THESIS

DETERMINANTS OF PRODUCER RESILIENCY: INVESTIGATING THE PROBABILITY THAT AGRICULTURAL PRODUCERS EXIT THE INDUSTRY IN THE FACE OF DROUGHT

Submitted by

Ron Nelson

Department of Agriculture and Resource Economics

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 2013

Master's Committee:

Advisor: Christopher Goemans
Co- Advisor: James Pritchett

Martin Shields

ABSTRACT

DETERMINANTS OF PRODUCER RESILIENCY: INVESTIGATING THE PROBABILITY THAT AGRICULTURAL PRODUCERS EXIT THE INDUSTRY IN THE FACE OF DROUGHT

For the last two years agricultural producers in Colorado have been faced with severe drought conditions resulting in significant economic losses. With a changing climate, likely leading to an increased probability of extreme and recurring droughts, it is becoming an ever more important policy concern to determine the effect that drought has on the resiliency of farmers and ranchers. To date, research on farmer resiliency in the developed countries has primarily been theoretical; the majority of empirical work focused on producers in developing countries. This paper analyzes survey data collected from 2012 to investigate which factors impact farmer and rancher drought resiliency within Colorado. Specifically, we are interested in determining if, and how, continued drought impacts the likelihood that farmers and ranchers will leave the industry. Results highlight the relative importance that a producer's overall wealth and the region where their enterprise operates.

ACKNOWLEDGEMENTS

I would like to thank the Colorado Water Conservation Board and the Colorado Department of Agriculture for funding this research effort. I would also like to thank my outside committee member, Martin Shields Ph.D., for his insightful contributions. Most of all I would like to thank my advisor, Chris Goemans Ph. D., and co-advisor, James Pritchett Ph.D., for a very enjoyable professional development experience. I learned a great deal from both of you. Finally, I would like to thank my girlfriend, Sarah, for the support that she gave me and sacrifices that she made for me to complete my master's.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

For the last two years agricultural producers in Colorado have been faced with severe drought conditions resulting in significant economic losses. The drought has led to widespread crop failures, damaged rangelands, and drastically reduced crop yields and livestock productivity. The financial impacts caused by the drought will be felt by agricultural producers for years to come and may threaten the long-term economic viability of some agricultural operations. Given the forward and backward linkages with other industries in the supply chain, the impact of drought extends well beyond those sectors and communities immediately impacted (Gunter, Goemans, Pritchett, & Thilmany, 2012). Federal and state agencies have responded to the drought by offering millions of dollars in emergency drought relief (USDA, 2013). With a changing climate, likely leading to an increased probability of extreme and recurring droughts (Schar, et al., 2004), it is becoming an increasingly important policy concern to determine the effect that drought has on the resiliency of farmers and ranchers in Colorado.

An agricultural producer that is resilient to drought will be able to endure the drought and return to a similar state of production. This paper considers drought as the agent of change within the resiliency framework, and is interested in deciphering the determinants that push agricultural producers past the threshold and out of the agricultural industry. It is not interested in whether or not the producer returns to the pre-drought level of production. Rather this paper is interested in the characteristics of the producers that choose or are forced out of the industry due to differing durations of drought. Figure 1 displays the process of a producer being shocked by drought and the different paths that can hypothetically occur– improved production capacity, a full return to the initial production capacity, a future decrease in production capacity, or exit. This paper is interested in the subset of producers who choose to exit. To investigate agricultural exit through the resiliency framework this paper integrates both areas of literature.

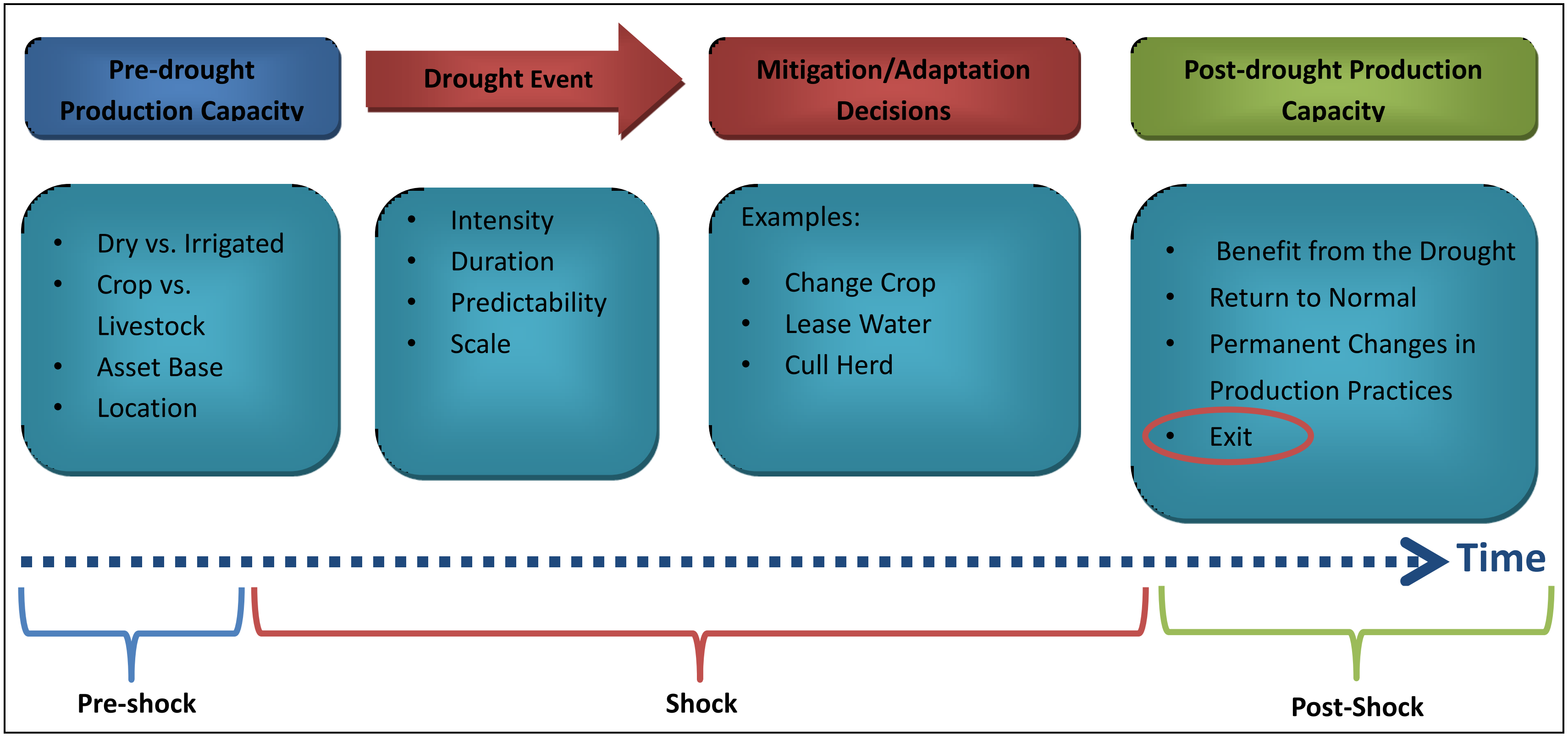

FIGURE 1**.** Agricultural exit as a subset within the resiliency framework**.** At the pre-shock period a producer is capable of producing at some pre-drought maximum production capacity. This capacity can be thought of as the maximum potential yield given the production function of the producer. The pre-drought production capacity is determined by variables within the producer's production function such as the type of production (dry or irrigated), where they are located, and the decisions that have determined their asset base. Then the producer is shocked by the drought event, which has differing impacts depending on its attributes such as intensity and duration. During the shock the producer can make decisions to change their crop or cull their herd as an attempt to mitigate or adapt to the drought. The decisions made before and during the drought can lead to different outcomes that ultimately determine the level of resiliency – improved production capacity, a full return to the initial production capacity, a future decrease in production capacity, or exit. This paper is interested in the subset of producers who choose to exit.

The agricultural resiliency literature evaluates how hazards impact agricultural producers and attempts to determine adaptation and mitigation techniques that encourage successful outcomes. Understanding the factors that influence the resiliency of agricultural producers is important for multiple reasons. First, understanding the resiliency of agricultural producers can begin to convey how adaptable agriculture is to extreme and changing climatic conditions. Second, resiliency indicates how long farmers and ranchers can endure an environmental stressor, such as drought, until they are ultimately forced to exit the agricultural sector. Third, because farmers and ranchers are key components of rural communities, their resiliency is directly correlated with the resiliency of rural communities. Fourth, small and mid-sized farms and ranches have been found to be less resilient than large farms (e.g. Weiss, 1999), which many believe decreases the adaptability of the domestic food sector and may lead to food security concerns in the future. Therefore, identifying the characteristics that influence resiliency can help us to improve food security. Lastly, by understanding the determinants of resiliency, decision makers can design policies that help agricultural producers adapt to the challenges presented by natural hazards. Through the lens of resiliency, this paper aims to develop a better understanding of what causes farmers to exit the industry during and after a drought, and what factors influence the impact of drought on resiliency.

Agricultural exit literature is interested in the determinants that encourage producers to exit the industry. Resiliency and exit literature are similar in many ways, but they differ in at least one important way. The resiliency literature assesses how environmental shocks affect agricultural systems, while exit literature assesses how social and political aspects shock agricultural systems. It is important to incorporate both of these frameworks together because these shocks are not mutually exclusive. The exit literature has been motivated by a drastic decrease in middle sized agricultural producers. In 1930, there were approximately 6.4 million farms in the United States, by 2007 there were approximately 2.2 million (NASS, 2008). Currently, fewer than 10% of farms account for over 60% of food production in the United States (EPA, 2013). The distribution of farm sizes transformed over this time with the highest reduction in the number of farms occurring in mid-sized farms. The loss of mid-sized farms is typical of many developed countries due to advances in technology and decreased labor requirements. However, the concentration that has occurred within large farms has raised concerns over the health of rural economies and food security. The concentration of production into larger farms has been correlated with out migration from rural areas, which has the potential to decrease the economic vitality of rural communities (Barkley, 1990; Dennis, 2007; Ward & Brown, 2009). These concerns encouraged economists to try to determine the factors that cause farmers to exit in order to retain a diverse agricultural sector and improve food security.

Past studies that have examined resiliency and the related field of agricultural exit indicate that there are multiple producer and enterprise characteristics that influence the ability to adapt to drought and the producer's decision to exit the agricultural sector. Characteristics that have been found to encourage farm exit include off-farm income, the size of the operation, experience, and age. Characteristics related to low drought resiliency include decreased crop yields, number of acres fallowed, the duration of drought, access to irrigation, and decreased profit. Most recently, theoretical models (e.g. Ranjan & Athalye, 2009; Ranjan, 2012) have been developed that suggest the overall wealth of a producer maybe another important determinant of agricultural resiliency. However, as is often the case, social scientists exploring resiliency and exit often have to deal with the data that is available as opposed to what would be optimal for their model. There are two persistent shortcomings to much of the data that has been used for empirical studies on resiliency and exit; the coarseness of data and a lack of financial information. Specifically, studies use aggregated county or regional data (e.g. Goetz and Debertin, 2001; Glauben et al., 2003; Malone and Brenkert, 2008) and many researchers have cited a lack of financial information, such as debt to asset ratio (e.g. Weiss, 1999; Gale, 2003; Breustedt and Glauben, 2007). There may also be a theoretical shortcoming within the exit literature, which is that exit literature does not look at how ecological shocks may influence exit. Hypothetically, ecological shocks, such as drought, could be responsible for many exits. This is evidenced by the assistance that is provided by the government for natural hazards.

Of particular interest in this paper are the roles that wealth and farm location have on farmer and rancher resiliency. This paper overcomes previous data limitation by using an online survey and collecting financial information that has previously been omitted from past studies. The survey was administered in the winter of 2012-2013 to agricultural producers throughout Colorado. The survey inquired about the circumstances faced during the 2012 drought and collected information on the characteristics of producers and their production enterprise(s). See Appendix A for more information about the survey used and Appendix B for a copy of the survey. This paper adds to previous literature on resiliency and agricultural exit by creating a new measure of drought resiliency, assessing the role of a producer’s debt-to-asset ratio, and provides insight into how resiliency varies across regions within Colorado.

The remainder of this paper is organized as follows 1) the background provides information on agricultural production in Colorado and how drought has historically impacted agriculture in Colorado, 2) the literature review summarizes the resiliency and agricultural exit literature, 3) the methodology details the specification, estimation, and the data used for the model, 4) the results and discussion highlights critical findings and their implications, and 6) the conclusion summarizes the study's purpose, process, findings, and implications.

