CENTRAL TEXAS LOCAL FOOD PRODUCERS IN THE 2011 DROUGHT:

VULNERABILITY, COPING STRATEGIES AND SUSTAINABILITY

by

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I. INTRODUCTION

During the year 2011, Texas experienced the worst one-year drought in its recorded history. The drought had a major impact on local food producers and brought many challenges. Drought is not a new phenomenon in Texas, periodically occurring throughout history. However, climate change has created drier and warmer conditions in central Texas. Projection models predict a much drier Texas on par with, or even exceeding, 10-year to 30-year droughts of previous centuries (Banner 2010). In addition, according to the National Aeronautics and Space Administration (NASA), nine of the ten warmest years on record have occurred since 2000, making the first decade of the new millennium the warmest decade on record (Cole and McCarthy 2010). As drought becomes a more common and intense event in central Texas, population is also expanding. Texas' population is projected to increase 82 percent between the years 2010 and 2060, growing from 25.4 million to 46.3 million people (Texas Water Development Board 2012). With an estimated population growth of 3 percent for 2012 and 2013, Forbes ranked Austin as the fastest growing city in the United States for the third year in a row, followed by Houston and then Dallas (Brennan 2013). With the combination of drier conditions and accounting for a larger population drawing on the water supply, water resources will become more scarce and local food production more difficult.

Under these circumstances, local food producers face challenging decisions regarding how to cope on a short-term basis and adapt over the long-term. Coping mechanisms and adaptation to drought take the form of various farm management strategies. Until now, few studies have addressed local food production coping strategies and adaptations in relation to drought. None have examined central Texas. Given the recent drought of record in central Texas, this study illuminates how local food producers coped with drought and what factors influenced their decisions.

This study has two main objectives. The first objective is to explore how the vulnerability of a local food producer influenced their coping strategies to the 2011 drought. Specifically, what factors prompted them to use agricultural (changes in production strategy made on the farm) or non-agricultural (changes made outside of the scope of agricultural production) coping strategies. The second objective of this research is to discover how local food producers in central Texas implemented different farming practices to cope with severe drought conditions. I used a survey of local food producers in central Texas to address these research questions: What effect did local food producer vulnerability have on implementing agricultural and non-agricultural coping strategies? Which coping strategies and vulnerabilities were most influential for local food producers? How are central Texas local food producers employing sustainable farming practices to cope with drought conditions?

The inevitability of future droughts, in combination with an increasing population in central Texas will result in probable water scarcity and highlights the need to understand local food production in drought. This thesis is organized as follows. After describing the study area and current situation, I review pertinent literature to provide the necessary background information on natural hazards and disasters, drought coping strategies, sustainability and local food production. The next sections illuminate the context of water in central Texas, describe the methods of this research, and detail the results. Results from this study will better inform local food producers of coping strategy trends employed by more and less vulnerable food producers. In knowing which characteristics indicate more or less vulnerability to drought and the common coping strategies used by this group of local food producers to overcome drought impacts, local food producers can better prepare themselves for future drought events. In addition, local food producers will benefit from this research by learning which sustainable agricultural strategies were widely used and successful. Implications of the findings from this study will have application to local food producers not only in central Texas, but also in drought-prone areas around the world. This research aspires to understand current conditions of local food production in drought-prone central Texas, and identify patterns that emerge, in order to foster sustainable long-term adaptation to inevitable future drought events.

II. DROUGHT AND LOCAL FOOD PRODUCTION IN CENTRAL TEXAS

A commonality shared by all local food producer locations was the experience of intense drought in 2011. During the drought of record, most of the state of Texas, including central Texas, fell into the category of "exceptional" drought while many other areas experienced "extreme" or "severe" drought (Fuchs 2012). Figure 2 shows the height of the drought of record on October 4, 2011 when 88 percent of the state fell into the category of "exceptional" drought (Armico et al. 2012). All local food producers in central Texas fell into the category of "exceptional" drought in 2011. The 2011 drought was the worst one-year drought since Texas rainfall data were first recorded in 1895 (Huber 2011). Average rainfall across the state in 2011 was only 14.8 inches (Armico et al. 2012). Many streams dried up entirely or decreased significantly in water flow. The Edwards Aquifer recharge in 2011 was 112,000 acre-feet per year compared to its average annual recharge of 712,000 acre-feet per year (Votteler 2012).

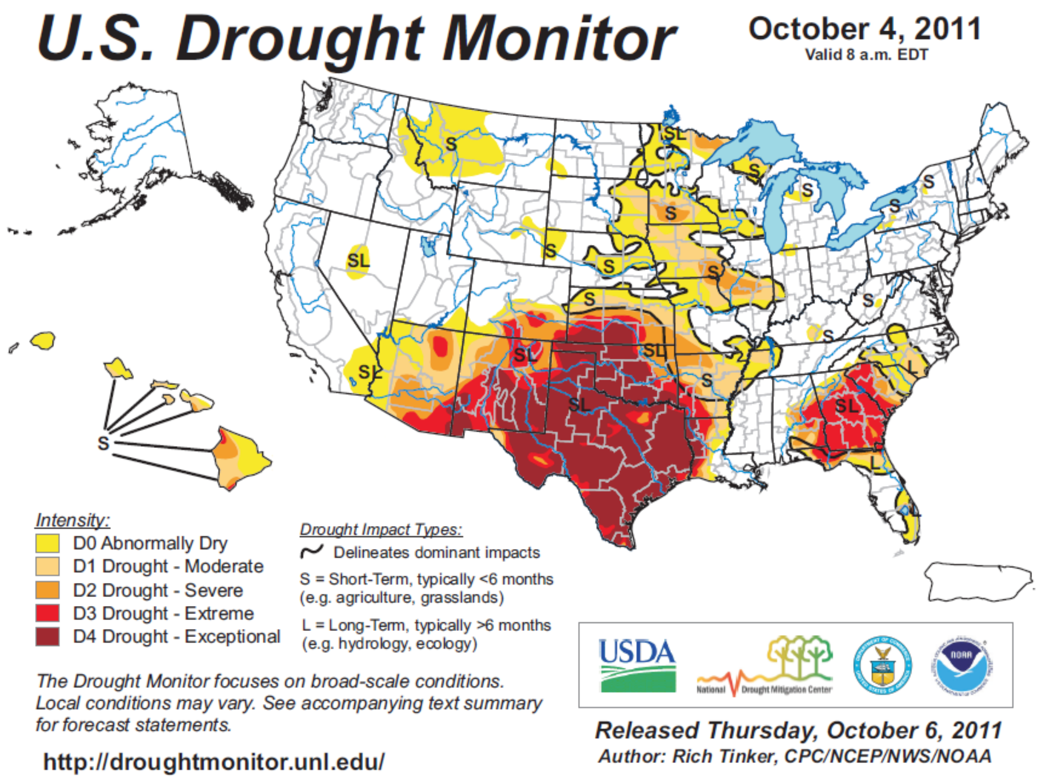

Figure 1. U.S. Drought Monitor on October 4, 2011 (University of Nebraska-Lincoln, n. d. 2011).

The impacts from the 2011 drought of record cannot be overstated. These extreme dry conditions resulted in 30,457 wildfires that spread over 6,240 miles, an area equivalent to half the size of the state of Maryland (Armico et al. 2012). In addition, 117 drought-related deaths occurred in Texas. There were water shortages in reservoirs and water wells and exceptional and widespread losses took place in crop and pasture agriculture (Fuchs 2012). Texas experienced agricultural losses during the drought of record reaching $7.62 billion, establishing another new unfortunate record in Texas history (Votteler 2012). The price of hay increased 200 percent and crop failure created severe dust storms in west Texas. This devastating drought put many local food producers across Texas out of business and challenged those remaining to adapt.

The local food production area under study stretches across a large expanse of land in central Texas. Local food producers included in this study are located in various counties and cities within central Texas. A rich body of literature has documented the distinct “urban” and “rural” locations and interests, and most recently, a third hybrid location has bridged the urban-rural dichotomy, the peri-urban. A peri-urban location is characterized by a heterogeneity of actors. Rural natives and newcomers combine with urban people, generally from nearby towns, to create this unique landscape (Overbeek 2009). This community holds diverse interests and often works in urban places. Peri-urban locations facilitate easier access to off-farm employment, which as discussed in the results section, is an important coping strategy for central Texas local food producers. Local food producers in this study are located in urban, rural and peri-urban locations. Within this landscape, this study focuses on thirty-seven local food producers, all of whom distribute their product through at least one of the Austin farmers’ markets (Figure 1). Local food producers distributing to Austin farmers’ markets are all located within a 150-mile radius of the city. As the definition of local food is somewhat controversial, it is interesting to note the geographical distribution of central Texas local food producers that distribute their products at farmers’ markets in Austin do in fact stay within a 150-mile radius of Austin. Central Texas farmers are in a variety of unique locations with a range of characteristics that affect production and management strategies, including farm size and location, farm product type and water access. Austin’s local food producers tend to be located more east and west from Austin than north and south. Within that area, there are also clusters of local food producers east of Austin, following the north and south trajectory of where the highway IH-35 is located. It is also worth noting that there are large numbers of local food producers in between the two large cities of Austin and Houston.

