources of influence are shaping farmers' personal values in ways that inhibit their support for programs that would better support the labor they need on their farms? 5) What are the sources of influence on extension at the county, university, and federal levels? What are their goals and (how) do they contribute to on-farm change?

The work in this dissertation thus raises several directions for future agricultural research. First and foremost, research into systems that are already facilitating transformative change of the conventional system will help raise awareness among both farmers and researchers of the positive means of reshaping the agricultural system in ways that can support both farmer livelihoods and food production with lower environmental impact. Among those, one important avenue will be research into the effectiveness of farmer training programs for transforming trainee mindsets. Also important will be research into how intentionally creating additional network connections among farmers, allowing them to increase their own awareness of effective solutions in distant systems, may facilitate transformation. Past research (Dowd et al. 2014) has suggested that distant information networks are key to facilitating transformation, and the networks of the transformative farmers in this study suggest the same. Additional research is needed to understand how deliberately created networks may have also offer the potential for transformation.

Also important will be additional research into the transformation of farmer values as well as broader rural values. As O'Brien and Hochachka (2010) point out, those who are involved in actions that contribute to climate change, which certainly includes everyone in the Global North, will need to carefully consider both exterior (i.e. political sphere) and interior (personal sphere) influences on decision-making as our cultures learn to move away from high-climate-impact practices. Farmers and rural people are constantly engaging with a changing system, but the ways in which their values are reshaped by engagement in that system still requires deeper understanding. Such research may include engaging with other frameworks of transformation, such as those coming from business, education, and psychology (Kegan and Lahey 2009; Rooke and Torbert 2005), to understand how rural transformation occurs. Such frameworks may also be usefully applied to understanding the positionality of extension in regard to climate change and broader societal shifts. The values of extension, in theory, would be expected to be similar to the values of farmers, so understanding how the values of extension are shaped and the degree to which those values reach farmers is also an important avenue of research.

As improvements in newer forms data, including geospatial data, make it feasible to better understand the connections between changing climate and crop choices and yields, additional spatial analysis will offer a further indication of how farmers are reacting to the climate challenges they are experiencing. Improvements in the U.S. cropland data layer (e.g. in the form of better land classification) and its use (e.g. improved methods of using it to analyze change over time) (Lark et al. 2017), will increasingly make it easier to analyze spatial change. Identification of key sites of change will therefore be increasingly feasible.

Recommendations for facilitating transformation

Substantial transformations in agricultural systems have often taken place when societal challenges were significant and immediate. World War II provided a key example in the U.S. and U.K. when Victory Gardens and the Dig for Victory campaign both produced radical change to encourage vegetable production in home gardens (and parks and estates in the U.K.) across both countries (Hopkins 2004; Endres and Endres 2009). Cuba, after the fall of the Soviet Union, also radically reshaped its agriculture. Cuba instituted programs to reduce reliance on agricultural petrochemicals by increasing use of biological controls for pests, opening composting centers, and increasing the use of animal traction rather than tractors (Endres and Endres 2009). Both the shifts in wartime U.S./U.K. production and in Cuba were the result of rapid changes in availability of previous resources. Access to imported food became untenable for the U.K. with its shipping lanes threatened, and both the U.S. and U.K. had to plan for wartime supplies for soldiers. In Cuba the loss of the Soviet Union as a major trading partner and subsidizer of oil imports meant that industrialized agricultural production was no longer feasible (Endres and Endres 2009). Shifts in all three cases meant a decline in use of fossil fuels for transport and production, and substantial proportions of the food supply came from hand work rather than tractor-based farming (Hopkins 2004; Endres and Endres 2009).

All of the above examples, however, must be referred to with caution in relation to a contemporary transformation of U.S. agriculture. Home production, for example, as in the U.S. and U.K. Victory campaigns, is unfeasible for many, for reasons of land access, materials access, and the current long work hours that tend to limit time for at-home work like gardening (Rivlin 2014). The gendered expectations attached to such work in the past, with women expected to shoulder much of the burden of home production, would also be unpalatable today (Bramall 2011). In addition, the use of the Dig for Victory campaign in recent discussions emerging from the Transitions movement has often highlighted a particular story, one that leaves out all but white, middle-class participants (Rivlin 2014). Thus, care must be taken to make use of previous examples in a way that clearly allows for wide participation among gender, ethnic, and socioeconomic groups. Intensive government control of resources and resource allocation was also important to both the war-time and Cuban examples (Endres and Endres 2009; British Wartime Food: How Britain Fed Itself During World War Two 2018), an aspect that would also be less than appealing to many in the United States.

Nonetheless, there are useful elements of these past systems as examples for transformation. They were produced rapidly, despite pre-existing industrialized systems (this is particularly true for Cuba). They increased the nutritional welfare of the population (Wansink 2002; Hopkins 2004; Endres and Endres 2009). They decreased the inputs of fossil fuels through limiting the need for transportation and increasing the biological production of soil fertility and pest management (Endres and Endres 2009; Hiranandani 2010).