CHAPTER 2: BACKGROUND

Agriculture and drought have an interrelated history in Colorado. In order to understand how drought impacts the resiliency of agricultural producers within each region, it is imperative to understand how agriculture in Colorado has changed through time. This section provides a brief history and the current status of farming in Colorado. It also introduces drought in a technical sense and briefly summarizes the interrelated history of drought and agriculture in Colorado.

Colorado's agricultural trends have, for the most part, mirrored the rest of the agricultural sector of the United States. Colorado has seen great increases in technological innovation and its adoption since World War II and a large decrease in the labor needed to produce agricultural products. This has caused a large decrease in the number of farms, while the number of acres in production has slowly decreased and looks to have plateaued recently (Figure 2). Since the early 1990's, there has been a steady increase in the number of farms, but as Figure 2 indicates the number of acres in production has stayed essentially constant or decreased slightly. For Colorado the increase in the number of farms has been due to "very small" farms entering the industry. Over the rest of the time period, the decrease in the number of farms has mainly been due to a loss in mid-sized farms[1] **(**Hoppe**,** 2010**)**. The decline in mid-sized farms has spurred concern over the economic viability of rural communities due to the out migration of rural residence causing a potential breakdown of the economic linkages that make rural economies viable (Hoppe, 2010).

[1] Large farms are consider those that gross over $500,000 and small farms are considered to be those that gross under $10,000 (USDA, 2011).

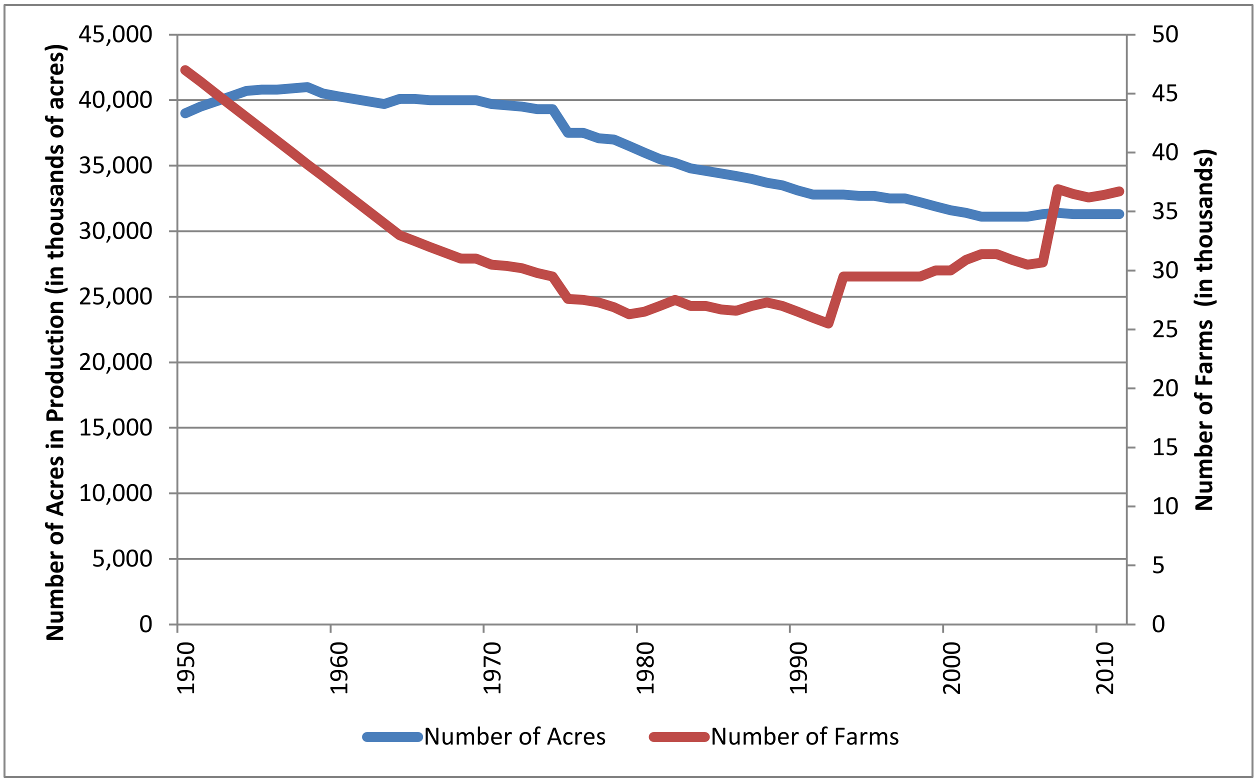

FIGURE 2. Colorado agriculture- Number of farms and acres in production 1950-2011. Source: USDA, 2012.

Increases in technology and changes in consumer preferences have changed the types of crops that have been grown in Colorado. Currently, the type of agricultural production in Colorado varies greatly by region. The agricultural regions of Colorado can be divided into eastern (northeast, east central, San Luis Valley, and southeast) and western (southwest and northwest and mountains) portions (Figure 3). The eastern portion of Colorado has higher portions of irrigated and non-irrigated croplands than the western portion of the Colorado. The eastern portion is flat, receives less rain, and produces mainly dryland crops except those few that have surface water rights or are over the Ogallala Aquifer (NASS, 2013). The western portion of Colorado has a few areas of intensive production, but for the most part farm production is more spread-out and sparse. This is partly due to the amount of federal and state lands in the western portion of Colorado. The western portion is mountainous, has diverse soil types, and more variable types of agricultural production.

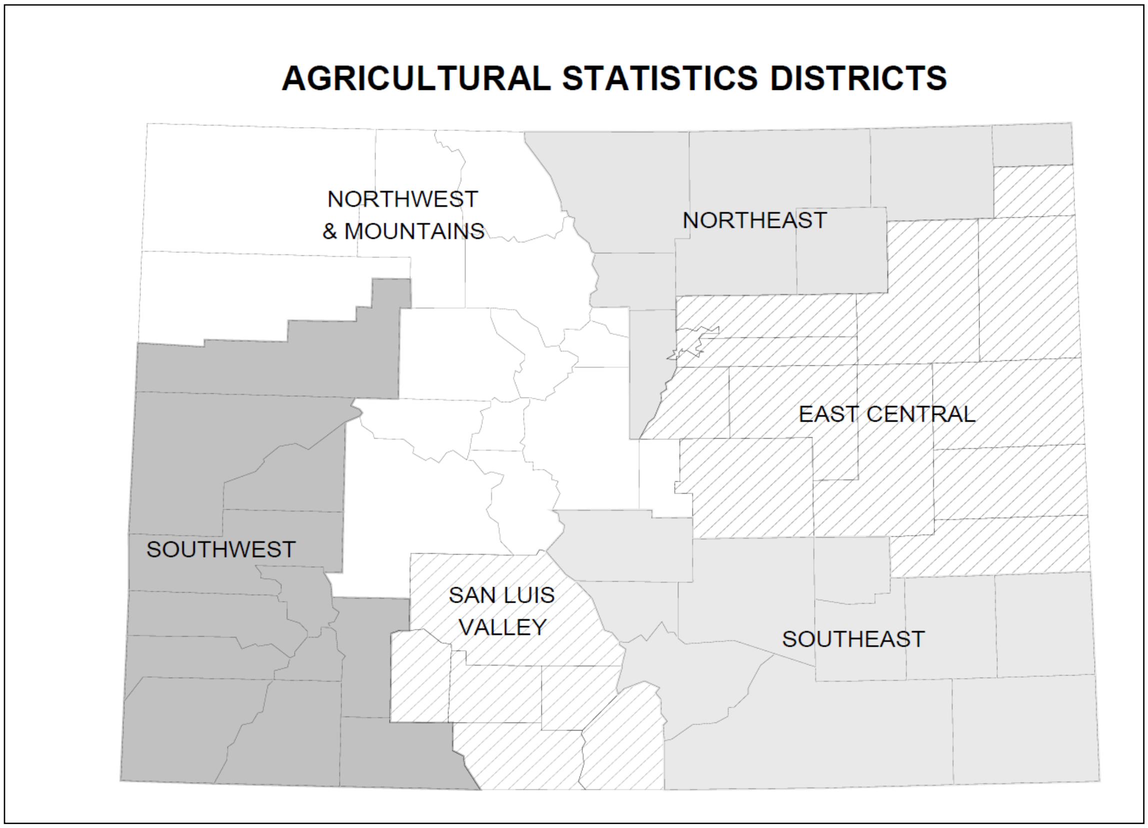

FIGURE 3. NASS agricultural statistics districts. Source: NASS, 2012.

The production types of the eastern and western portions can then be further differentiated from each other. The eastern portion of Colorado produces large amounts of corn for grain, winter wheat, alfalfa, and livestock in the form of cow-calf operations (NASS, 2013). However, each sub-region differs in its production slightly. The Northeast (NE) region has the largest number of cow-calf operations, and has substantial acreage dedicated to irrigated beets and sunflowers (Colorado Agricultural Experiment Station, 2008). The East Central (EC) region produces more corn for grain and winter wheat than the two other eastern regions combined **(**NASS**,** 2013**)**. The EC also has substantial irrigated acres dedicated to beets and sunflowers **(**Colorado Agricultural Experiment Station**,** 2008**)**. The Southeast (SE) region has a more equal distribution of agricultural production, but has less irrigated acreage than the other two eastern regions. The San Luis Valley (SLV) is intensively irrigated and specializes in potato production.

The western portion of Colorado specializes in cattle and growing forage. The differences in regional production are due to the different growing conditions that exist throughout Colorado – different climates and drought frequencies, soils, and elevations.

2.1 Drought in Colorado

Drought's most simplistic definition is a deficient supply of moisture over a period of time (McKee, Doesken, Kleist, & Shrier, 2000). However, the level of disruption caused by a drought and the impact subsequently felt by agricultural producers depends on many variables, such as the duration, intensity, and scale of the drought. For this reason, researchers and policy makers have developed tools that help measure environmental and socioeconomic impacts related to drought. These tools include drought indices[2] and economic impacts analyses. The tools are important because they are used as indicators for the meteorological intensity being felt by agricultural producers, which is related to their overall resiliency.

Drought indices are used to measure variables that are related to the intensity and duration of drought, such as soil moisture and precipitation, so that droughts can be categorized. Economic impact analysis is used to quantify the socioeconomic effects that drought has on regional economies and specific economic sectors. By defining, categorizing, and economically quantifying the impacts of droughts, it is possible to begin to assess how one drought compares to another. There are two main reasons why comparing droughts is important. First, comparisons allow policy makers and the stakeholders impacted by drought to assess if mitigation and response policies and practices are increasing or decreasing resiliency. Second, comparisons provide context so that policy makers can assess whether or not a drought is severe enough to

[2] Please see Appendix C for a more detailed discussion of indices, monitoring, and drought planning.

elicit a response and the type of response. Without attempting to normalize or categorize droughts evaluation across droughts become very difficult.

Since definitions, indices, and responses to drought have varied over time, it is difficult to compare droughts across time. However, having a brief understanding of the history of drought in Colorado can help indicate whether or not agricultural producers have become more or less resilient to drought over time. Comparisons can be made by using common drought metrics that were collected at the time of the droughts or metrics that can be reconstructed. Evaluating similarities and differences between historical and current droughts may reveal important determinants that impact resiliency.

The Dust Bowl (1931-1941) was one of the most disastrous droughts in Colorado's history and the United States' (McKee, Doesken, Kleist, & Shrier, 2000). In 1935, 65% of the US was covered by severe to extreme drought (Folger, Cody, & Carter, 2013). The drought conditions were exacerbated by poor agricultural and grazing practices, which led to catastrophic wind and water erosion during the Dust Bowl that forced many farmers and ranchers out of the industry (Hornbeck, 2012). During the Dust Bowl, 21% of all rural families collected some form of disaster aid in the affected area, while some counties had disaster aid collection rates as high as 90% (Warrick, 1980). Approximately 68% of the total collectors were farmers (NDMC, 2013). The total assistance allocated to those impacted by the Dust Bowl was estimated to be $18 billion (in 2013 dollars) (Riebsame, 1991). The extreme economic and ecological impacts, including high exit rates, caused by the Dust Bowl indicate that early European settlers had very low resiliency with respect to drought. The drastically low resiliency to drought was likely attributable to poor agricultural practices and the inexperience of the government responding to natural hazards.

After the Dust Bowl, the United States government established multiple policies that encouraged erosion control and conservation such as the 1936 Soil Conservation and Domestic Allotment Act and the 1938 Agricultural Adjustment Act (Hornbeck, 2012). The bills encouraged agricultural reform that included moving croplands off of less productive lands, moving grazing onto the less productive land, restoring rangelands, and educating agriculturalist about alternative tilling practice (Baumhardt, 2003). These policies were constructed to increase the resiliency of the landscape to drought. For instance, vegetative buffers protect against washing precious topsoil downstream if a large rain follows drought conditions. By increasing the landscape resiliencies against drought, the policies were early attempts at adapting farmers in Colorado and the Great Plains by encouraging them to plan for future droughts.