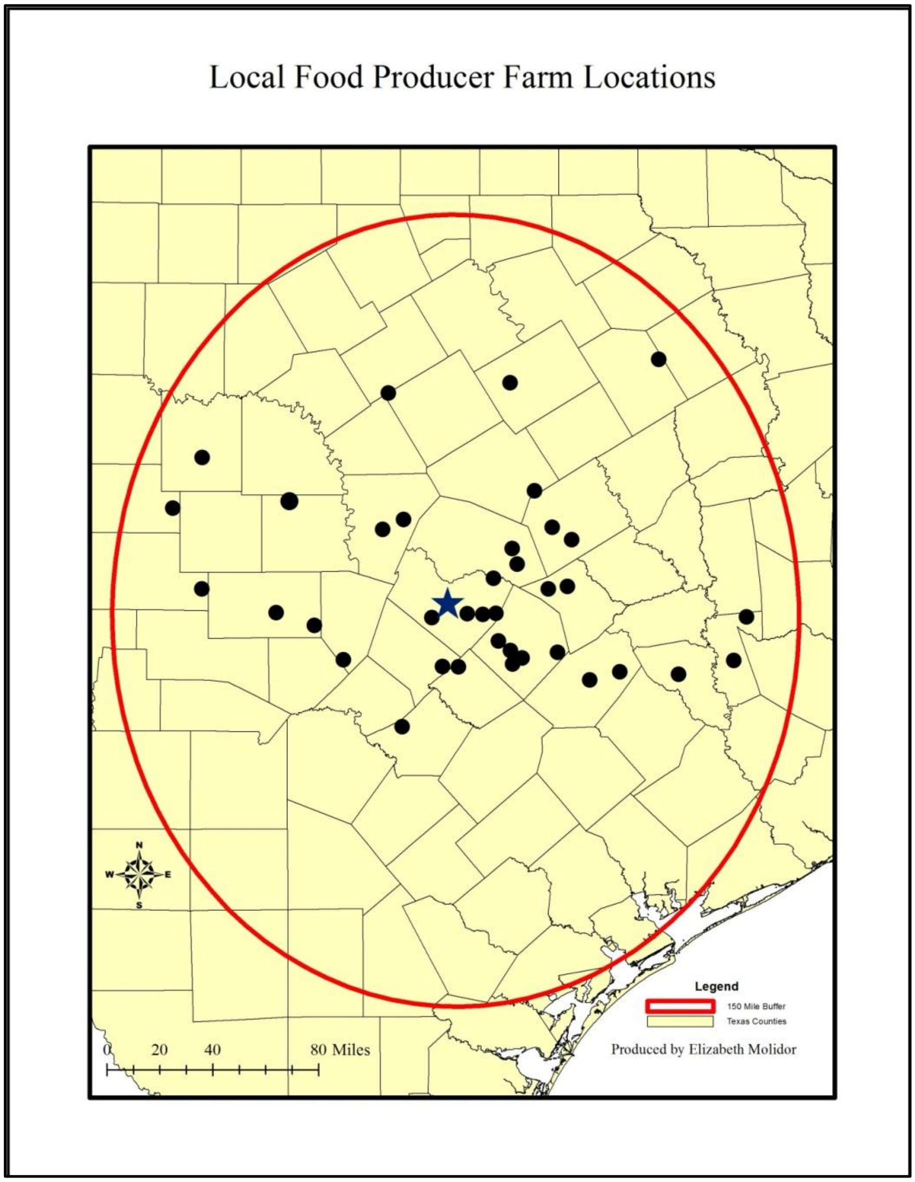

Figure 2. Area of Local Food Production for Austin Farmers' Markets. The city of Austin is the blue star in the center and the local food producer farm locations are the black dots.

Although the 2011 drought was the worst one-year drought on record, the Intergovernmental Panel on Climate Change (IPCC) predicts that the central North American region is to experience drought with increased intensity (IPCC 2012).

Implications of this prediction, along with scientific evidence that Texas' climate is becoming drier and warmer, are that continued drought in central Texas will present significant challenges to both local food producers and natural systems. The importance of local food production adaptation in the context of water availability within central Texas is clear as future drought events *will* occur and the viability of local food production *is* at risk. The theoretical framework structuring this thesis draws on current debates and ideas within the natural disaster and sustainability literature. These allow for a comprehensive examination of local food production in the context of a major drought event. A review of the literature provides rationale for incorporating both natural disaster and sustainability perspectives.

III. LITERATURE REVIEW

Natural Disasters

The leading perspective on natural disasters leading up until the mid-1900s upheld the belief that natural disasters were "acts of God", beyond human influence. In the 1940s however, Gilbert White introduced a new perspective on natural disasters, referred to as the dominant, hazard-based or perception approach (Whyte 1986, Smith 2002, Gaillard 2008). This new perspective challenged the idea that natural disasters were isolated events, separate from society, and introduced a social perspective into natural hazard literature (Smith 2002). In particular, White viewed natural hazards through a human ecological lens and saw the natural hazards process as an interface between the natural and human systems (Smith 2002). Additionally, the hazards-based approach emphasized mitigating loss from natural hazards through human adjustments (Smith 2002). Joining White in the human ecological approach was Robert W. Kates and Ian Burton, who together formed the leading school of natural hazards and produced multiple works, most notably, *Environment as Hazard* (Burton, I., R. W. Kates and G. F. White 1978). Summarizing the hazards-based approach, Robert W. Kates described a natural hazard as an interaction between nature and people that is directed by adjustment processes, which are influenced by individual risk perception and awareness of possible adaptations (Peet and Thrift 1989). Risk perception is the process by which individuals perceive the environment and environmental risk (Smith 1992). An individual's perception of risk is influenced by many interrelated factors such as "past experiences, present attitudes, personality and values together with future expectations" (Smith 1992). Adjustments to the hazard include modifying the loss burden of the affected population, modifying the hazard events, and modifying human vulnerability. Whichever adjustments are applied, in turn affect future capacity to absorb environmental problems (Peet and Thrift 1989).

After criticism of the hazard-based paradigm from anthropologists and social geographers in the late 1970s, a new theoretical approach emerged, referred to as the disaster-based approach, vulnerability paradigm or structuralist paradigm (Smith 2002, Gaillard 2008). Two key works that challenged the hazard-based perspective and created this theoretical shift among disaster theorists were O'Keefe et al.'s 1976 *Taking the Naturalness out of Natural Disasters*, and Kenneth Hewitt's 1983 *Interpretations of Calamity from the Viewpoint of Human Ecology*. In 1994, another major work by Blaikie, Cannon, Davis and Wisner continued this theoretical approach with *At Risk: Natural Hazards, People's Vulnerability and Disasters*. Authors of these works argued that not enough emphasis was given to the sources of social influences (Zappa 2009). This shifted from a focus on human ecology and mitigating losses through human adjustment to understanding the social response of the community during the disaster (Smith 2002). From these works, disasters are understood as products of the social, political, and economic environments, which structure the lives and adaptations of the people, in addition to natural hazards (Blaikie 1994). In simple terms, this shift moved from a focus on "disaster as agent" to "disaster as social vulnerability" (Flint and Luloff 2005). This perspective emphasizes people's vulnerability to a natural hazard (Zappa 2009).

Vulnerability describes a natural disaster as a complex interaction between natural hazards and society (Blaikie 2005). As a key work within the disaster-based approach, Wisner et al. (1994) created the Pressure and Release (PAR) model presented in Figure 3 to illustrate this concept. The PAR model illustrates how the social vulnerabilities of society combine with a natural hazard to result in varying magnitudes of a natural disaster (Wisner et al. 1994). More specifically, as presented in Figure 3, root causes, dynamic pressures and unsafe conditions in society determine the degree of social vulnerability. Natural hazards in this context are the threat of potential harm to a human population (Smith 1992). The capacity of adaptation and response to a hazard varies significantly with the socio-economic situation of an individual, household or community (Bardsley and Hugo 2010). Susan Cutter describes vulnerability as a social-ecological perspective that is conceptualized as an equity or human rights concern (Cutter et al. 2008). This viewpoint illustrates the need to regard hazards and disasters as processes with long-term precursors and consequences, and not merely a single "event", which may lead to greater vulnerability should a subsequent hazard strike (Chhotray and Few 2012). Vulnerability is an important concept in understanding existing conditions, which affect adaptations to the hazardous event.

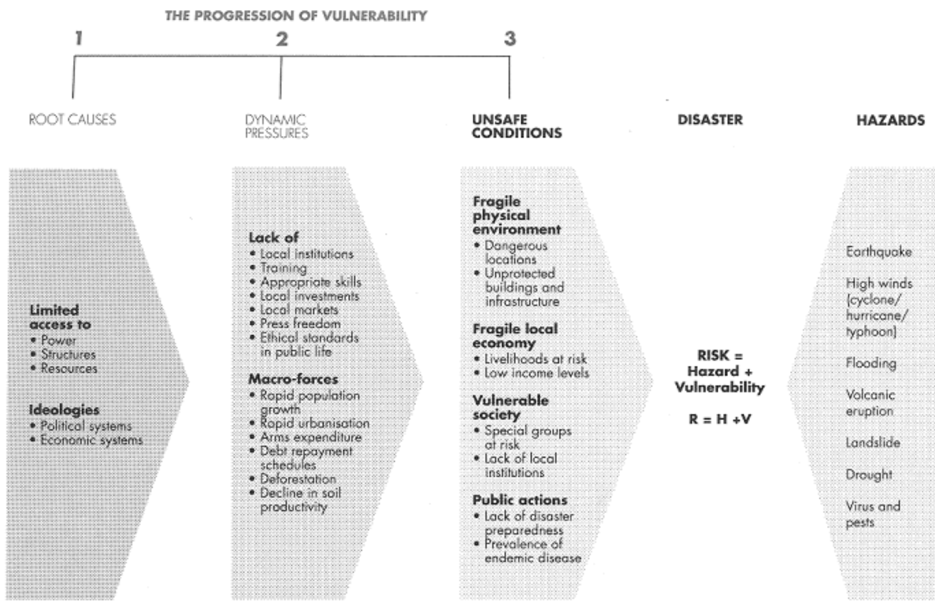

Figure 3. Pressure and Release (PAR) model: the progression of vulnerability (Wisner et al. 1994)

Contemporary disaster literature reflects a split emphasis on both the hazard-based and disaster-based perspectives. With this, scholars recognize that both approaches have strengths and weaknesses (Zappa 2009). The hazard-based perspective emphasizes that individuals or society will adjust to a hazard depending on their perception of how extreme the hazard is, while the disaster-based perspective argues that social, economic and political forces outside of their control shape the behavior of individuals or society (Zappa 2009). Smith (2001) outlines these strengths and weaknesses in both paradigms, emphasizing that the hazard-based perspective neglects to account for environmental quality and has a lag in recognizing the role of global forces, while the disaster-based approach helps to protect the most disadvantaged in society by emphasizing poverty and vulnerability.