Future transformation should certainly include the latter two elements of historical transformation among their goals: better nutrition and decreased fossil fuel use. Means of creating more access to land among those without it will also be important. Land prices make the acquisition of farms increasingly prohibitive for most in the U.S. who do not have the option of acquiring land from family (Niewolny and Lillard 2010). History suggests that more equitable access to land can reduce inequities overall when agriculture is a central element of livelihoods (Santiago-Caballero 2013). Future transformation will also benefit from drawing on examples from ecologically complex systems like forest gardens (Kumar and Nair 2004; Wiersum 2004), agroforestry systems (Wilson, Lovell, and Carter 2018), and permaculture systems (Ferguson and Lovell 2014; Guégan and Leger 2015). Notable progress has already been made toward increasing the complexity and perennial nature of existing agriculture systems, though research like that occurring in the Wisconsin Integrated Cropping System Trials (WICST) (Bernstein et al. 2011; Sanford 2014; Liang et al. 2016) and elsewhere (Cong et al. 2014; Philip Robertson et al. 2014). Research at The Land Institute has now resulted in a commercialized perennial grain, and progress continues to be made on other perennial grassland species (Ryan et al. 2018). All of these systems provide ideas for future directions of agriculture.

But even those systems that are relatively closely tied to conventional and industrial-style production, like the WICST research, are still relatively underrecognized among conventional farmers who are geographically distant from such work. Moreover, the realities of tractor-based production still mean that much of farming is centered around the simplicity of monocultural fields out of necessity. As the example of Mateo, suggests, however, past machines can be brought back. And new machines have become reality for many who are carrying out no-till agriculture, since traditional machines like planters are often replaced by those more up to the task of dealing with pre-existing mats of vegetation.

But how can broader change take place? How can the examples of perennial and polycultural agriculture be offered as at least ideas from which to begin change? And how is that change likely to happen? Evidence suggests, first and foremost, that change is best modeled by other farmers. And evidence from this study and from work at CSIRO (Dowd et al. 2014) suggests that extended networks of information beyond local networks of farmers and suppliers can offer potentially transformational new models and ideas for farmers as they consider changes to their farm systems. Most farmers in this study make use of the internet in some form or other, making the internet one viable way to create and maintain extended networks of farmers. Farm visits are also an important way of understanding change, and internet-based networks could establish funding and systems to increase the ability of farmers to visit very different systems from their own, as Zach was able to do through his work with the US Farmers and Ranchers Alliance. Such networks could incorporate social learning through which farmers, extension agents, suppliers, and breeders could participate in extended learning opportunities. Such learning could include on-farm research as well as training on topics including decreasing greenhouse gas emissions from farming, creating training experience for employees, health insurance and labor, working effectively with diverse crops, and incorporating livestock in an integrated farm system. Training might include in-person sessions, but also videos, video-conferences, and online chatrooms.

Perhaps the most important means of achieving change, however, will be in attracting, educating, and supporting new, and especially young farmers. The average age of farmers is rising. With increasing land costs, it is increasingly difficult to enter farming without taking over a family farm. So, there is a dearth of younger farmers. Training programs that focus on farming (rather than elements of the agricultural system) are relatively few and far between. Land grant institutions offer courses in soil science, crop science, weed management, economics, and the like, but prospective farmers in these programs may feel like Christopher. He said of his agriculture courses at his nearest university, “That’s why I quit college. The whole thing was not very helpful.” He speaks of wishing he had had courses on bookkeeping and dealing with taxes, courses that were not part of the agriculture studies he undertook. Beginningfarmers.org lists college-based farmer training programs in the U.S., and there are only six, including the Wisconsin School for Beginning Dairy and Livestock Farmers (Beginning Farmer Training Programs 2017). The USDA opens its “New Farmers” website with “Step 1: Start to Farm,” and it takes some digging into the website to find any discussion of training programs. Even when the site describes ATTRA, now called the National Sustainable Agriculture Information Service, it does not mention the farm internships advertised through the service. Little else is mentioned in the way of formal training aside from discussion of the grants USDA provides to organizations that engage in new farmer training (Education and Assistance 2017). There is, in short, substantial need to increase the offerings of new farmer training programs, and to make information about them easily accessible on the internet for a generation for whom that is where most information is accessed.

Alternatives to the current conventional paradigm are available, but minimally adopted on the majority of U.S. agricultural land. Some, like permaculture, remain under-researched. Many of the directions in which agriculture could transform are, however, already have university research behind them, in addition to the extensive practical experience of systems like permaculture. What is needed most to prepare agriculture for the future is a combination of expanded and re-prioritized education, networking, and a new set of narratives of what constitutes successful farming. For many of the farmers in this study, it was narratives of limited options as much as real barriers in their systems that prevented them from engaging in substantial change. The real barriers also need to be addressed, but perhaps the most compelling way to change both agricultural laws and institutions as well as farmer options is to create new narratives among both farmers and policy makers of what the future of farming should be. In short, we need to change the story of farming. In the words of Carleton (2017), “for all those interested in seeing changes in agriculture or agricultural policy: it may be just as useful to take hold of pen as it would a hoe.”

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