The increased resiliency that was provided by these alternative agricultural practices was quickly tested by the 1951-1957 drought. While the 1950's drought was not as intense as the Dust Bowl, it was thought to be more persistent (Folger, Cody, & Carter, 2013). Record high temperatures throughout the Great Plains cut yields in half and drove up hay prices to the point where many ranchers were forced to exit the agricultural industry (NOAA, 2003). However, the economic and ecological impacts were much less severe than the Dust Bowl. Specifically, there were fewer exits out of the agriculture sector and agricultural land prices were not as greatly impacted[3] (Hornbeck, 2012). This suggests that the policies enacted after the Dust Bowl may have been effective at increasing the resiliency of farmers and ranchers (McKee, Doesken, Kleist, & Shrier, 2000).

[3] Stable agricultural land prices indicate that short and long term value was not impacted by the drought.

Due to the timing and location of the 1974-1978 and 1981 droughts, their impacts were mainly felt by the tourism industry (McKee, Doesken, Kleist, & Shrier, 2000). However, the magnitude of the economic losses and the ease of linking these impacts directly to the drought caused the state government to become involved. In 1981, Colorado State passed its first drought related legislation that created the Colorado Drought Response Plan (currently the Colorado Drought Mitigation and Response Plan) and formed the Water Availability Task Force. These were important legislative actions because they gave the state power to act on drought related hazards, which had previously been controlled solely at the federal level.

The 1988-89 drought was estimated to be the most economically devastating in US history with over $70 billion ($2013) in total damages with $9 billion of the damages occurring in the agricultural sector (NOAA, 2002; NOAA, 2013). However, the drought largely missed Colorado except for the southeastern portion. The 1988-89 drought is important to note because it was so widespread that it greatly increased commodity prices and likely benefited Colorado farmers (Whittaker, 1990). In fact, the drought may have improved the financial standing of many commodity crop farmers the in the US. The reason for this is that the increase in commodity prices may have been relatively greater than the decline in yields (Whittaker, 1990). The result was that many commodity crop farmers', in and outside of the drought affected area, were better off after the drought. Specifically, the number of debt-free farms increased and the number of financially distressed farmers decreased (Whittaker, 1990). The 1988 drought is an example of how a drought that impacts a large spatial area that produces a substantial proportion of food commodities can actually benefit farmers by driving commodity prices up, more than off-setting lost productivity.

The 2002 drought was one of the most severe droughts in Colorado history with respect to water availability (Pielke, et al., 2005). Low snow accumulation in the year leading up to the drought caused critical water shortages for agricultural producers, municipalities, and the industrial sector (Pielke, et al., 2005). Water shortages led to a 60% decrease in winter wheat production and 14% decline in the total number of livestock in Colorado (Schuck, Frasier, Webb, Ellingson, & Umberger, 2005). However, the other areas affected (Utah, Arizona, and New Mexico) by the 2002 drought were not large agricultural production areas compared to Great Plains states. This diminished or completely negated an increase in commodity prices and led to lower widespread damages but more localized damages to the agricultural sector in Colorado (Pielke, et al., 2005). The spatial distribution and severity of the 2002 drought may have combined to impact Colorado's agricultural sector as much if not more than any other drought.

The total economic impact of the 2011-13 drought is not currently known due to the fact that is currently ongoing. However, there have been studies (e.g. Gunter et al., 2012; WWA and NIDIS, 2012; NOAA, 2013) completed that have assessed the initial economic impacts, made meteorological comparisons, and provided qualitative impacts that provide insight into the droughts severity and impact. The first signs of the drought began early in 2011, but a policy response was not deemed necessary until the summer of 2011. The response came in the form of primary disaster designations within 17 counties of Colorado mainly within the Southeast and San Luis Valley of Colorado (Figure 4). The 2011 drought decreased economic activity by $105 million, equivalent to a loss of over 1,000 jobs, in the Southeast of Colorado, while economic activity increased by $5 million in San Luis Valley (Gunter, Goemans, Pritchett, & Thilmany, 2012). The difference in the impact was driven by high potatoes prices, a primary crop in SLV, and whether or not the producer had irrigation. Irrigated farmers had substantial snowpack to draw from the 2010-2011 winter and were not affected to the extent that dryland farmers were by the drought (Gunter, Goemans, Pritchett, & Thilmany, 2012).

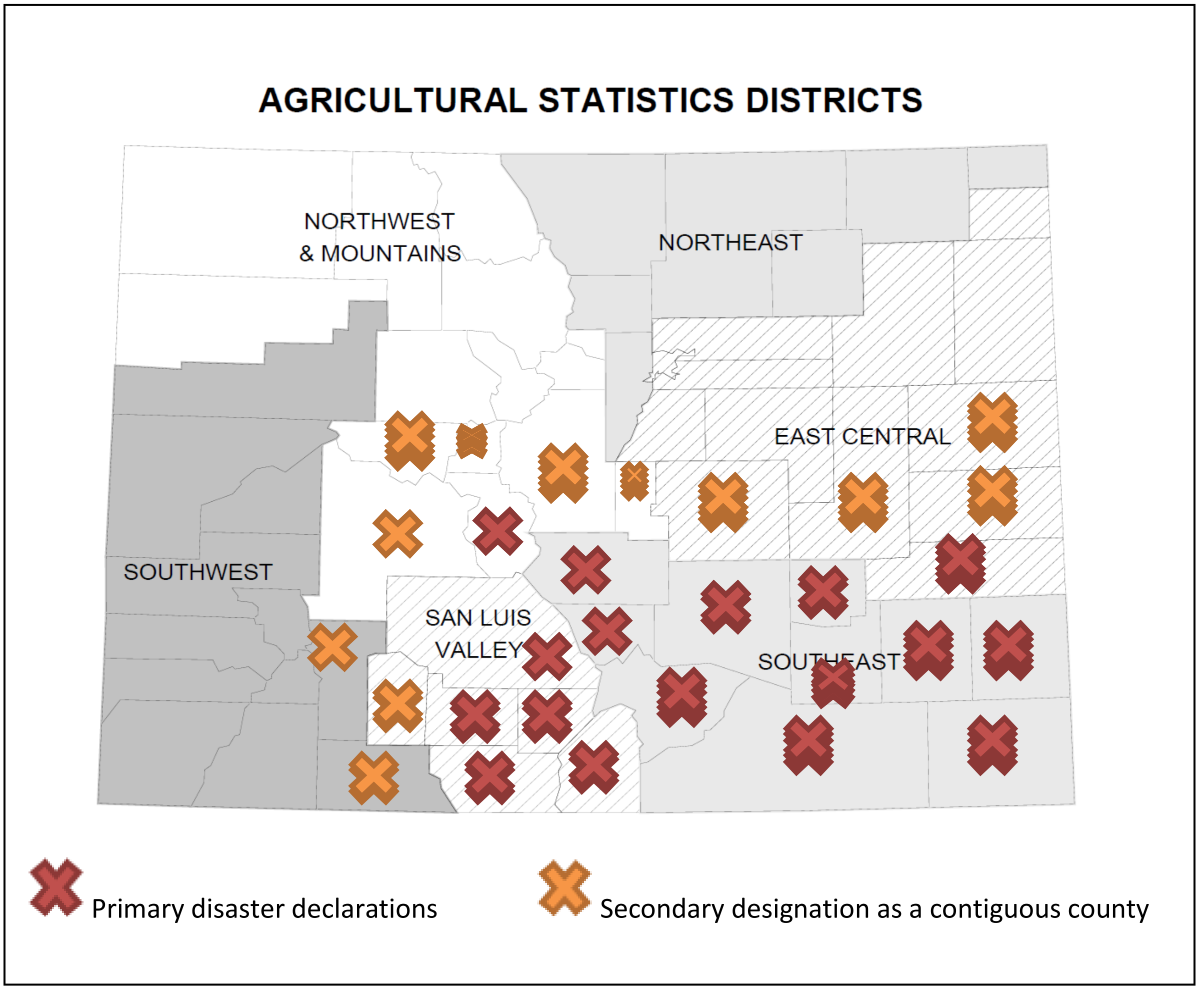

FIGURE 4. Primary disaster designations by NASS districts in 2011. Source: NASS, 2012; Gunter et al., 2012

By the summer of 2012, the drought was at its most severe point to date with 62 of 64 counties receiving disaster declarations (Colorado.gov, 2012). The precipitation deficit from May to August was more severe than the driest summers of the Dust Bowl (Hoerling, Schubert, & Mo, 2013). The spatial scale of the drought also increased during 2012 with 80% of the contiguous US experiencing some level of drought during August according to the US Drought Monitor (Folger, Cody, & Carter, 2013). It was estimated that yields throughout the US decreased by 26% for corn and by 10% for soybeans (Henderson & Kauffman, 2013). There were also hundreds of thousands of commodity crop acres not planted or abandoned subsequent to planting but before harvest. A curtailment in the production of corn of this magnitude has not been recorded since the Dust Bowl (Hoerling, Schubert, & Mo, 2013). Commodity shortages led to a 40% price increase in corn, a 30% increase in soy, and a 15% increase in alfalfa (Henderson & Kauffman, 2013). Commodity price increases along with the fact that 70% of the pastures in the US were designated as poor to very poor decreased the return on cow-calf pairs by $100 per head (Henderson & Kauffman, 2013). This has culminated in an estimated increase in the price of beef by 4% (Henderson & Kauffman, 2013). Currently, the drought is predicted to continue well into the growing season of 2013 (Thomas, 2013).

Although the intensity of the 2011-2013 drought is as extreme as any on record, the high commodity prices caused by the large spatial range of the drought may offset the impact of the drought for some producers. For this reason, it is important to look at how producers were impacted financially to understand how the meteorological characteristics of the drought impacted the productivity of the producer's enterprise. Two measures of the financial impact of the drought will be considered. First Figure 5 shows how producer's profit differed from normal during the 2012 drought. Profit provides a measure of how intense the given year of the drought was on the producer's operation. However, a one year shock may have different effects on a producer's operation over the long-run depending on how well the producer can absorb one year of below average profit. Debt to asset ratio, the second financial measure, may more accurately convey the long term impacts of the drought on the producer's operation. Looking at the debt-to-asset changes aggregately (Figure 6) indicates that the sample's debt to asset ratios went from the lower categories to higher ones. There was approximately a 13% increase in dangerously high debt to asset ratio categories (40% and greater). Dangerously high debt to asset ratios can preclude producers from being able to access more credit and can potentially lead to exiting the industry. Figures 5 and 6 indicate that the drought caused both short and long run complications with many agricultural operations throughout Colorado.