A holistic approach incorporates the two paradigms and identifies the advantages of using both perspectives to understand disasters (Zappa 2009). This approach recognizes that disasters are a result of natural and human components. Contemporary research places priority on incorporating both approaches to balance the differences and develop policy that creates a safer environment (Zappa 2009). In the holistic perspective, sustainable development offers a solution to mitigating a disaster event (Figure 4). The United Nations International Strategy for Disaster Reduction (ISDR) supports both the holistic approach and sustainable development. Since the Millennium Development Goals were set in 1992, the UN has continued the pursuit of achieving sustainable development worldwide (United Nations 2012). Sustainable development bridges the gap between natural environment and human use systems to maximize the benefits and limit the costs to both sides (Smith 2001). As sustainable development is a balancing act to improve disaster management, local food producers will clearly benefit from sustainable development in their farm management strategies.

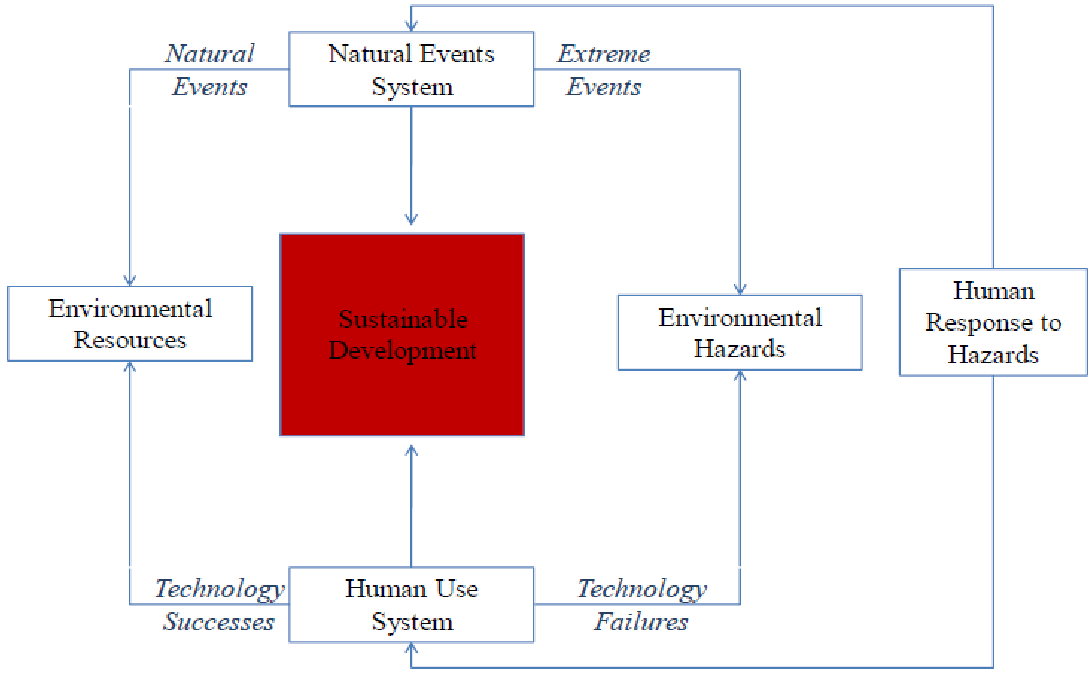

Figure 4. Sustainable Development is suggested as a Disaster Mitigation Technique for Holistic Hazards Model (Smith 2001).

Household Disaster Recovery

As many local food producers are family-run operations, recovery from the drought of record in the context of the household is an important process that influences farm management decisions. *Reconstruction Following Disaster* by J. Eugene Haas, Robert W. Kates and Martyn J. Bowden touched off a new discourse in disaster recovery (1977). This work delineated and described the different stages of recovery after a disaster (Haas, Kates and Bowden 1977). These periods of recovery illustrate how the disaster initiated changes in the household and in the community. Household decision-making plays a key role in adjusting to a natural hazard and directly influences the larger community adaptations. Household characteristics influence adaptation and recovery from a disaster (Haas, Kates and Bowden 1977). Household decisions are influenced by prior experience with the hazard, the economic situation of the individuals, personality traits and the individual's perceived role in a social group (Burton, Kates and White 1978). An approach held by Watts proposes that people respond in different ways to a hazard depending on their economic position, social and political networks (Peet and Thrift 1989, Paul 1998). In addition, Robert Geipel found that cultural and socio-economic characteristics have a direct influence on how an individual copes with disaster (1982). Factors important in the context of a household include the "household structure, gender, occupational and tenancy characteristics, farm size and educational status of the households" (Paul 1998). In addition, pre-disaster conditions and resources in the household as well as the degree of the direct impact of the disaster make a difference in adaptation and recovery. As evidenced, household decisions involve a myriad of influences. This decision process generates the adaptations and coping strategies that a household employs throughout a hazard (Burton, Kates and White 1978).

Drought

Drought is the most complex of natural hazards and affects more people than any other hazard (Keshavarz, Karami and Vanclay 2013). It is the most widespread hydro-meteorological condition of a "prolonged period of water scarcity affecting natural resources, environment and, thereby, the people" (Gupta, Tyagi and Sehgal 2011, 1795). Drought events are comprehensive in scope, affecting natural and societal aspects of communities alike. Unlike other natural hazards, drought is a slow moving phenomenon that covers large areas. Because of this, drought processes are often hard to separate from other processes that may make an area prone to drought (Smith1992). For instance, the beginning and end of a drought are hard to determine based simply on the difficulty of recognizing a departure from normal conditions in an area that may already have dry characteristics. These factors can make drought a difficult phenomenon to distinguish and study, which has resulted in less drought research in comparison to other hazards (Smith 1992). As a result, complex drought impacts at various scales have only been identified in a few studies and there are very few databases to track drought impacts and trends (Keshavarz, Karami and Vanclay 2013). The processes that initiate drought are not well understood, and the outcome is that drought is defined in terms of effects rather than causes (Smith 2002).

Furthermore, drought lacks a universal definition. Over 150 definitions of drought exist, reflecting the range of regions, needs and policy implications (University of Nebraska-Lincoln, n. d. 2012). In response to this, Wilhite and Glantz (1985) developed four basic categories of drought: meteorological, agricultural, hydrological and socioeconomic (University of Nebraska-Lincoln, n. d. 2012). For the purposes of this study, agricultural drought, which links meteorological and hydrological drought to agricultural impacts, best describes the 2011 drought of record. Agricultural drought manifests in precipitation shortages, soil water deficiency, and reduced groundwater and reservoir levels, which results in an inadequate water supply for plant needs (University of Nebraska-Lincoln, n. d. 2012).

The aftermath of drought is manifested through many different impacts on agricultural production. Examples include decreases in surface and groundwater resources and a decreased water supply, decreased water quality, crop failure, reduced productivity, increased livestock sales, production shortfalls and a resulting food crisis (Keshavarz, Karami and Vanclay 2013). Overall, impacts are economic, environmental and social (Paul 1998). Environmental impacts include the physical damages resulting from the drought, such as reduced forest and crop productivity, increased temperature and evapotranspiration, decreased water resources and water quality, increased incidence of wildfire and degradation of landscapes (Keshavarz, Karami and Vanclay 2013). These environmental impacts are otherwise known as first-order impacts, which have direct effects on biological production (Kates, Ausubel and Berberian 1985). Second-order impacts are economic and social, as they arise from the effects of decreased yields or first-order impacts (Kates, Ausubel and Berberian 1985). Examples of economic and social impacts are reduced household income, increased workload, shortage of alternative income sources, difficult water access and water use, rural to urban migration, impoverishment, physiological impacts, changes in family plans and weakening of family or community ties (Keshavarz, Karami and Vanclay 2013).

Coping Strategies

The changes that local food producers made in response to the 2011 drought are influenced by many factors and take the form of various coping strategies. Adaptation is defined by the IPCC as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (2012, 3). Short-term adjustments to drought conditions are coping strategies that buffer against short-term impacts in farming systems (Campbell, Barker and McGregor 2011). These strategies are mainly used to counteract the immediate impacts from a drought. Although coping strategies are defined as less sustainable than adaptive strategies, which are better suited to handle long-term concerns, coping strategies aim to mitigate and spread the immediate risk during a poor season (Campbell, Barker and McGregor 2011). Coping strategies are important for local food producers during a drought and are the focus of this study, as an immediate response is necessary for the survival of the farm through sustained drought. Response to drought begins at the household level, as people attempt to reduce drought impacts by using agricultural and non-agricultural coping mechanisms (Paul 1998). An example of an agricultural coping mechanism is conserving soil moisture or implementing a more efficient water irrigation system, while an example of a non-agricultural coping mechanism is finding an outside source of income, such as selling livestock or off-farm employment (Brammer 1987, Paul 1998). Table 1 presents categorizations of different coping strategies from studies around the world. These coping strategies are employed differently depending on various factors within the household such as occupation, landownership, livelihood assets, tenancy, and education of the household, which in turn influence the vulnerability of that household (Paul 1998, Campbell, Barker and McGregor 2011).