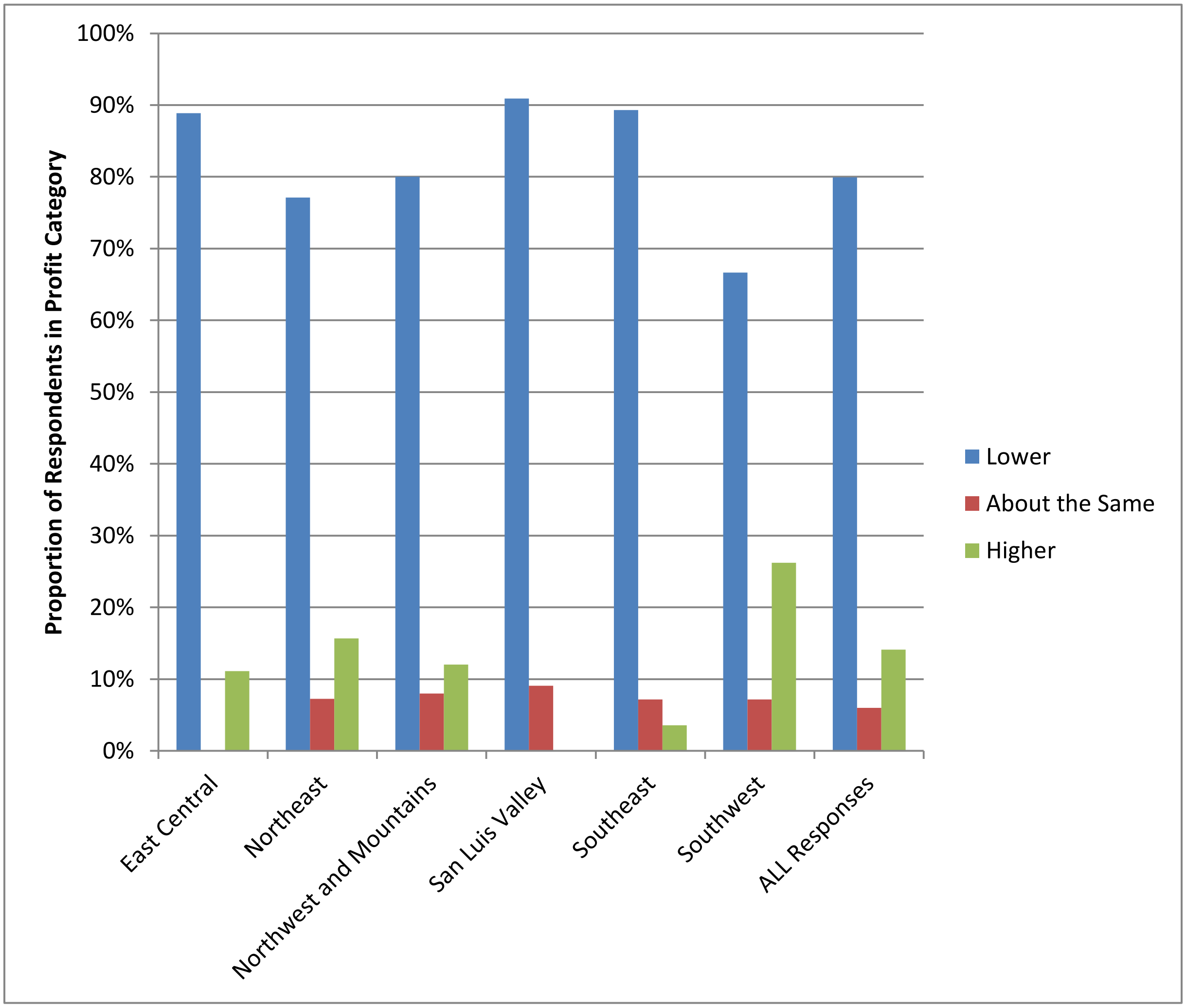

FIGURE 5. How the 2012 drought impacted producer's profits relative to normal. Source: Nelson, Pritchett, and Goemanns, 2013

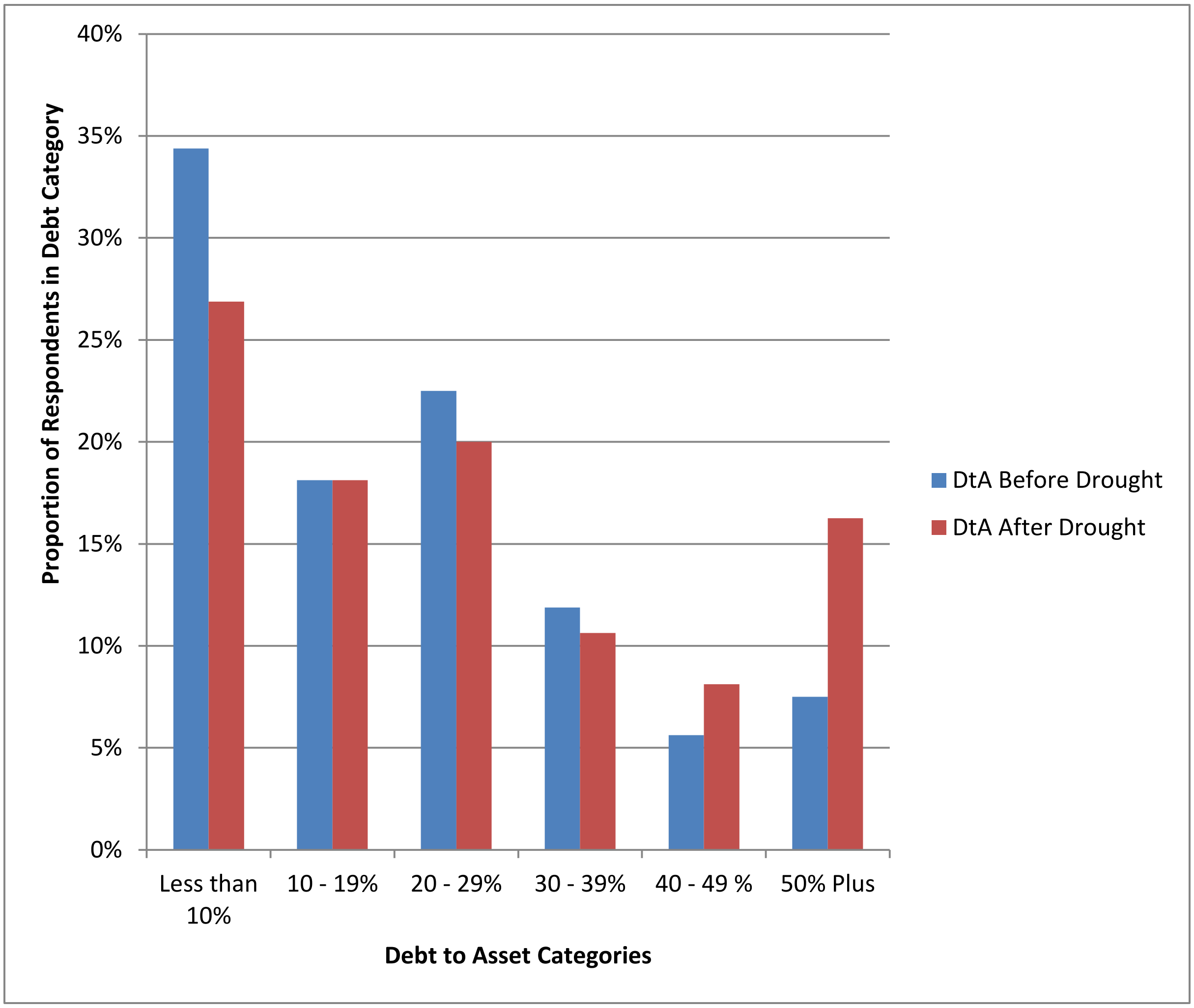

FIGURE 6. How the 2012 drought impacted debt to asset ratio categories. Source: Nelson, Pritchett, and Goemans, 2013.

Qualitatively comparing historical droughts on an aggregate scale can help indicate how drought impacts the resiliency of the agricultural sector. However, an aggregated evaluation does not provide policy relevant information. In order to obtain policy relevant information, it is necessary to assess farm-level determinants that effect drought related resiliency. Farm-level information can provide details on how exactly the resiliency and decision to stay in farming is impacted by drought.

CHAPTER 3: LITERATURE REVIEW

Of primary interest in this study is how drought impacts farmers and ultimately their decision to farm or not farm, drought is one of the many factors influencing industry exit. Exit is meant to be interpreted in its most general sense – the producer (i.e. a manager or owner) is no longer actively farming or ranching the land. Agricultural exit literature is important because it provides insight into how to control for variables that could decrease resiliency under normal circumstances and throughout time. By controlling for these variables, it may be possible to more clearly explain how drought impacts resiliency. It may also be possible to determine if exit stressors change by intensifying or if different exit stressors become more relevant during drought. Exit literature has been primarily conducted in developed countries (e.g. Weiss, 1999; Key and Roberts; 2007), while drought resiliency literature has been conducted primarily in developing countries (e.g. Keil et al., 2008), providing insight into important variables within the context of Colorado. The resiliency literature is important because it focuses on how farmers and ranchers handle shocks to their production. By combining concepts from the two areas of literature, it is possible to explore the factors that affect producer's resiliency during drought and to determine the factors that most influence the impact of drought on resiliency. The theoretical models of drought resiliency have only just been created so this section will first explore the empirical literature related to exit and resiliency.

Exit literature emerged from research on how farm growth and size influence structural change within the agricultural sector. Much of the literature on farm growth and the sector's structural change has focused on the validity of Gibrat's Law of proportionate growth, which states that the size of a farm and its growth rate are independent (Weiss, 1999). The models that were created using Gibrat's Law lacked economic structure, which inspired researchers to analyze some of the implicit assumptions made by the models (Weiss, 1999). Early explorations assessed the importance of human capital (e.g. Sumner and Leiby, 1987; Upton and Haworth, 1987). Later, Evans (1987) suggested that in order to effectively model size, growth, and structural change that it was necessary to control for the effects that exit and entry have on the sector, which eventually led to researchers focusing solely on the determinants of exit and entry[4] (Jackson-Smith, 1999).

The economic problem that exit literature is considering is that of maximizing a producer's net present value of utility. At the beginning of each period a producer faces the decision to remain in or exit the industry. Their choice depends on the expected utility that they will receive from continuing to actively manage their agricultural enterprise versus alternative opportunities such as retiring, leasing their land, changing locations to seek other types of employment, seeking other types of employment within their current location, or short selling their enterprise. With each new period the circumstances faced by the producer change. For example, the producer may experience a lower profit that increase their debt to asset ratio going into another period, or a drought may have impact their production one year and they may be fearing that it will continue into the next period. These potential changes from one period to the next impact the expected utility of exiting the agricultural industry.

One of the more obvious factors influencing exit is the age of the farmer or rancher. There are two types of exit related to age, forced and not forced (i.e. retirement). Not surprisingly, older farmers have higher exit rates (Gale, 2003). However, most exits from farming are voluntary, so the more interesting cases of exit are forced exits. When only forced

[4] The data used in this paper only has information pertaining to exit and therefore entry will not be discussed.

exits are considered younger producers have higher exit rates (Gale, 2003). Older farmers are believed to have more financial liquidity, higher levels of farming relating knowledge, and have a more stable lifestyle in general (Gale, 2003). Younger farmers have been found to be more vulnerable to financial and economic shocks because during the middle of many careers producers often try to expand their operation, which requires accumulating more debt (Gale, 2003). Therefore, older farmers have higher overall exit rates when compared to younger farmers, but younger farmers are more vulnerable to financial and economic shocks.

The type of operation has been found to affect the probability of exit. Most frequently the type of enterprise is modeled using a variable that depicts the proportion of crops and livestock within the operation. Findings indicate that for diversified farms higher proportions of livestock production decrease exit rates, and that higher proportions of crops increase exit rates (Glauben, Tietje, & Weiss, 2003; Bruestedt & Glauben, 2007; Bassi, Chilliemi, & Paggiaro, 2010). Crop type has also been found to affect exit rates (Key & Roberts, 2007). Goetz & Debertin (2001) found that the larger proportion of irrigated land that a producer had the lower their rate of exit. In aggregate, the literature indicates that having livestock and irrigation increase resiliency.

During Weiss's (1999) investigation of the disappearing mid-sized farm, he found that farmers in Austria with off-farm income were more likely to exit. Weiss (1999) contributed to the literature by being the first to use the Heckman two-stage estimation procedure to avoid the bias that sample attrition causes within exit data, which has been repeated by numerous other authors exploring exit data (e.g. Goetz and Debertin, 2001; Key and Roberts, 2006). Weiss's (1999) findings supported the hypothesis that farmers see off-farm income as an opportunity cost and that this increases the rate at which they leave farming. However, Kimhi & Bollman, 1999 compared exit rates in Israel and Canada using a probit model on agricultural census data and found that farmers in both countries experienced lower exit rates if a producer had off-farm income. Similarly, most other studies have found that off-farm income stabilizes farms by subsidizing the business, lowering the rate of exit (Kimhi A. , 2000; Glauben et al., 2003; Breustedt and Glauben, 2007; Bassi et al., 2010) or has had no effect (Goetz and Debertin, 2001). The lowering of exit rates due to off-farm income is thought to be the product of increasing financial stability through enterprise diversification. Furthermore, farmers may be willing to sacrifice higher paying off-farm work in order to maintain a farming lifestyle. Off-farm incomes impact on exit rates is still debated and may be determined by factors that are difficult to control for such as political institutions and agricultural policies.

It can be safely assumed that one of the objectives of government assistance to agriculturalists is to stabilize the farm and therefore decrease exit rates. Due to the historically large amount of government payments that farmers and ranchers receive, researchers have been interested in whether these payments have an effect on exit and if the payments are equitably distributed throughout the agricultural sector. Goetz and Debertin (2001) examined county level data in the United States and found that government payments increased the number of exits in counties that were already experiencing net exits, ceteris paribus. Yet, three subsequent studies from Key & Roberts (2006a; 2007a; 2007b) found that government payments decreased exit rates, and in one instance (Key and Roberts, 2007a) they found that the magnitude of the effect increases with the size of the farm. There are several competing hypotheses behind the differing results. On one hand, government payments increase the net worth of the farm and liquidity, which should increase the financial stability of the farm. Government payments also make farming more profitable compared to other pursuits, which lowers the opportunity cost of alternative employment and may reduce exits. On the other hand, government payments increase the price of fixed resources such as land, which can cause farmers that do not receive payments to shrink or exit. Government payments also make it easier for those that receive them to buy out farmers looking to exit. As it stands, the literature has not clearly established which affect is more dominant.

The resiliency framework emerged from a field of ecology in the early 1970's that addressed ecosystem dynamics (Holling, 1973). One of its most famous applications is the predator-prey model. It was quickly realized that the concept of resiliency differed from other pursuits in ecology because resiliency focuses on how humans interact with ecosystems while traditional ecology mainly considers humans as external to the systems studied (Folke, 2006). The resiliency framework is used to examine how humans shock ecological systems or how hazards shock human-ecological systems with the objective of determining sustainable pathways for humans by understanding and adapting to the shocks (Folke, 2006). Many disciplines such as anthropology, ecological economics, and other social sciences have adopted the resiliency framework because of its "human in the environment" perspective (Folke, 2006). Many methodological forms have been implemented under the guise of the resiliency framework (see Zhou et al, 2010 for a thorough discussion of the topic). This paper focuses on the resiliency framework that explores the social-ecological systems, which prompted a move towards policies that are developed for dynamic social-ecological systems as opposed to solutions for static systems that are assumed to be stable or that will return to equilibrium once the human disturbance has been removed (Folke, 2006). The framework and models that have been developed to assess resiliency have used different proxies (discussed below) as a measurement of resiliency. They then evaluate this measurement before and after a shock to provide a sense of whether the adaptation was successful or not.

Recently, researchers have adapted the resiliency framework to explore how agricultural systems and producers cope with drought and other environmental hazards. Keil et al. (2008) adapted the sustainable livelihood framework (e.g. Scoones, 1999) to a more quantitative and economically focused framework that this paper refers to as the drought resiliency framework. Keil et al. (2008) used household consumption data, as a measure of drought resiliency, to assess the impact of drought on farmers in central Sulawesi, Indonesia. Specifically, Keil et al. (2008) assessed how expenditures on essential household items (e.g. rice and corn) changed due to drought. The findings from their Tobit model suggests that the resiliency of farmers is increased with liquid assets, access to long term forecasts, access to credit, and the possession of superior agricultural technology. They also found that the impacts on drought resiliency varied depending on the aggregate wealth of the farmer.

Researchers have evaluated resiliency at the macro-level to project how resiliency may change due to climate change. Malone & Brenkert (2008) use a model to forecast how two states in India will change over the next 90 years and what determinants most influence each state's resiliency. Their results suggest that resiliency may be improved if decision makers attempt to intensify production on agricultural land, as opposed to increasing the spatial extent. Eakin and Wehbe (2009) explore farmer resiliency through two case studies in Latin America, and suggest that macro policies can have positive affects at the farm-level that can spread throughout the large social system. These macro level analyses attempt to evaluate how policy will impact farm level decisions as opposed to micro level studies that often assess how farm level decisions are or should be and then attempt to create efficient policy.

Theoretical models of farm-level decision makers have revealed many interesting findings that would otherwise be impossible or difficult to get at using empirical data. Ranjan and Athalye (2009) measured resiliency as the ability of a farmer to survive a certain number of consecutive droughts. Pressures from urbanization, the duration and frequency of drought, and the planning horizon of producers have been found to be important influences on resiliency when modeling farm level decision making. Ranjan and Athalye (2009) findings suggest that farmers do not adopt water savings technologies as a drought mitigation technique, and that pressures from urban areas negatively affect drought adaptation by increasing the opportunity cost of farming. However, these decisions depend on the perceived risk of future drought, which is often underestimated and decreases resiliency. Again stressing the importance of multiyear droughts, Ranjan (2012) created a mathematical model of drought resiliency. Ranjan’s (2012) model suggested that the planning horizon and beginning level of wealth were very important in determining a farmer’s drought resiliency. Modeling the behavior of farmers has provided insights by including normally unobservable variables, especially financial ones, which could potentially be driving resiliency more than past empirical models have shown.

The application of the resiliency framework to agricultural systems is in its infancy. The literature has still not agreed on basic concepts such as how to most effectively measure resiliency for policy purposes. However, it does improve the exit framework by acknowledging that the agricultural system does not only operate in a purely economic and political bubble – it also is impacted by environmental and ecological factors that may be changing more rapidly due to climate change.

CHAPTER 4: METHODOLOGY

4.1. Specification

This paper adopts an analytical framework that is similar to Keil et al. (2008) and uses survey data to specify two models. Keil et al. (2008) employed an asset-based approach that uses household consumption data to create a drought resiliency index for farmers in Indonesia. Their analytical framework is altered slightly to account for differences in the data collected and the economic structures of the two study areas. Specifically, the probability of the drought event occurring is omitted because respondents are asked to make assumptions about the duration of the drought; therefore, the probability of drought is taken as a given. The framework is also altered by including alternative proxies for variables within the model. The rest of this chapter will provide a description of the analytical framework, the mathematical specification proposed for each model, and a description of the survey data and the variables employed to model resiliency.

Resiliency is the likelihood a producer will return to a similar size and scale of production after having endured a shock. A non-resilient producer is therefore one whose production practices permanently change in response to the shock. This paper is interested in a particular form of non-resiliency, the likelihood that the producer permanently exits due to the shock. Equation 1 defines E as the likelihood a producer exits following a shock. E is dependent upon their asset base and their risk preferences (Keil et al., 2008). It is assumed that a producer's risk preferences are endogenously related to their asset base, which has been shown to be a safe assumption (Morduch, 1995). Therefore risk preferences are modeled implicitly through the asset base's variables.

$$E = Likelihood\ a\ producer\ exits\ following\ a\ shock \qquad Eq\ 1$$

The proposed form of E has two types of variables – those that can be changed by the producer for the purpose of risk management and those that explain characteristics of the shock that are not possible for the producer to change. The producer's asset base consists of the variables that can be changed by the producer and can be expressed as various forms of capital. For example, producers at some point choose to purchase the land they are going to farm (natural capital), continue drought education or not (human capital), and save or not save money for future hazards (economic and financial capital). Each of these variables is more or less controlled by the producer and increases or decreases the risk faced by the producer. Producers have no control over the pressure or predictability of drought, which are included in the shock variable within Equation 2. Pressure represents the intensity of the impact. Predictability is the amount of warning a producer has before the drought begins to impact production. The various forms of capital are measures of knowledge and wealth that may contribute to the producer's probability of exiting.

$$E = f(Human\ Capital, Natural\ Capital, Economic\ and\ Financial\ Capital, Shock)$$

$$Eq\ 2$$

Given a set of characteristics of a drought a producer's probability to exit changes from one point in time to another since a longer drought impacts expected utility. This model evaluates the probability of exiting using two periods. Period one is the likelihood that a producer exits if drought ends mid-drought (Equation 3), and the second period is the probability of a producer exiting if the drought continues (Equation 4).

$$E^0 = Likelihood\ a\ producer\ exits\ if\ drought\ \boldsymbol{ends} \qquad Eq\ 3$$

$$E^1 = Likelihood\ a\ producer\ exits\ if\ drought\ \boldsymbol{continues} \qquad Eq\ 4$$

The difference between E^1 and E^0, ΔE, is also of interest (Equation 5) because it provides insight into the types of farmers that are most vulnerable to an increased duration of drought.

$$(E^1 - E^0) = \Delta E = Change\ in\ probability\ of\ exit\ depending\ on\ duration\ of\ drought \quad Eq\ 5$$

The determinants of E^1 and ΔE were derived[5]. The estimable forms for E^1 and ΔE are as follows:

$$E^1 = \alpha + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \qquad Eq\ 6$$

$$\Delta E = \alpha^{\sim} + \sum_{j=1}^{k} \beta_j^{\sim} x_{ij} + \varepsilon_i^{\sim} \qquad Eq\ 7$$

Where E^1 and ΔE are the dependent variables. β and $\beta^{\sim}$are vectors of estimated coefficients that detail the magnitude of the explanatory variables denoted by x_j where j = 1…k is the index for both Equations 6 and 7. The observations index is i = 1…N, and ε and $\varepsilon^{\sim}$ are the error terms for both equations.

4.2. Data

The data that was used to estimate Equations 6 and 7 was obtained from Colorado agricultural producers through an online survey during the winter of 2012-2013. The survey's purpose was to gauge the various impacts that the drought of 2012 had on farmers and ranchers in Colorado. The survey was designed using Qualtrics and administered through a listserve, agricultural extensions, state and local newspapers, and radio broadcasts. The survey was pretested by agricultural producers and agricultural extensions agents. There were 394

[5] A model was created using E^0 but all variables were found to be insignificant due to a lack of variation in E^0.

respondents that completed the survey. Only 113 of these respondents answered all questions necessary to be incorporated into the model. The reason for the low number of usable observations was the small number of responses related to questions about finances. When compared to NASS demographics the sample of farmers and ranchers had more acreage, higher gross incomes, and were more educated than the average Coloradoan producer. The marketing for the survey purposely attempted to skew the sample in this way to avoid observations from "ranchettes", and to construct a sample that was more policy relevant. Table 1 displays the summary statistics for the variables that act as proxies for the functional relationship found in Equation 1 and 2, and that are used to estimate the mathematical formulation in Equation 3.

E^1, the dependent variable of Model 1, is measured as the probability that a farmer or rancher will leave the industry in the next 5 years if drought continues into the following year. The benefit of this measurement of *resiliency* is that it is easily obtained; while the shortcoming is that it is a stated versus an observed measure. For each of the questions that gave the data for E^0 and E^1 the respondents were provided with a sliding scale that they could move from 0 to 100, to denote said probability. These measures of resiliency/exit probability are subjective, but get at the stress directly perceived by a multiyear drought.

TABLE 1. Summary statistics

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
E^1	The probability that a producer will leave in the next five years if drought continues	113	0.29	0.31	0	1
ΔE	The probability that a producer will leave if the drought does not continue minus drought resiliency	113	0.20	0.27	-0.93	1
Acres	The natural log of the number of acres in operation	113	7847.59	24915.09	3	200745
DtA	Debt to asset after the 2012 drought	113	22.76	17.99	0	50
Profit	Profit for the year of 2012 measure on a continuous Likert scale centered at 50 (average)	113	25.8	22.49	0	92
SE	Southeastern Colorado dummy variable	113	0.14	0.35	0	1
SLV	San Luis Valley dummy variable	113	0.05	0.23	0	1
Producer Type	Dummy variable that is one if the producer has any irrigated land	113	0.37	0.49	0	1
Off Farm Income	The percent of income that comes from off of the farm	113	0.44	0.35	0	1
Experience	The number of years a producer has farmed or ranched	113	34.9	14.04	3	64
Government Payment	A dummy variable that is valued at one if a producer received state or federal funding in 2012	113	0.12	0.32	0	1

The explanatory variables incorporated into these models are proxies for the various forms of capital, pressure, and predictability measures in the analytical framework of E in Equation 2. Variables related to financial and economic capital were included to determine the effect that the wealth, short-term profits, and opportunity cost had on farmers and ranchers during drought conditions. The *debt to asset ratio after the drought (DtA)* variable is the selfreported debt-to-asset ratio after the 2012 drought had ended. This variable provides a longer-term financial measure than found in previous literature and is considered a proxy for wealth. *DtA* was measured on a scale from 0 to 50 percent. *DtA* is hypothesized to have a positive sign. Note that positive and negative signs of coefficients indicate the same meaning in each of the models – a positive sign indicates that resiliency has been decreased. L*n(acres)* is the natural logarithm of the number of acres farmed or ranched by the respondent. To limit the effect of large farms, the natural log of *acres* was taken to get the variable *ln(acres).* Previous literature has used the same procedure (e.g. Key & Roberts, 2007). Farm acreage has been found to positively related to survival in the agricultural sector due to increased access to credit (Weiss, 1999). The size of the operation is hypothesized to increase resiliency and therefore have a negative sign. The *off-farm income* variable is the proportion of income that is generated off the farm. *Off-farm income* represents the agricultural producers opportunity cost. The effect of off-farm income on exit rates has been mixed, but is hypothesized to have a stabilizing effect on farms and ranches in Colorado because of lifestyle preferences.