Table 1. Common Coping Strategies of Local Food Producers Worldwide

Categories	Coping Strategies
Agricultural	Crop diversification
	Suspend portion/all of crop cultivation
	Improve or alter irrigation system
	Companion planting practices
	Conservation of soil moisture
	Scaling down production
	Re-sowing crops
Non-Agricultural	Sale of livestock
	Seek employment off of farm
	Sell other assets
	Out-migration
	Borrow money
	Social network support

Sources: Brammer 1987, Paul 1998, Mortimore and Adams 2001, Eriksen and Silva 2009, Venot, Reddy and Umapathy 2010, Campbell, Barker and McGregor 2011, Biazin and Sterk 2013, Keshavarz, Karami and Vanclay 2013.

Sustainable Agriculture and Local Food Production

Sustainability has grown to be a leading concept worldwide and its importance is evident throughout multi-disciplinary research. A widely adopted definition of sustainability is "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Dillon, Hennessy and Hynes 2009, 2). However, as seen at the 1992 Rio Earth Summit (Earth Summit), there is global support for sustainable human actions. Sustainability was the main goal in the declaration of the Earth Summit, which declared environmental, economic and societal factors as the three pillars needed to achieve a sustainable outcome (Rio Declaration on Environment and Development 1992). Directly following the Earth Summit, immediate and widespread interest across academic disciplines took off in the pursuit of development and identification of sustainability. A debate regarding how to best measure and implement sustainable practices is ongoing, as there are over 500 sustainable indicator efforts (Parris and Kates 2003). Although there is ambiguity surrounding the application of sustainability, Figure 5 shows a thematic representation of sustainability incorporating social, economic and environmental elements.

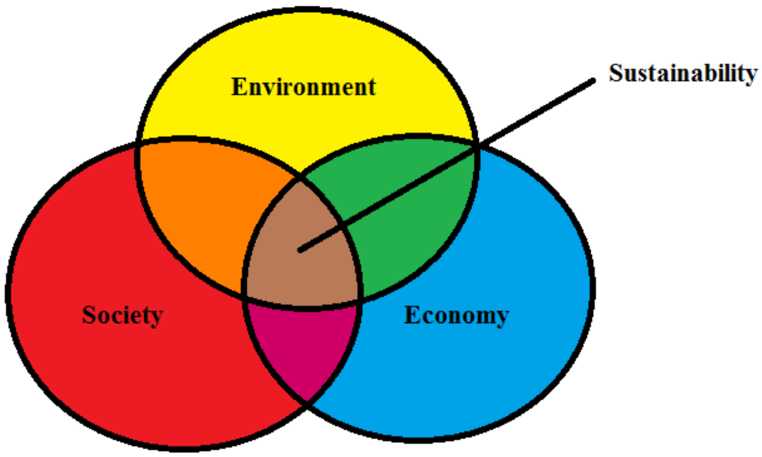

Figure 5. The Sustainability Concept

There continues to be a growing interest in sustainable agriculture. This interest arises out of criticism of harmful practices by conventional agriculture, such as the deterioration of the environment and resource availability, worsening human health conditions, the increase of farm difficulties and rural desertification (Gafsi et al. 2006). These conditions have led many to rethink agriculture practices in our society (Gafsi et al. 2006). The idea of sustainable agriculture stems from a concern that the farming practices of today will have a negative impact on farming and food production in the future, and that future generations will have fewer options to choose from within food production (Park 1998). Agricultural sustainability is an approach that will protect our options in the future (Robert et al. 1997). Therefore, in this context, sustainability is viewed as the "maintenance of the adaptive capacity of farming systems" (Park 1998, 227). Sustainable agriculture is more explicitly defined by the Food and Agriculture Organization of the United Nations as "the use of agricultural practices which conserve water and soil and are environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (Fowler and Rockstrom 2001).

Local Food Production

Local food production is a sustainable agricultural food system that grew out of a critique of the current industrial food system, characterized by industrialization, globalization, centralization, the anonymity of actors as well as origin of the food (Feagan, Morris and Krug 2004, Kremer and DeLiberty 2011). Problems associated with the industrial food system include environmental and health problems such as deforestation, biodiversity loss, over-use of cropland, water and soil pollution, outbreaks of disease and contribution to obesity and diabetes in the developed world (Kremer and DeLiberty 2011). The local food system brings the concept of locality and place back into the spotlight as necessary elements and as a way of reconnecting with food (Winter 2003, Marseden 2004). Localization is the main criteria of the local food movement, highlighting the avoidance of the increasing distances food travels, and associated energy use inherent in the global and industrial food system (Feagan, Morris and Krug 2004).

The local food system, which consists of a Shortened Food Circuit (SFC), represents a sustainable alternative to the current industrial food system, by incorporating the economic, environmental and social health of a place (Feenstra 2002, Renting, Marsden and Banks 2003). Proponents argue that a SFC will positively influence the economic and social viability of regions (Renting, Marsden and Banks 2003). In addition, tailoring food production and its consumption to local conditions is central in developing a sustainable food system (Feagan, Morris and Krug 2004). The local food movement and its implicit concept of sustainability have recently gained momentum in central Texas and are visible in the growth of local farmers' markets (GRACE Communications Foundation 2013).

However, a focus on local food production is more than an alternative solution to industrial food systems. It is the beginning of a process to rebuild agro-ecological systems, which "integrate space and nature into production processes" (Feagan, Morris and Krug 2004, 237). A local food system is rooted in a specific place, which provides an economically viable option for farmers and consumers. In addition, local food systems encourage the use of environmentally correct production and distribution practices that enhance social equity and democracy for the community (Feenstra 2002). Furthermore, various studies have found that as the quality of foods, along with farming production, becomes more important to the consumer, the spatial aspects of food become an essential factor (Feagan, Morris and Krug 2004). As the local food movement becomes more widespread, local water access and restrictions play a key role and greatly influence local food production, especially during a drought.

IV. WATER IN CENTRAL TEXAS

This section provides context for understanding of local food producers' access to water resources and what influences shaped their coping strategies to the drought of record. On individual farms, water access and use plays a major role in farm production. Throughout Texas, farmers rely on many different water sources, broadly categorized as surface and ground water. Fundamentally, the water policies that manage surface and groundwater shape the avenues in which farmers may access water, which affects drought adaptation. The farmers who overcame challenges presented by the 2011 drought altered their farm management strategies through the routes that were available to them based on the policy structure in place.

Texas water laws are notoriously complex, combining a history of Spanish and English law, which results in the "legal fragmentation of the hydrologic cycle" (Templer, Texas Water Law). By examining the history of Texas water laws, the evolved complexities of state water policies become clearer. The "legal fragmentation of the hydrologic cycle" refers to a division of the hydrologic cycle in Texas resulting in two categories: surface and groundwater (Templer, Texas Water Law). Groundwater, otherwise known as percolating water, is located beneath the Earth's surface in the spaces between soil and rocks, and provides for more than 60 percent of the state's water needs. Surface water on the other hand, is considered "waters of the United States" defined in *Rapanos v. U.S.*, 547 U.S. 715 (2006) and refers to permanent, standing or flowing bodies of water that form geographic features such as rivers, lakes, and streams. Texas water legislation regulates these two distinct categories of water separately.

Local food producers obtain their water either from surface water or groundwater sources. Local food producers interested in securing surface water may appropriate surface water use via permit application through the Texas Water Commission (TWC) (Texas Water Code, §11.023). Water appropriation for agricultural use has a preferential standing in the TWC (Texas Water Code, §11.134 (b) (2) and §11.024). Obtaining a permit for water use from the TWC is required, as is the requirement to submit a water conservation plan that is consistent with the approved regional water plan created for implementation during periods of drought or water shortages (Texas Water Code, §11.121, §11.1272 (a)). Landowners with property "adjoining or contiguous to a canal, ditch, flume, lateral, dam, reservoir, or lake" have the right to use water in accordance with their contract (Texas Water Code, §11.038). However, a permit granted by the TWC bases water appropriation on the §11.027 statute that the "first in time is the first in right" (Texas Water Code). For example, water rights established over a century ago that are still standing maintain the same level of appropriated water, which reduces the remaining amount of available water for appropriation in the future. This system makes it difficult for new permit users to request the amounts of water that are needed to run a farm, especially during a drought. When local food producers are able to acquire a permit for water use, the local food producer must record all irrigation work and use only the amount of water specified for the purposes specified in the permit (Texas Water Code, §11.043 & §11.025). Along with obtaining water appropriation rights from the TWC, local food producers also fall under the jurisdiction of Irrigation Districts. Irrigation Districts have the responsibility and authority to deliver untreated water to use for irrigation, to drain the land or implement other functions that might be related to accomplishing their main objective (Texas Water Code, §58.121 & §58.122). Surface water is also commonly accessed by purchasing it through municipal utilities systems, a co-op, or city utilities. In the case of the local food producers in this study, surface water is acquired through these systems and not through permit rights.