The climatic effect of drought strains agricultural enterprises in multiple ways, but in general the intensity and duration, or pressure, of the drought may be the most important climatic attributes (Ranjan, 2012). As a measure of duration, the two regional dummy variables of the *Southeast (SE)* and *San Luis Valley (SLV)* are included to test if being in the second consecutive year of drought significantly impacts resiliency. However, it should be noted that the regional variables may also be explaining other variation due to the uniqueness of reach region. Both regions had been in drought for two years at the time of the survey, but the regions were kept separate because it is hypothesized that the *SE* is more adapted to drought conditions due to a higher frequency of past drought conditions. It is hypothesized that the coefficient on *SE* will be negative and positive for *SLV*. A variable indicating the intensity of the drought as depict by the US Drought Monitor was not included because it is thought that drought intensity is more accurately modeled by farm level indicators such as profit. The variable *profit* measures the immediate financial effect that the drought had on the farmer or rancher. Other studies have attempted to model the immediate financial effect of a drought by incorporating variables such as crop yield and forced fallow (Keil et al., 2008). These variables are useful proxies when data is limited but ignore the income created by the amount of the crop that was grown and the exact costs that were incurred when forced to fallow. Therefore, the annual net impact of the drought is thought to be better explained by using *profit*. The *profit* variable was measured using a sliding continuous Likert scale that was center at average (50) and went to extreme low (0) and extremely high (100). The *profit* variable is hypothesized to have a negative value. *Government payments* are meant to lessen the pressure felt by producers before, during, and/or after a drought. For this reason, it is predicted the *government payments* will have a positive effect on the dependent variables.

The predictability of the drought is important because it determines the amount of time farmers and ranchers had to plan for the drought before outcomes could no longer be avoided by taking action. Early planning can lower costs by investing less into crops that are likely going to fail or by switching to less water intensive crops. This can be modeled by asking producers when they first reacted to the drought. However, the effectiveness of the decision is likely felt through the effect of the profit variable because a reaction does not guarantee a profit improving decision. This proxy was included into the model but was found to have nonsensical results. This may have been due to the variables explaining other types of variation not directly related to predictability. The significance of the variables within the models was not impacted by the inclusion of the predictability variable. For these reasons, the reaction variable was omitted from the final estimation.

Enterprise and manager characteristics reveal important aspects related to natural and human capital. Since many farmers in Colorado are diversified and produce many different crops and types of livestock, the *producer type* variable divides producers into simple production categories – those that have water and those that do not. Access to irrigation water is used as a proxy for natural capital because during drought it lowers the risk of decreasing yields and crop failures in most cases. *Producer type* is hypothesized to have a positive effect on resiliency (i.e. a negative sign). The *experience* variable is the number of years that a producer has farmed or ranched, and is assumed to be a close approximation for age. This variable incorporates many unobservable qualities related to the human capital possessed by the producer that may increase resiliency. However, at some point the margin benefits of an addition age decrease and possibly become negative. To address this the quadratic of experience was included. For this reason, the *experience* variable is squared. It should also be noted that the regional variables may implicitly express aspects of natural capital because they closely correspond to the different sub-climates and elevations found in Colorado.

4.3. Estimation

Model 1 is estimated as follows:

$$E^1 = \alpha + \beta_1 Acres + \beta_2 DtAAfter + \beta_3\ Profit + \beta_4\ DtAAfter * Profit + \beta_5 Southeast + \beta_6\ San\ Luis\ Valley + \beta_7\ Producer\ Type + \beta_8 Off\ Farm\ Income + \beta_9 Experience + \beta_{10} Experience^2 + \beta_{11} Government\ Payment + \varepsilon \qquad Eq\ 8$$

Measuring E^1 as a probability creates a proportional and bounded dependent variable, which renders estimation by ordinary least squares (OLS) inappropriate. As the mean response moves towards a boundary, the variance decreases and the skew increases (i.e. bounded intervals are often non-linear) (Verkuilen & Smithson, 2012). OLS can predict outcomes outside of the boundary, violating the theoretical constructs of the dependent variable. It should also be noted that a Tobit model is also inappropriate for estimation because E^1 is not a censored dependent variable, as probabilities outside of [0, 1] are not theoretically feasible (Baum, 2008). The fractional logit proposed by Papke & Wooldridge (1993) resolves the issues related to the estimation of E^1. It accomplishes this by incorporating the logit link function and the binomial distribution into a generalized linear model (GLM) (Baum, 2008). The GLM allows for values of exactly 0 and 1 and the theoretical non-linearity that occurs within the model. Specifically, the command in Stata is "glm depvar indepvars link(logit) family(binomial) robust". This command uses a logit model and assumes that the dependent variable comes from a binomial distribution. The coefficients that are generated are difficult to interpret so marginal effects are generated at the mean of each variable. As a check for robustness the model was also estimated using OLS. The significant variables and their magnitude did not differ at any practical level. ΔE was estimated using ordinary least squares (OLS).

Model 2 is estimated as follows:

$$\Delta E = \alpha^{\sim} + \beta_1^{\sim} Acres + \beta_2^{\sim} DtAAfter + \beta_3^{\sim} Profit + \beta_4^{\sim} DtAAfter * Profit + \beta_5^{\sim} Southeast + \beta_6^{\sim} San\ Luis\ Valley + \beta_7^{\sim} Producer\ Type + \beta_8^{\sim} Off\ Farm\ Income + \beta_9^{\sim} Experience + \beta_{10}^{\sim} Experience^2 + \beta_{11}^{\sim} Government\ Payment + \varepsilon^{\sim} \qquad Eq\ 9$$

CHAPTER 5: RESULTS AND DISCUSSION

Table 2 displays results for both the GLM and OLS models. Marginal effects[6] are evaluated at each of the variables means for the E^1 model, and standard OLS results are displayed for Model 2 with robust standard errors. The deviance from the GLM indicates that Model 1 performed well when compared to other models found within the resiliency and exit literature. The assumption of normally distributed errors for Model 2 was found to be violated according to White's Test for heteroscedasticity. To correct for heteroscedasticity robust stand errors are reported. The R^2 of the OLS model indicates that it performs about as well as other models found in the literature and the OLS model is extremely significant as a whole.

Several key findings emerge from the two models. Both models suggest that location is an important determinant of E^1 and ΔE. Specifically, the results indicate that the SE region of Colorado is more resilient than other regions of Colorado. The interpretation of the marginal effect from the E^1 model indicates that producers in the SE of Colorado are approximately 15% less likely to exit the industry if drought continues into the next year, all else constant. Model 2 indicates that the SE's resiliency is less impacted by an increase in the duration of drought than other areas in Colorado. Specifically, the change in resiliency caused by drought decreases the SE's exit probability by approximately 20% when compare to the rest of the state. This finding is interesting partly because the SE region is in its second year of drought while most other regions of Colorado are in their first. The increased drought resiliency that the SE possesses may be due to the fact that the SE has a long history of drought and therefore has different coping and mitigation techniques. The SE has been dryland farming for generations and has experienced numerous multi-year droughts over the last 100 years. The experience and knowledge gained

[6] Marginal effects represent an instantaneous change as opposed to OLS coefficients that indicate are interpreted by a one unit increase of the dependent variable.

from these droughts, along with producing essentially the same crops over a long period of time, may have made them more resilient to the shock of drought. This finding may indicate that the duration of a drought is not as important as where the drought is occurring and if that area has been repeatedly exposed to repeated droughts over a relatively short period of time. A policy implication of this finding is that drought assistance in form of educational outreach and financial resources may be better utilized by regions less familiar with adapting and planning for drought.

There are additional alternative interpretations of the SE variables significance. First, the SE may also lack off farm employment options that are close to where the producers operate. This increases the opportunity cost of leaving farming and may decrease their likelihood of leaving agriculture. Second, producers may self-selected into the SE because they are more resilient and seek out riskier production areas. It is likely that the SE's significance reflects parts of each of these explanations. With additional research it may be possible to control for these different possible explanations to decipher which has the strongest effect.

TABLE 2. Results of model 1 and 2

GLM and OLS Results		
	Model 1: Drought Resiliency	Model 2: Resiliency Change
	Marginal Effects at the Means	OLS Results
Drought Resiliency	0.281	
Ln(acres)	0.002 (0.014)	0.014 (0.013)
DtA	0.006* (0.003)	0.008*** (0.002)
Profit	-0.001 (0.002)	0.001 (0.002)
DtA*Profit	0.001 (0.001)	0.001 (0.001)
SE	-0.153* (0.069)	-0.199* (0.077)
SLV	0.105 (0.129)	0.117 (0.122)
Producer Type	0.056 (0.070)	0.023 (0.056)
Off Farm Income	0.086 (0.098)	0.066 (0.078)
Experience	0.008 (0.008)	0.010 (0.008)
Experience^2	0.001 (0.001)	0.001 (0.001)
Government Payment	-0.090 (0.099)	-0.019 (0.097)
Constant		-0.195 (0.185)
	GLM Fit	OLS Fit
	Deviance = .509	N = 113
		R-sq = 0.249
		Root MSE = 0.247
		F = 2.74**
Standard errors in parentheses		
="+ p<0.10, * p<0.05, ** p<0.01, *** p<.0001		

Additionally, both models indicate that the producer's DtA is a key determinant. As a proxy for the wealth of the farmer or rancher, this variable reflects, the overall financial well-being after the 2012 drought. The results from model 1 indicate that a producer's E^1 is reduced by .7% when their DtA increases slightly. Figure 7 examines the DtA variable from the GLM more in depth. It shows that as DtA increases its impact on E^1 increases. This indicates that as producers increase their DtA they realize their probability of exiting is increasing. Model 2 indicates that if a producer's DtA increases by one percent that resiliency change increases by almost one percent. DtA's importance reveals that a one year drought may not be a significant factor in motivating an agricultural producer to exit the sector since DtA is not likely to decrease drastically in a single year. Furthermore, profit from the year 2012 was not found to significantly influence E^1, which furthers the claim that a one year drought may not impact the probability of a producer exiting the industry. However, multi-year droughts will surely increase the DtA of most agricultural producers, decreasing drought resiliency, and possibly increasing agricultural exits.

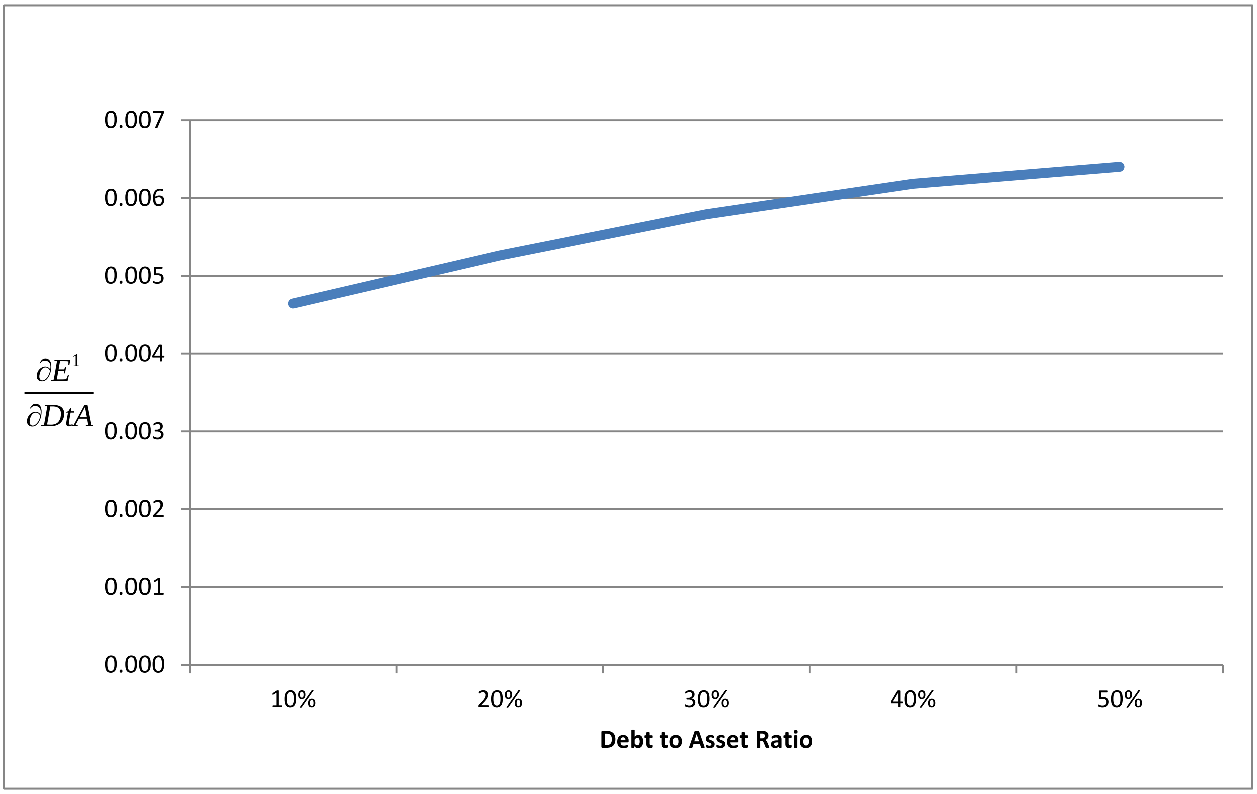

FIGURE 7. Average marginal effects of debt to asset ratio with respect to E1

The DtA finding has implications for policy makers, agricultural producers, and industry. First, producers and insurers need to be educated on how preparing financially for drought may increase the viability of a producers enterprise. Second, the form of assistance currently offered, low interest emergency loans, may be decreasing farmer and rancher resiliency by increasing their DtA. However, low interest emergency loans may be minimizing the negative impact felt by agricultural producers and their communities, and may be the best policy option available for the circumstances. For example, the worst case scenario is that the emergency loan delays the producer from going out of business, which would have a positive effect on society by avoiding a large economic collapse in the agricultural industry during the drought. The best case scenario created by the emergency loan is that the farmer is provided additional time to recover and is successful, again having a likely positive impact on society. To further determine whether or not low interest emergency loans are the best option for drought assistance, additional research could compare the exit rates of those farmers that choose to take low interest emergency loans versus those that do not.

The frequently studied variable of off-farm income was not found to have a significant impact on the dependent variable in either of the models. This may be due to the fact that in past literature off-farm income was explaining some of the DtA's importance due to the correlation between the two variables. No other study has had information on a producer's debt-to-asset ratio, which may have previously caused the importance of correlated variables to be overstated. This may also help explain why the findings about off-farm income's effect on exit have been conflicting. On the other hand, it may be that off-farm income's importance is better detected using time series data, or that the shock created by drought is large enough that off-farm income does not provide substantial protection. Additionally, the finding that having irrigation does not impact the probability of exit is counter intuitive and goes against much of the modeling that has been proposed in the resiliency literature. The explanation for irrigation is similar to that of off-farm income; access to irrigation only provides help against a drought when it helps to decrease a farmer's debt to asset ratio. Therefore, these two variables may also be correlated. Savings may be the key component to surviving a shock to a farmer's or rancher's enterprise and improving drought resiliency.

CHAPTER 6: CONCLUSION

The intensity, duration, and occurrence of drought are likely to increase in the future. Due to the high economic costs that drought imposes on agricultural producers and rural communities, research is needed to better understand the main determinants that effect producer's ability to recover from drought. This paper attempts to identify these determinants by developing a model of resiliency that uses survey data from agricultural producers in Colorado.

Colorado is a state that is almost always in some level of drought. In areas such as Colorado, it is important to have a comprehensive understanding of how to assess, mitigate, and respond to drought. In order to assess the impacts of drought, this paper proposed an alternative way to measure and model resiliency. The model identified the importance of a producer's debt to asset ratio and the location of their farm within Colorado as important determinants of resiliency. Furthermore, the paper highlighted policy implications related to these findings. Findings suggest that educational assistance related to drought preparedness should be focused on areas that are less frequently exposed to multi-year drought but will likely experience a higher likelihood of multiyear droughts due to climate change in the future. The findings also suggest that those in the SE may have fewer employment opportunities or may have self-select into the area given its unique climatic. The current form of drought assistance, emergency low interest loans, may provide long-term benefits to society by delaying or decreasing exit. However, this policy increases producer's debt-to-asset ratio, which was found to decrease the resiliency of farmers.

While this paper benefited from the insight that a survey provides, it suffered from some shortcomings and inspired more research questions. First, the measure of resiliency depended on a stated probability versus an observed probability. Future research would benefit by having time series data in order to have data that contains observed exits. Second, more information about the type and timing of debt may provide more insight into why debt to asset ratio is important. Lastly, additional detail on why the SE differs from the rest could begin to provide insight into the unobserved characteristics that increase resiliency.

The findings of this paper can be used by governmental and non-governmental organizations to help with decisions regarding drought mitigation and response policy and financial institutions attempting to lower risk. Furthermore, this research contributes to a larger body of literature that attempts to determine how agricultural producers can best adapt or absorb the shock that is brought on by drought and remain in the agricultural industry. The findings of this paper are a preliminary attempt at building a foundation for resiliency frameworks that examine how agricultural producers cope with drought and the decision to exit the industry.

BIBLIOGRAPHY

Barkley, A. (1990). The determinants of the migration of labor out of agriculture in the United States. *American Journal of Agricultural Economics*, 567-573.

Bassi, F., Chilliemi, O., & Paggiaro, A. (2010). Survival of farms in the Veneto Region of Italy 1999-2004. *Agribusiness*, 477-502.

Baumhardt, R. (2003). The Dust Bowl Era. *Encyclopedia of Water Science*, 187-191.

Bruestedt, G., & Glauben, T. (2007). Driving forces behind exiting from farming in Western Europe. *Journal of Agricultural Economics*, 115-127.

Colorado Agricultural Experiment Station. (2008). *Making Better Decisions - 2007 Colorado Sunflower Variety Performance Trials.* Colorado State University.

Colorado.gov. (2012). *Federal government approves drought disaster for Colorado.*

CWCB. (2011). *Financial Assistance.* Colorado Water Conservation Board.

Dennis, B. (2007). Productivity growth and agricultural out-migration in the United States. *Structural Change and Economic Dynamics*, 52-74.

EPA. (2013). *Ag 101 - Demographics.* EPA.

Evans, D. (1987). Tests of alternative theories of firm growth. *The journal of political economy*, 657-674.

Folger, P., Cody, B., & Carter, N. (2013). *Drought in the United States Causes and Issues for Congress.* Congressional Research Service.

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global environmental change*, 253-267.

FSA. (2012). *Newsroom: Fact Sheets.* USDA.

Gale, F. (2003). Age-specific patterns of exit and entry in US farming, 1978-1997. *Review of Agricultural Economics*, 168-186.

Glauben, T., Tietje, H., & Weiss, C. (2003). Agriculture on the move: Exploring regional differences in farm exit rates (No. 0308). *FE Working paper Department of Food Economics and Consuption Studies*.

Goetz, S., & Debertin, D. (2001). Why farm quit: A county-level analysis. *American Journal of Agricultural Economics*, 1010-1023.

Gunter, A., Goemans, C., Pritchett, J., & Thilmany, D. (2012). *The Economic Impact of the 2011 Drought on Southern Colorado: A combined input-output and EDMP analysis.* Colorado Water Conservation Board.

Henderson, J., & Kauffman, N. (2013). Initial Impacts of the 2012 Drought. *The Main Street Economist Agricutural and Rural Analysis*.

Hoerling, M., Schubert, S., & Mo, K. (2013). *An Interpretation of the Origins of the 2012 Central Great Plains Drought.* NOAA Drought Task Force.

Holling, C. (1973). Resilience and stability of ecological systems. *Annual review of ecology and systematics*, 1-23.

Hoppe, R. (2010, September). US Farm Structure: Declining - But Persistent - Small Commercial Farms. *Amber Waves*.

Hornbeck, R. (2012). The enduring impact of the American Dust Bowl: Short and long-run adjustments to environmental catastrophe. *American Economic Review*, 1477-1507.

Jackson-Smith, D. (1999). Understanding the Microdynamics of Farm Structural Change: Entry, Exit, and Restructing among Wisconsin Family Farmers in the 1980's. *Rural Sociology*, 66-91.

Keil, A., Zeller, W., Wilda, A., Sanim, B., & Birner, R. (2008). What determines farmers; resilience towards ENSO-related drought? An empirical assessment in Central Sulawesi, Indonesia. *Climatic Change*, 291-307.

Key, N., & Roberts, M. (2006). Government payments and farm business survival. *American Journal of Agricultural Economics*, 382-392.

Key, N., & Roberts, M. (2007). *Commodity payments, farm business survival, and farm growth.* USDA - ERS.

Key, N., & Roberts, M. (2007). Do government payments influence farm size and survival. *Journal of Agricultural and Resource Economics*, 330-348.

Kimhi, A. (2000). Is Part-Time Farming Really a Step in the Way Out of Agricultural? *American Journal of Agricultural Economics*, 38-48.

Kimhi, A., & Bollman, R. (1999). Family farm dynamics in Canada and Israel: The case of farm exit. *Agricultural Economics*, 69-79.

McKee, T., Doesken, J., Kleist, J., & Shrier, J. (2000). *A history of drought in Colorado: Lessons learned and what lies ahead.* Colorado State University.

Morduch, J. (1995). Income smoothing and consumption smoothing. *The journal of economic perspectives*, 103-114.

NASS. (2008). *2007 Census of Agriculture - Farm Numbers.* USDA.

NASS. (2013). *Colorado Agricultural Statistics 2012.* USDA.

NDMC. (2013). *Comparison of Major Drought Indices: Palmer Drought Severity Index.* University of Nebraska, Lincoln.

NDMC. (2013). *Drought Monitor: State-of-the-Art Blend of Science and Subjectivity.* University of Nebraska, Lincoln.

NDMC. (2013). *Economics of the Dust Bowl.* University of Nebraska, Lincoln.

Nelson, R., Pritchett, J., & Goemans, C. (2013). *2012 Colorado State University Agricultural Drought Survey.*

NOAA. (2002, September). Economic impacts of drought and the benefits of NOAA's drought forecasting services. *NOAA Magazine*.

NOAA. (2003). *North American Drought: A Paleo Perspective.* NOAA Paleoclimatology Program.

NOAA. (2013). *Billion-Dollar U.S. Weather/Climate Disasters 1980-2012.* Asheville, NC: National Climatic Data Center .

Pielke, R. S., Doesken, N., Bliss, O., Green, T., Chaffin, C., Salas, D., et al. (2005). Drought 2002 in Colorado: an unprecedented drought or a routine drought? *Pure and Applied Geophysics*, 1455-1479.

Riebsame, W. (1991). *Sustainability of the Great Plains in an Uncertain Climate.*

Schuck, E., Frasier, M., Webb, R., Ellingson, L., & Umberger, J. (2005). Adoption of more technically efficient irrigation systems as a drought response. *Water Resources Development*, 651-662.

Thomas, J. (2013). *Drought could reduce acreage in corn by 100,000 to 200,000 arces statewide.* DenveriJournal.

USDA. (2012). *Land in Farms and Livestock Operations 2011.* USDA.

USDA. (2013). *Disaster and Drought Assistance.* USDA.

Ward, N., & Brown, D. (2009). Placing the rural in regional development. *Regional Studies*, 1237-1244.

Warrick, R. (1980). Drought in the Great Plains: A case study of research on climate and society in the USA. *Climatic constraints and human activities*, 93-123.

Weiss, C. R. (1999). Farm growth and survival: econometric evidence for individual farms in Upper Austria. *American Journal of Agricultural Economics*, 103-116.

Whittaker, G. (1990). *Effects of the 1988 Drought on Farm Finances.* USDA - Economic Research Service.

Wilhite, D., & Glantz, M. (1985). Understanding: the drought phenomenon: the role of definitions. *Water international*, 111-120.

APPENDIX A: SURVEY INFORMATION

Introduction

Drought disrupts rural economies as farmers and ranchers adopt mitigating strategies to cope with water shortages. Agricultural producers absorb the direct economic impacts by reducing production and dealing with increased input costs. However, the economic impacts associated with drought also spread into the broader regional economy. For example, cow-calf operations may not be able to purchase locally produced hay due to shortages and has to substitute with more expense grain feeds from outside of the region. This puts strain on all the companies who do business with agricultural producers. The reach and impact of drought depends on the severity, persistence and geographic scale.

In early 2011, southern Colorado began to experience drought conditions, which spread to engulf the entire state by the summer of 2012. The impacts are significant, but stakeholders and policymakers wanted more detailed information so they could attempt to increase the resiliency of Colorado to drought.

In order to better understand the drought's economic impact, the Colorado Water Conservation Board, Colorado Department of Agriculture, and Colorado State University initiated a collaborative project. The project's goal was to describe and quantify the impacts of the 2012 drought to Colorado. The survey's objective was to describe how farm and ranch managers changed their business practices in the face of a persistent drought, and ultimately to build a model that helped determine how drought and other determinants affect producer's resiliency. The remainder of Appendix A describes the surveys scope, questionnaire type, sampling strategy, development, and distribution.

Survey scope, type, and sampling strategy

The survey's scope encompassed all of Colorado. All types and sizes of producers were permitted to respond. However, we were most interested in farms that gross over $250,000 for policy purposes. The survey's objective was to describe and quantify the mitigating responses that farmers and ranchers took, if any, to the 2012 drought. Survey results better represent actual conditions when the survey questionnaire can be widely distributed to farm and ranch managers in Colorado, and when survey responses are representative of existing operations. At the same time, the survey questionnaire needs to be relatively easy to complete for respondents, be designed for a variety of diverse livestock and farm operations and be cost effective in its design, dissemination, and results tabulation. Based on these factors and a relatively short timeline, the research team chose an internet based questionnaire (Qualtrics), and then advertised the survey website heavily via newsletters, LISTSERV's and personal contacts with Colorado agricultural organizations and allied groups. Example institutions that advertised the survey included the Colorado Department of Agriculture newsletter and Farm Credit Services of Colorado. Commodity organizations advertising the survey included, but were not limited to, the Colorado Wheatgrowers Association, Colorado Corn, and the Colorado Cattlemen's Association.