In contrast to surface water acquisition, groundwater in the state of Texas belongs to the landowner, not the state, and permission for appropriation is not necessary (Texas Water Law). Therefore, obtaining water via groundwater is a process much less regulated than surface water, having few limitations and no cost, which makes groundwater acquisition more appealing to farmers. The most common way to acquire groundwater is for the landowner to dig a well and pump water from beneath the surface of their land. In 1904, the Rule of Capture was established in Texas in *Houston & Texas Central Railway Co. v. East* 81 S.W. 279 (Tex. 1904) and is the most influential groundwater regulation to date (Patoski 2010). In this case, the Texas Supreme Court chose to support the English common law of the Rule of Capture, first articulated in 1843 in *Action v. Blundell*. As the Rule of Capture states, landowners have the right to pump as much water as desired without concern for the impact on other water users (Templer, Texas Water Law).

In 1949, a new law addressed the lack of regulation and oversight of groundwater extraction and provided for a voluntary establishment of local conservation districts for groundwater. The resulting Groundwater Conservation Districts (GCDs) are the only entity to exercise any control over landowner rights to groundwater (Templer, Texas Water Law). GCDs have the power to create rules limiting groundwater extraction to provide for "conserving, preserving, protecting and recharging of the groundwater"

(Texas Water Code, §36.101). Even though permission for appropriation is not necessary, GCDs still require a permit for the drilling, operating, equipping and completing of wells. For a farmer to apply for this permit, he or she must state the purpose of the well, the amount of water to be used, a conservation plan, location of the well, well closure plan and a drought contingency plan (Texas Water Code, §36.113). A GCD also has the ability to enforce the rules created through injunction, civil penalties, and other appropriate remedies set forth in a court (Texas Water Code, §36.102). Overall, the GCD develops a groundwater management plan. This plan incorporates the most efficient use of groundwater to prevent waste of groundwater and subsidence, along with natural resource issues, conservation, mutual surface water issues and drought conditions (Groundwater Conservation Districts). However, despite the GCD rules and enforcement mechanisms, groundwater acquisition is largely unregulated across the state. Given the drought of record, groundwater extraction would have been even more appealing to farmers.

However, continued groundwater extraction is unsustainable in the long-term. According to the IPCC, long-term reductions in precipitation or drought are exacerbated by groundwater extraction, which reduces ground water levels and causes spring-fed rivers to disappear (IPCC 2012). An example within Texas is the Ogallala aquifer, located under the panhandle of Texas, where 94 percent of the total groundwater was used for crop irrigation. The Ogallala has continued without adequate recharge, resulting in greatly depleted groundwater levels today (Madramootoo 2012). In central Texas, the greatest median water-level change from 2010 to 2011 was a decline of 16.7 feet in the Trinity Aquifer wells with the least median decline of 0.7 feet in the Texas Edwards-

Trinity wells. With the overall decline of aquifer levels ranging between 0.7 feet to 16.7 feet during the drought, the practice of water extraction from groundwater sources with few limits is not sustainable. Groundwater exploitation can result in conflicts of drinking water and irrigation use, reduced aquifer discharge in surface water-flows, degradation of aquatic ecosystems and in excessive cases, salinization of aquifers and land subsidence (Garduno and Foster 2010). Local food producers in Texas rely heavily on groundwater resources for their livelihood and with added pressures of population growth and drought, this resource may become even scarcer.

V. RESEARCH METHODS

The objective of this study was to determine how local food producers coped with the 2011 drought of record. To determine this, I collected from local food producers in drought-affected central Texas and specifically examined changes in local food producers' farm manages practices resulting from the 2011 drought of record. The area under study encompasses a 150-mile radius of Austin in central Texas and is considered "local" in the context of Austin farmers' markets. Within this local landscape, there is a range of local food producers with varied farm and farm manager characteristics, which in turn affect farm management practices.

The study population consists of local food producers that live within central Texas and distribute their products at one or multiple farmers' markets in Austin, TX. Local food producers under study yield either vegetables, fruits or nuts from an orchard, animal products or a combination of products. In addition, local food producers across central Texas vary in household structure, gender, occupational and tenancy characteristics, farm size, educational status, socio-economic characteristics, social networks, and prior experience with drought. All of these local food producer characteristics affect farm management coping strategies in response to drought.

The research strategy employed utilized a mixed methods approach, combining quantitative and qualitative data through surveys and semi-structured interviews. A mixed methods approach allows for an evaluation of how the drought of record affected farm management practices. The survey was designed to include quantitative questions: close-ended questions in the form of multiple choices, and yes/no questions. In addition, qualitative, open-ended questions were included to explore further farm management coping strategies to the drought and other unanticipated insights. Through using survey and semi-structured interview methods, this study addresses key issues of interest in a structured yet flexible process to allow for expected and unexpected insights (Maxwell 2005).

To ensure that the survey questions were correctly targeting my objective, I first conducted a pilot study at two different farmers markets. I used both multiple choice and open-ended questions to gain a holistic grasp of local food producer responses. The pilot study allowed an identification of both agricultural and non-agricultural coping strategies used by central Texas local food producers. It also helped to clarify local food producers' access to water and what strategies were sustainable in the context of central Texas. With the pilot study, I also addressed household characteristic questions, which helped to delineate vulnerability indicators and the range of coping strategies used. Using the pilot study to refine survey questions and tailor them to central Texas local food producers, I was able to include relevant multiple choice and open-ended questions that were both qualitative and quantitative in my final survey in order to answer my research objectives.

I administered the survey and conducted semi-structured interviews to every willing local food producer at eight Austin farmers' markets (Edible Austin 2005) over the course of the summer of 2013. I had no refusals, and therefore achieved a 100 percent response rate. I surveyed and completed semi-structured interviews with thirty-seven local food producers at eight farmers' markets. Some farmer's markets were well established; however, others had opened, closed or moved locations. For this reason, I created an updated list using a current listing of Austin farmers' markets and hearsay to create a comprehensive list of all Austin farmers' markets. In the summer of 2013, five of the twelve Austin farmers' markets had closed or relocated to unspecified locations, and I discovered one additional farmers' market by chance and added it to the list. With the final list of eight Austin farmers' markets, I surveyed local food producers through a convenience sample. Through the convenience sampling technique, I utilized purposeful selection, in which the farmers' market setting, local food producers and their coping strategies to the drought were deliberately selected to provide information unavailable through other choices (Maxwell 2005). This sample selection achieved a representativeness of local food producers that distribute to Austin farmers' markets, while also capturing the heterogeneity of the population, allowing for comparison (Maxwell 2005).

This study had two main objectives that I explored through the survey and semi-structured interviews. The first was to understand how the local food producer's degree of vulnerability to the 2011 drought influenced their coping strategies and what factors influenced them to use agricultural or non-agricultural coping strategies. As local food producers vary in degree of vulnerability, I was interested in evaluating if one or multiple characteristics have influenced their ability to implement either agricultural or non-agricultural coping strategies. The second objective was to discover how local food producers in central Texas were implementing different sustainable farming practices to cope with severe drought conditions.

With the results from the survey, I used the Statistical Product and Service Solutions (SPSS) software to analyze qualitative and quantitative responses. My first step was to use SPSS to conduct frequency, cross-tabulation and Pearson's chi-square test analyses on quantitative and qualitative questions of the survey results. I coded survey responses and grouped the coded numerical responses into more and less vulnerable categories. I then compiled the results to gain a comprehensive view of local food production during the drought of 2011. Many of the cross-tabulated scenarios of vulnerability and coping strategies were statistically significant. These types of analyses facilitate a multivariate index of local food producers, farms types and farm management decisions, to indicate the most influential factors in farm management decisions.

VI. RESULTS

The following section is a comprehensive look at local food producers in central Texas that successfully survived the drought of record. Recognizing that local food producers vary in the factors that create vulnerability, I designed the survey and interview questions around the assumption that the coping strategies utilized by local food producers would depend on their degree of pre-existing vulnerability. Local food production as a movement advocates sustainable practices; therefore, my expectation was that the majority of local food producers in central Texas were practicing sustainable agricultural management strategies. In an analysis of the survey data, this study examined what sustainable practices the local food producers in central Texas use and how their drought-related coping strategies were influenced by vulnerability. This section is organized as follows. After describing the demographic makeup of local food producers in central Texas, I explore six different vulnerability indicators: household income, farming experience, land ownership, water access, the type of product that is produced, and land size and the impact of each on which coping strategies were adopted. The final section illuminates key features of sustainable farming in central Texas by analyzing three sustainability categories: water access and management, sustainable practices employed by vegetable and orchard local food producers, and other unanticipated farm management strategies.

This section draws on the surveys and semi-structured interviews of thirty-seven local food producers in central Texas taken during the summer of 2013. To understand the situation of central Texas farmers and subsequent choices made, Table 2 gives an overview of five farm manager demographic characteristics, including gender, ethnicity, age, marital status and highest level of education. The typical farm manager in central Texas is a white male between the ages of 50-59 with a Bachelor's degree, married or in a long-term relationship. Deviating from this typical farm manager description was the one-third of farm managers who were female, a higher percentage than anticipated. In addition, I had expected to find around 60 percent of farmers aged 55 years or older, which would follow the United States' general trend (United States Environmental Protection Agency 2013). However, survey results indicated that the central Texas farmers' market producer population had only 37 percent of farmers aged 55 or older. The average age of the central Texas farm manager in this study was younger than the national average as well: 47 years of age compared to the national average of 57 years. Although the central Texas farm manager population is not following then national trend, perhaps it is characteristic of this type of farm manager.

Table 2. Farm Manager Demographics

Farm Manager Characteristics		Number	Percentage
Farm Manager Gender			
	Male	25	68%
	Female	12	32%
Farm Manager Ethnicity			
	White	34	92%
	Hispanic	2	8%
Farm Manager Age			
	20-29	3	5%
	30-39	9	24%
	40-49	8	22%
	50-59	10	27%
	60+	8	22%
Farm Manager Marital Status			
	Single	5	13%
	Married/long-term relationship	29	78%
	Divorced	0	0%
	Widowed	3	8%
Farm Manager Highest Level of Education			
	< High School	2	5%
	High School	8	22%
	Home School	1	3%
	Some College	2	5%
	Associate Degree	2	5%
	Bachelor Degree	13	35%
	Graduate Degree	9	24%

Vulnerability and Coping Strategies

Which factors indicated vulnerability within the central Texas local food producer population and to what degree did this vulnerability influence coping strategies employed? The progression of vulnerability in a population is influenced by a range of factors (see Figure 3), some of which apply to all farmers globally and others that are more specific to farmers in the developed world.

Throughout this study, I use relative sales during the 2011 drought as the dependent variable to determine vulnerability. The producer's household income, in this case sales due to the drought, significantly affects the response and adaptation of an individual, household or community to a hazard such as drought (Bardsley and Hugo 2010). The survey question used to measure sales during the drought year was "Did the 2011 drought result in higher, lower or the same sales?" Higher or lower sales due to the 2011 drought are a measure not only of vulnerability but also of economic success. In this study, I compared sales as a result of the 2011 drought (the dependent variable) to six independent characteristics of local food producers: household income, land ownership, water access, farming experience, crop variety and farm size. For simplicity, I created two groups of vulnerability to drought, those less vulnerable to drought and those more vulnerable. Those referred to as "more vulnerable" are local food producers with fewer sales as a result of the 2011 drought and those referred to as "less vulnerable" had the same or higher sales.

Household Income

In central Texas, off-farm income was a very important coping strategy for local food producers. As in developing countries, non-agricultural coping strategies such as off-farm income, led to greater security for local food producers (Paul 1998, Mortimore and Adams 2001, Eriksen and Silva 2009, Venot, Reddy and Umapathy 2010, Keshavarz, Karami and Vanclay 2013). For most of the local food producers making $60,000 or more, off-farm income was a vital source of income needed to survive the drought. Specifically, for nine (64 percent) of these local food producers, 40-100 percent of their total household income was from off-farm sources, compared to five (32 percent) of local food producers making less than $60,000 (Table 3). As one farmer from Rogers, Texas stated, "we lost a lot of money, that's when my brother went to get a job. It was a lot of work." Although previous studies support the finding that food producers with a higher income utilized off-farm income more than food producers with a lower income (Keshavarz, Karami and Vanclay 2013), I had expected to find a higher percent of local food producers with a lower income utilizing this non-agricultural strategy.

Table 3. Total Household Income and Off-Farm Income Contribution

Total Household Income	**Percent of Off-Farm Income Contribution to Household Income**			
	0-35%	**40-50%**	**60-100%**	**n/a**
$0-60,000	5 31%	2 13%	3 19%	6 37%
$60,00 and above	2 14%	6 43%	3 21%	3 21%

Off-farm income in central Texas was a coping strategy that local food producers with lower sales as a result of the drought used to survive. Local food producers with lower sales were able to compensate for this loss with off-farm income. Stated differently, local food producers with lower sales due to the drought also tended to have higher percentage of off-farm income. Specifically, out of all local food producers with lower sales, 80 percent of them had off-farm contributions to the overall household income of 50 percent or more. Off-farm income was vital to these more vulnerable local food producers because without it, they would not have survived the drought. An extreme example of this was a 63-year-old local food producer who reported that 95 percent of his total household income was from off-farm investments. Thirteen of 17 local food producers with lower sales as a result of the 2011 drought stated that that off-farm income was necessary to compensate for lower sales. Not having a source of off-farm income led to greater vulnerability among local food producers in terms of total household income.

The farm manager's spouse or long-term partner's off-farm income proved to be an important asset for local food producers in compensating for fewer sales from the drought. Local food producers with 40-100 percent of off-farm income reported only one or two adults contributing to the household income, as compared with local food producers with 0-35 percent off-farm income, of which five local food producers had three or more adults contributing. Stated differently, one or two adults with off-farm incomes contributed the majority or all of their off-farm income to the overall household income, compared with three or more adults with off-farm incomes who contributed a much smaller portion of their off-farm income to the overall household income. Of the households with adults working off the farm, 15 of 23 adults were the spouse of the farm manager compared to 6 of 23 that were not. A spouse and/or possibly one other family member working off the farm thus contributed more income to the total household income compared to local food producers with more than two adults working off the farm. Local food producers with a working spouse were an asset to offsetting a bad season.

For local food producers without a spouse to compensate for lower sales, the Community Supported Agriculture (CSA) or farm-to-table relationship with a restaurant was an important agricultural coping strategy. In the central Texas survey population, 29 of 37 (78 percent) of the local food producers were married, three were widowed (8 percent) and five (33 percent) were single. Of the producers between the ages of 40-50, five (33 percent) had a spouse that contributed off-farm income. Despite the fact that 80 percent of these 40-50 year olds had fewer sales and were considered more vulnerable, the spousal off-farm income was able to compensate for the loss. In comparison, only one local food producer, aged 60-82, had a spouse or long-term partner that contributed off-farm income. The remaining seven local food producers aged 60-82 did not have off-farm income from a spouse, thus were more vulnerable to drought, and were forced to implement different coping strategies. Of those seven, two were widowed and two were single farm managers. In addition, two farm managers between 21-39 years old were single and without the aid of off-farm income. In this population of central Texas farm managers, six out of eight producers aged 21-39 and 60 or older, who were single or widowed and could not take advantage of off-farm income generated through a spouse, utilized the coping strategy of operating a CSA or farm-to-table relationship with a restaurant to compensate for lower sales as a result of the 2011 drought. As an example, the only female farm manager in the group of producers aged 60 or older was a single

Hispanic woman with 27 years of farming experience who coped by borrowing from a bank and operating a CSA to survive. CSAs offer a form of sustainable agricultural production, enhancing the social, environmental and economic relationships and maintaining the economic viability of small- and medium-scale local food producers (Galt, R. E. et al 2012). It is clear that the CSA and farm-to-market restaurant relationships were vital agricultural coping strategies for farm managers without a spousal off-farm income contribution.

Farmland Ownership and Water Access

Owning farmland in Texas has long been an advantage for local food producers. In owning farmland, the producer also owns the rights to all groundwater resources under the land, which is an advantage in farming. In this study, owning farmland resulted in less vulnerability, whereas leasing the farmland resulted in more vulnerability. A total of 34 food producers (93 percent) surveyed owned some or all of their farmland: 28 (73 percent) owned their farmland and an additional six (20 percent) owned and leased their farmland. The fact that the overwhelming majority of local food producers own their farmland only further emphasizes that land ownership is an important factor for local food producers who survived the drought. Although only two local food producers did not own their farmland, both had the same sales due to the drought and had one crop type, producing one product such as animal or vegetable products only, and are in a CSA or farm-to-market relationship. One of these local food producers had animal products only and as an additional coping strategy, he borrowed from a bank. Conversely, the other local food producer that leased farmland sold vegetables only and was a non-profit organization for disadvantaged children. Both used the CSA or farm-to-market agricultural coping strategy to procure financial support, which allowed them to survive the 2011 drought.

In the context of central Texas, a local food producers' access to water may be varied, and plays a key role in influencing farm management decisions. Those with groundwater access were less vulnerable to the drought as compared to those without it. Sales as a result of the 2011 drought were used to determine how water acquisition influenced a local food producer operation in central Texas. Previous research would indicate that water acquisition is vital to successful survival of drought (Paul 1998, Venot, Reddy and Umapathy 2010, Keshavarz, Karami and Vanclay 2013). In central Texas, 73 percent of the surveyed population (29) had access to groundwater resources, leaving 27 percent (8) to rely on city, county and/or co-op water supplies. It is clear that local food producers with groundwater access, which comprise the majority of central Texas local food producers, had an advantage over other local food producers and were less vulnerable to drought. Those with groundwater resources did not make significant agricultural adjustments to their farm management strategies.

However, to counter the disadvantages that come to those without groundwater access, the majority of local food producers without groundwater access employed a creative array of agricultural coping strategies not employed with the same intensity by those with groundwater access. Over half of local food producers without groundwater access increased the number of products they sold, signaling a diversification of products. The farmers without groundwater access also were more creative and used the most recent technology to improve the water efficiency on the farm. One farm manager who relied on using city water discussed the details of installing a hydroponics irrigation system; while a farm manager using county water discussed the mechanics of having tents with misters in them for her chickens and possibly installing an air conditioning unit in the future. Another two farm managers using county water invented a bucket watering system to conserve water, and explained a system of no-tilling and cover cropping strategies incorporating “lay flat bags” and the use of fungi and coal to accelerate plant growth. Finally, the farm manager using county and co-op water supplies recently constructed a greenhouse. In addition, all local food producers that did not have groundwater access and showed the most creativity were 44 years old or younger and had eight or less years of experience. These farmers without groundwater access did not have abundant and free water resources, as the local food producers with groundwater access did, and were compelled to be innovative and use alternative agricultural coping strategies to conserve water and improve water use efficiency on their farm.

Farming Experience, Product Variety and Farm Size

Surprisingly, local food producers with less experience farming emerged as the group of local food producers that were the least vulnerable to drought. As evident in Table 4, local food producers with 3-6 years of experience had the highest percentage (42%) of the same or higher sales due to the 2011 drought. Interestingly, the less farming experience the farm manager had was distinct from the farm manager’s age. Of the farm managers with less experience: six were aged 21-39, six were aged 40-50 and five were aged 51-58. The years of farming experience in Table 4 also indicate that those with more experience showed more vulnerability to drought. Prior experience with a hazard influences adaptation to a hazard (Burton, Kates and White 1978, Smith 1992). Although previous studies maintain that more years of farming experience would reduce vulnerability to drought (Moran et al 2006), results from this study do not support that claim. The experience of the local food producers studied here indicates that more experience may not lead to better adaptation to a hazard like drought and consequently to less vulnerability.

Table 4. Sales as a Result of the 2011 Drought and Farm Manager Farming Experience

Did the 2011 Drought result in higher, lower or about the same sales?	Number of Years Farming			
	3-6	**7-15**	**16-30**	**31-60**
Lower (More Vulnerable)	2 11%	7 37%	5 26%	6 26%
Same or Higher (Less Vulnerable)	6 42%	3 21%	2 14%	3 21%

The majority of these local food producers with less farming experience sold one type of crop (animal or vegetable). Specifically, 77 percent of local food producers with one type of crop had less than 7 years of farming experience (Table 5). Comparing the 2011 sales and product variety in Table 6 yielded a statistically significant result: 73 percent of local food producers with one type of crop had about the same or higher sales and 85 percent of local food producers with multiple crops had lower sales. Put differently, a local food producer with multiple crops was more likely to have 15 years or more farming experience and to have lower sales. The local food producers selling one type of crop were less vulnerable to drought than local food producers that had multiple crops, two or more diverse crops (either animal, vegetable or orchard crop), on the same piece of land. This finding contradicts previous research that indicates utilizing a mixed farming approach with multiple crops would spread the risk of a bad season between the different crops (Mortimore and Adams 2001, Venot, Reddy and Umapathy 2010, Biazin and Sterk 2013). Though unexpected, local food producers in this study with less experience and without crop variety did not experience a decline in sales as a result of the drought.

Table 5. Product Variety and Farm Manager Experience.

Types of Products Produced on Farm	Number of Years Farming	
	3-15	**16-60**
Animal or Vegetable Only	10 77%	3 23%
Combination of Animal, Vegetable and/or Orchard	8 38%	15 62%

Table 6. Sales as a Result of the 2011 Drought and Product Variety.

Did the 2011 Drought result in higher, lower or about the same sales?	Types of Products Produced on Farm	
	Animal or Vegetable Only	**Combination of Animal, Vegetable and/or Orchard**
Lower (More Vulnerable)	3 15%	17 85%
Same or Higher (Less Vulnerable)	11 73%	4 27%

A possible explanation of why local food producers with one crop type had the same or higher sales may lie in the multigenerational family farm structure. The multi-generational farm structure offers many advantages to the less experienced farmer, most importantly land acquisition and education. Beginning with land acquisition, the less experienced local food producers owned large plots of land. As local food producers just starting out would be unlikely to purchase such a large amount of land, a multigenerational family farm structure or inheritance offers the best explanation of how these local food producers were able to have such a large amount of land with less experience. For example, seven of the 17 local food producers with less than 15 years of experience had 67-170 acres and four of 17 had between 197-7,000 acres. Together, 65 percent of local food producers with less experience had between 67-7,000 acres. Of the 37 local food producers in this study, seven fit the profile of a less experienced member of the generational family farm, having less than or equal to 15 years of farming experience, one crop type and ownership of 67 or more acres. Assuming this is the case for those seven local food producers, many of these generational local food producers grew up on the family farm and had inherited their farmland and farming knowledge. In the generational family farm structure, the family assists, in either the background or forefront, in farm management decisions. At Austin farmers' markets, the generational spread of family farms was noticeable as siblings, parents, and cousins of all ages helped at the farm stand. There is reason to believe the multi-generational family farm structure benefitted the more experienced farmers as well, as four producers with more than 15 years of experience mentioned how many generations the farm had been in the family in the semi-structured interview. Farming knowledge is also a significant advantage local food producers in a multigenerational family farm structure enjoy. One 35-year-old farmer that had been raised on a farm stated, "in the last 3 years all new farmers haven't stayed with it, but we are going to do a kick start for a teaching center on the farm." Not only does this statement imply that many new farmers did not survive the drought of record, but it suggests unsuccessful implementation of coping strategies and perhaps a lack of farming knowledge for central Texas played a role in their failure. Inheriting large amounts of farmland and farming knowledge are great advantages in this population of local food producers and are likely to have been highly influential in the success of less experienced local food producers.

As demonstrated with the local food producers that fit the multigenerational family farm profile, those with bigger farms tended to have one crop type and were less vulnerable to drought. The variety of products, multiple crop types or one crop type (animal or vegetable only), was compared with farm size to illustrate this relationship. This comparison showed that for farms between 67-7,000 acres, 68 percent of local food producers had one crop type whereas 65 percent of farms between 0-60 acres had multiple crop types (Table 7). The more land a local food producer had, the more likely he or she would only have one crop type. In addition, those with fewer than 60 acres had fewer sales and were more vulnerable, whereas farms with 67 acres or more had about the same or higher sales and were less vulnerable (Table 8). Farmers that sold animal products had an average of 530.6 acres, with the highest acreage of 7,000. However, those that did not sell animal products averaged 28.13 acres of farmland. This significant difference supports the conclusion that most of the food producers with animal products had more land and in addition had the same or higher sales. This correlation may be linked to the additional advantages that are likely to accompany local food producers with large plots of land, such as groundwater access, land ownership and possible a multigenerational family farm structure.

Table 7. Product Variety and Farmland Acreage.

Variety of Products Produced on Farm	Acres of Farmland							
	0-15		16-60		61-170		171-7,000	
Animal or Vegetable Only	2	15%	2	15%	4	31%	5	39%
Combination of Animal, Vegetable and/or Orchard	6	30%	7	35%	4	20%	3	15%

Table 8. Sales as a Result of the 2011 Drought and Farmland Acreage.

Did the 2011 Drought result in higher, lower or about the same sales?	Acres of Farmland							
	0-15		16-60		61-170		171-7,000	
Lower (More Vulnerable)	6	32%	7	37%	3	16%	3	16%
Same or Higher (Less Vulnerable)	2	14%	2	14%	5	36%	5	36%

For those local food producers with large amounts of land that sold one crop type, borrowing money was an important coping strategy for some. Overall, borrowing money from a bank or the social network was not widely used as a coping strategy in central Texas; however, the majority of animal-only farmers did utilize this coping strategy. Local food producers with one product type shared many characteristics, but when vegetable-only and animal-only local food producers were compared, many distinctions arose between the two. All of the local food producers that sold vegetables only reported selling the same or higher sales as a result of the 2011 drought. However, only 66 percent of those that sold animal products only reported the same or higher sales in comparison. An additional notable difference between these two local food producers is that none of the vegetable-only producers borrowed money, whereas 55 percent of animal-only producers borrowed. Vegetable-only local food producers may not have needed to borrow money as all of them reported the same or higher sales from the drought. However, animal-only producers had the highest percentage of borrowing by far. As an example, the next highest rate of borrowing was from the vegetable and orchard producers, of which 32 percent borrowed money as a coping strategy. As illustrated by the percentage of the next highest borrower, overall, borrowing money was not a common strategy for the central Texas local food producer but for the animal producer it was. One vegetable and animal farm manager with 30 years of farming experience summarized the sentiments of many others by stating, "…do the best you can and live off what you make, drought or flood is coming, so steel yourself. Remain liquid, not in debt, because you can't borrow yourself into prosperity".

Livestock sales were also an important coping strategy for animal producers. To illustrate this, 53 percent of farmers with animal products sold livestock to cope with the drought. However, the local producers with fewer sales as a result of the 2011 drought did not utilize selling livestock as a coping strategy at a higher percentage than local producers that made the same or higher sales. Livestock sales were a consistent strategy for both more and less vulnerable local food producers. With the combination of over half of animal-only local food producers borrowing and 55 percent of animal producers selling livestock, it is unsurprising that animal producers were not as affected in sales from the 2011 drought of record. Although their total sales did not suffer, these local food producers undoubtedly felt the impacts of the drought, as many went into debt and sold half of their herd to survive. One 51-year-old farmer in Waller, Texas lost one of their ranches and after selling a large portion of their herd in 2011, said they would not be able to increase herd size again. Through selling livestock as a coping strategy, the local food producer is able to buffer against a poor season. These local food producers can survive and even have the same or higher sales in a drought year. However, the future landscape of animal producers is uncertain as 11 of 19 local food producers with goat, sheep, swine or cattle sold a portion of their herds to cope with the drought.

Among the variety of coping strategies employed during the 2011 drought, the most utilized non-agricultural coping strategies were off-farm income, borrowing money, and selling livestock. A CSA or farm-to-market relationship and diversification of products were the most common agricultural coping strategy employed by local food producers.

Sustainable Farming in Central Texas

As expected, the majority of central Texas local food producers practice sustainable agricultural management strategies. To determine which practices central Texas food producers are or are not using, this study analyzed three areas of sustainability: water access and management, practices specific to vegetable and/or orchard farming and other alternative farm management strategies.

According to the Texas Water Development Board, 78 percent of farmers in central Texas rely on groundwater to supply their water, and from 2010 to 2011, central Texas wells declined between 0.7 and 16.7 feet (Texas Water Development Board 2013). Deepening and digging new wells as a farm management strategy suggests an unsustainable long-term solution to water acquisition. Of the 29 central Texas farmers in this study reliant upon groundwater sources, 80 percent (23 of 29 producers) made no changes to their wells and did not dig new wells. Farmers that did not make well-related changes were more likely to have implemented other sustainable options, like a rain catchment system, to supplement their water supply. To show this, six local food producers made well-related changes because of the drought, and of these, two producers either had a rain catchment system in place or installed a rain catchment system due to the drought. Comparatively, eleven of the twenty-three local food producers that did not make well-related changes either already had or recently installed a rain catchment system. Comparing local food producers that deepened a current well or dug a new well to local food producers that did not, only 30 percent of those that made well-related changes had a rain catchment system, compared to 48 percent of those that did not make well-related changes. For those local food producers that did not install a rain catchment system, 73 percent had the same or higher sales. This fact shows that those farmers that were less vulnerable to the drought were also less likely to have or install a rain catchment system. On the other hand, nine of the 20 more vulnerable local food producers had already installed a rain catchment system and four more installed one as a response to the drought. The more vulnerable local food producer implemented a more sustainable water acquisition solution, although perhaps this was done out of necessity.

Sustainable farm management strategies specific to vegetable and/or orchard local food producers demonstrate that the majority of vegetable and orchard farms in central Texas are utilizing sustainable farm management strategies (Table 9). This evidence is consistent with studies that argue that the local food movement is a sustainable alternative to the current industrial food system (Feenstra 2002). Table 9 shows the vegetable and orchard local food producers' agricultural management strategies that are sustainable. Interestingly, when comparing these four characteristics of sustainable agricultural coping strategies to the entire local food producer population sampled, there is again a tendency of more vulnerable farmers to implement more sustainable agricultural practices. As this local food producer with 197 acres in Rockdale, Texas states, "(the drought) is a good awakening or you won't survive. Bigger farms are starting to change as well, doing crop rotations, cover crops that are drought resistant and learning how to deal with drought and still be productive. Those that change will survive." This local food producer reinforces the notion that by implementing more sustainable agricultural practices, they were able to survive the drought.

Table 9. Utilization of Sustainable Farm Management Strategies.

Sustainable Farm Management Strategies	Utilization of the Sustainable Farm Management Strategy			
	Yes		No	
Efficient Water Irrigation	22	81%	5	19%
Conserve Soil Moisture	24	92%	2	8%
Companion Planting Practices	16	62%	10	38%
Plant Drought-Resistant	8	53%	7	47%

Farm managers in the semi-structured interview (Figure 6) volunteered a variety of sustainable coping mechanisms as well. Because of the voluntary nature of these responses, the extent to which these strategies were used across the entire surveyed population is not known. However, it is interesting to see what alternative strategies central Texas farmers were employing specific to central Texas and outside of what previous studies might suggest. Interestingly, the most common response was related to animal husbandry, which involved descriptions of changed rotation patterns for grazing. By implementing more intensive grazing patterns, not only will the herd be fed more effectively but also the grass fields will continue to produce, reducing the producers' reliance on hay purchased off the farm. It is not surprising to find that local animal producers practice these sustainable agricultural coping strategies because they follow the same local food movement ideology as vegetable and orchard local food producers. The second most common response was rationing water use. This is an expected response, as many local food producers agreed with one local food producers' response of, "drought or no drought, you need to conserve water."

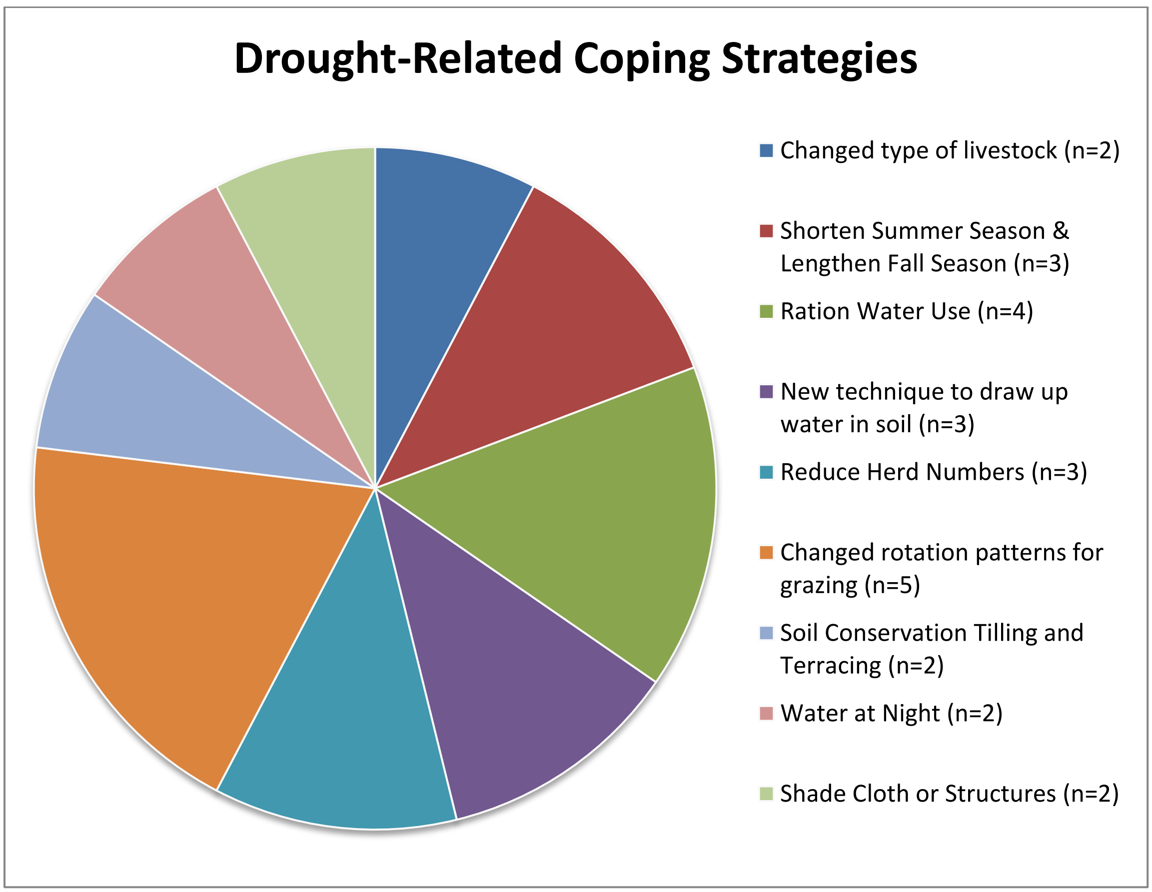

Figure 6. Drought Related Agricultural Coping Strategies.

Many of the responses in Figure 6 illustrate the sustainable nature of farming practiced in central Texas. In addition, the farm managers surveyed also demonstrated a high level of flexibility in their strategies; changing their growing seasons, watering at night, introducing tilling techniques employed in ancient times such as terracing and creating structures to provide shade for their products. These strategies paint a picture of the central Texas farmer as inventive and open-minded in their drought adaptations. One 31 year old farmer in Kyle, TX, expounding on his latest agricultural coping strategies, described using “coconut peat to balance water retention, granular humate to put carbon back into the soil and mychorize fungus to spread out and draw moisture from the ground to give water to the crops”. As this farmer and many others maintained sustainability in their farm management practices through past droughts and during the drought of record, it would seem a certain level of creativity and flexibility are essential.

VII. CONCLUSION

As the population in central Texas continues to increase rapidly and projections of future drought are expected to increase in intensity and frequency, the issue of water access and water scarcity will remain in the spotlight. Water scarcity in the future raises many questions for local food production. Underlying the main objectives in this thesis is the viability of local food production and its associated benefits in central Texas and other drought-prone landscapes. How farmers were able to utilize coping strategies to cope with a drought of this magnitude is a vital question.

Local food producers in central Texas, with a diverse range of characteristics, employed many agricultural and non-agricultural coping strategies to lessen or increase their vulnerability to drought. Non-agricultural coping strategies led to greater security for local food producers. This was especially true of off-farm income, which was able to compensate for lower sales that resulted from the drought of record. Water access was also key to agricultural coping strategies. Those without groundwater resources utilized innovative agricultural solutions to maximize water efficiency. Surprisingly, the least experienced of the local food producers (15 years or less) who survived the drought had the same or more sales from the drought and were the least vulnerable. Contrary to previous studies, this finding indicates that more experience in farming may not be indicative of less vulnerability to drought. In addition, the crop type that was produced for sale also influenced a local food producers' vulnerability to drought. Those that had one crop type, animal or vegetable, were less likely to have reduced sales due to the drought. Advantages from the multigenerational family farm structure, such as inherited farmland and farming knowledge, may also have influenced local food producers' success. In this study, seven of the 37 local food producers fit the profile of a less experienced member of the multi-generational family farm, as they had less than or equal to 15 years of farming experience, sold one crop type and owned more than 67 acres. Borrowing money, although uncommon in the population as a whole, was a common coping strategy for animal food producers as was the sale of livestock. More than half of local food producers with animal products sold livestock to cope with the drought. Finally, the majority of central Texas local food producers practiced sustainable agricultural management strategies. Interestingly, those who were more vulnerable were more likely to implement sustainable agricultural strategies. Overall, central Texas local food producers showed great resourcefulness and dedication to sustainability principles.

Through their knowledge of both successful coping strategies and sustainable options for farm management practices, local food producers have the necessary information to create more sustainable long-term adaptations. This study gives an indication of the impact vulnerability has on coping strategies to drought, the characteristics of a successful local food producer in central Texas, and the future viability and sustainability of local food production in central Texas. Findings from this study will assist local food producers in planning and adapting to inevitable future droughts. The findings will also assist policy makers and leaders in central Texas and elsewhere, to realize the context and the coping strategies local food producers undertake in drought. This knowledge will help facilitate informed and appropriate decisions for the future. Conclusions drawn from this study have economic, social and environmental implications for central Texas and beyond.

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