An internet survey questionnaire has many advantages. For example, skip logic can be programmed into an online survey in order to save the respondent time. On the other hand there are disadvantages to online surveys, the main disadvantage being under-sampling those producers without access to the internet or a computer. However, this number is thought to be relatively small, especially for larger producers. Our approach of advertising the survey to commodity organizations and advocacy institutions may also omit some potential respondents as compared to a traditional mail survey effort. Unfortunately, this approach does not allow for a traditional measure of response rate (i.e., number of questionnaire responses divided by the number of valid mailings), but comparisons can be made between the demographics of respondents and responses to the USDA Agriculture Census. In summary, our demographics tended towards larger more educated producers, which is common amount agriculturally related surveys.

Survey development and distribution

The questionnaire was collaboratively designed by agricultural economists at Colorado State University and reviewed by a selected group of extension specialists and farmers for accuracy, consistency and relevance. Sections in the questionnaire include asking respondents to designate their operation's location, operation characteristics, input buying and marketing behavior, production type(s), how finances were impacted, if they had full allocation of water, drought mitigation alternatives, use of drought/climate information and personal demographics. In total 63 questions made up the survey, but the use of logical sequencing likely shortens the survey to only relevant questions. For example, if a producer does not have a cow-calf operation, then he/she would not have to answer or see any more questions about cow-calf operations.

The survey was hosted by Qualtrics, an online software company that specializes in the development and distribution of online surveys. The survey was assigned a distinctive URL, and this was embedded as a hyperlink into the before mentioned emails and newsletters. A short paragraph accompanied the URL to inform participates of its purpose, the entity administering the survey (CSU), and why it was important to participate. Once the survey was accessed online, the opening prompt further introduced the survey with a more involved explanation of its purpose and importance. For the purpose of this paper the survey was open from November 2012 to February 2013, and 393 responses were collected.

APPENDIX B: SURVEY

A copy of the survey follows. Please note that the formatting shown may not match the formatting used on the online survey.

Drought 2012

Q1 Dear Colorado Farmer/Rancher: We need your help. As you are well aware, Colorado experienced a serious drought during 2012. We know that many producers were severely affected; however, the full impact of the drought on Colorado agriculture is unknown. To better understand these impacts, we are conducting a survey called "Telling the Story - Drought in Colorado". Our goal is to summarize survey results in a written document as well as presentations to the public. This effort is intended to tell the story of 2012 drought and help farmers and ranchers prepare for the future. We are doing this work for the Colorado State University (CSU) Agriculture Experiment Station and CSU Extension. Our efforts are funded by CSU as well as the Colorado Department of Agriculture and the Colorado Water Conservation Board. Your participation will provide information that will be used by the Agricultural Experiment Station and Cooperative Extension Service in responding to the current and future droughts. Your participation in this research is voluntary and there are no known risks associated with completing this Internet survey. We are taking careful measures to protect your privacy. Your response is anonymous. We cannot and will not track your individual response. Average responses will be published as findings, and individual responses will not be singled out. Your response is valued. We appreciate you taking time out of your busy day to complete this Internet survey. It should take about 20 minutes to complete. Please attempt to answer every question in the survey. If you cannot or do not wish to answer a particular question, please skip that question and proceed through the remainder of the questionnaire. There may be no direct benefit to you for participating in this research; however, every response will help provide a clearer picture of the true impact of the Colorado drought. If you have any questions or comments regarding this survey, please don't hesitate to e-mail or call James Pritchett, Ph.D., 970-491-5496 or James.Pritchett@ColoState.edu. Thank you! James Pritchett, Farm and Ranch Extension Specialist Agricultural & Resource Economics, Colorado State UniversityJames.Pritchett@ColoState.edu (970) 491-5496

Q2 Would you like to take the survey?

- ❍ Yes (This will take you to the questionnaire) (1)
- ❍ No (This will exit you from the survey) (2)

If No (This will exit you from... Is Selected, Then Skip To End of Survey

3 Did you complete an internet drought survey from Colorado State University last year?

- ❍ Yes (1)
- ❍ No (2)

Q67 Was your production impacted by the drought in 2011?

- ❍ Yes (1)
- ❍ No (2)

Q4 We believe that the size of a farm or ranch may play an important role in the overall impact that the drought has on the resiliency of the operation. Could you please provide the number of acres that you own and rent in your operation? (Please enter numbers only -- no commas, labels or other characters.)

Q5 Of the acres that you listed above, about how many acres do you lease or rent? Please enter the amount in the box below without using commas or labels.

	Rented/Leased
	Acres (1)
Number of Acres (1)	

Q6 The location of your farm and/or ranch likely plays an important role in how the drought impacted you. Could you please provide the zip code in which the majority of your operation is located?

Q7 We would like to know where you sell your products so that we can measure the impact of the drought on the local community. Please select the percentage of the agricultural goods you sell within 50 miles of your farm or ranch and the percentage you sell outside of Colorado. Please do this for a typical year rather than focusing on 2012. As an example, if you sell 40% of your crops within 50 miles of your operation, you would type 40 in the first box of the second column.

	Percent sold to customers within 50 miles of your farm or ranch	Percent sold to customers residing outside Colorado	I do not sell this product or service (please check)
	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)
Crop Sales (1)			❍
Livestock Sales (2)			❍
Dairy/Milk Sales (3)			❍
Custom Farm or Ranch Work for Others (4)			❍

Q8 Just like with your sales, we would like to know where you purchase inputs so that we can better understand how drought impacted your local community. Please select the percentage of the goods you purchased from within 50 miles of your farm or ranch and the percentage you purchased outside of Colorado. As an example, if you purchase 40% of your direct expenses within 50 miles of the operation, you would type in 40.

	Percent purchased within 50 miles your farm or ranch operation	Percent purchased outside of Colorado's borders
	Answer 1 (1)	Answer 1 (1)
Direct Expenses (e.g. seed, fertilizer, livestock for resale, fuel, etc) (1)		
Capital Expenses (e.g. equipment, breeding livestock, etc.) (2)		
Farm or Ranch Services (e.g. real estate, legal, insurance, labor, custom hire, etc.) (3)		

Q9 In this part of the questionnaire, we would like to know how individual enterprises were impacted by the drought. What enterprises did you operate in 2012? Please check all that apply.

- ❑ Forage Crops (1)
- ❑ Dryland Cropping (Non-Forage) (2)
- ❑ Irrigated Cropping (Non-Forage) (3)
- ❑ Livestock Feeding (4)
- ❑ Cow - Calf Production (5)
- ❑ Sheep Production (6)
- ❑ Dairy (7)
- ❑ Other Enterprise (Please Type In) (8) ____________________

Q10 We are interested in how your forage production has changed in 2012 compared to a TYPICAL year. Please us the sliders to indicate these differences.

______ Yields (1)
______ Quality (2)

Q11 How did you measure the difference in forage quality? (check all that apply)

- ❍ Animal Preference/Gain (1)
- ❍ Forage Quality Analysis (2)
- ❍ Reduction in Legumes (3)
- ❍ Visual (please describe) (4) ____________________

Q12 Forage production is a key enterprise for many farms and ranches. Please indicate how your forage production per acre compared to a TYPICAL year. Only numbers are needed in the boxes, so please do not add commas or labels.

	Irrigated Acres (1)	TYPICAL Yield per Acre (2)	2012 Yield per Acre (3)

Alfalfa Hay (Tons) (1) Grass Hay (Tons) (2) Grass Pasture (AUM's) (3) Other (Please List) (4) Other (Please List) (5)			

Q13 If you applied nitrogen fertilizer in 2012, what was its impact on forage yields?

- ❍ Increased Yields (1)
- ❍ Yields remained the same (2)
- ❍ Decreased Yields (3)
- ❍ Nitrogen fertilizer was not applied (4)

Q14 If you harvested hay earlier than normal, how much earlier did you harvest?

- ❍ Yes, and I harvested about ________ earlier than normal (1) ______________________
- ❍ I did not harvest earlier than normal (2)

Q15 The 2012 drought may impact yields on your forage crops for years to come. If precipitation returns to normal in 2013, how long do you think it will take for your fields and pastures to return to normal production? Please use the slider bar to indicate the number of years.

_______ Number of Years to Return to Normal Production (1)

Q16 The 2012 drought may have caused a decrease in irrigated crop yields compared to expected yields, and/or may cause fewer acres to be harvested. Please type in what you expected on average for irrigated yields and acres in 2012 (no commas or labels are needed), and then what you actually experienced at harvest. Please estimate average yields including "0" yields for abandoned acres. If you do not grow the crop, please leave the boxes blank. If you purchased crop insurance for crops listed below, please indicate so by checking the appropriate box in the far right column. Also check the space in the last column if you received an indemnity payment or expect to receive a payment.

	Expected Yield	Actual Yield	Planted Acres	Harvested Acres	Did you buy an insurance product for this crop? Please check if so.	Did you (or will you) receive an indemnity for this crop? Please check if so.
Corn Grain (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1) ❍	Answer 1 (1) ❍

Corn Silage (2)					❍	❍
Irrigated Wheat (3)					❍	❍
Dry Beans (4)					❍	❍
Barley (5)					❍	❍
Potatoes (6)					❍	❍
Other Crop (7)					❍	❍
Other Crop (8)					❍	❍

Q17 The impact of a drought on an irrigated cropping operation might influence the drought's impacts. Please indicate the sources of your irrigation water in 2012 by writing the percentage of water from each source. As an example, if you receive 80% from a Direct River Diversion you would write 80 in the box next to that label.

Direct River Diversion (1)
Groundwater Well (2)
Reservoir Water Delivered Through Canal (3)
Canal/Ditch Water from Direct River Diversion (4)
Other Water Source (5)

Q18 We would like to learn a little about your plans to change irrigation technologies so that we can target technical assistance. Could you please answer the following questions? First, do you plan to upgrade your irrigation system in the next 5 years?

❍ Yes (1)
❍ No (2)

Q19 You are planning to upgrade your irrigation system. What type of system do you CURRENTLY USE? (check all that apply)

	flood irrigation (1)	siphon tube (2)	gated pipe (3)	collapsible pipe (4)	center pivot sprinkler (5)	side roll sprinkler (6)	drips system (7)	other (8)
My current system includes .... (1)	❑	❑	❑	❑	❑	❑	❑	❑

Q20 What type of system do you plan to UPGRADE too? (check all that apply)

	lined ditches (1)	siphon tube (2)	gated pipe (3)	collapsible pipe (4)	center pivot sprinkler (5)	side roll sprinkler (6)	other (7)
I plan to upgrade to ... (1)	❑	❑	❑	❑	❑	❑	❑

Q21 What do you plan to MODIFY with? (check all that apply)

	install drop nozzles (1)	remove end guns (2)	add flow meter (3)	change a nozzle package (4)	computerized panel (5)	None of these (6)
Click to write Statement 1 (1)	❑	❑	❑	❑	❑	❑

Q22 Why are you choosing to UPGRADE, MODIFY OR REPLACE your system? (Please check all that apply)

- ❑ More uniform application of water (1)
- ❑ Improve crop productivity (2)
- ❑ Reduce energy costs (3)
- ❑ Provide more flexibility in drought (4)
- ❑ I have a reduced pumping allocation's (5)
- ❑ To reduce labor requirements (6)
- ❑ I have leased or sold water (7)
- ❑ I can no longer lease water (8)
- ❑ To make water available for leasing (9)
- ❑ Public funding is available (EQIP, salinity control, CWCB, etc) (10)
- ❑ Other (Please type in) (11) ____________________

Q23 In Colorado, farmers/ranchers periodically have to deal with reduced irrigation supplies due to drought conditions. We would like to learn your opinion about the reduced irrigation practices listed below even if you have not been faced with limited water supplies. Please check whether you would adopt the practices listed in the table below. If you would not adopt the practice, please check the reason(s) why.

	If facing reduced irrigation water, I would adopt this practice. (1)	This practice reduces profits per acre too much. (2)	I do not have the funds to implement this practice. (3)	I do not know how to implement this practice. (4)	My farm's soils are not suited for this practice. (5)	I lack the equipment to adopt this practice. (6)	Legal barriers prevent me from adopting this practice. (7)
Reduce irrigation (deficit irrigate) throughout the season (1)	❑	❑	❑	❑	❑	❑	❑
Irrigate fully early in the season, and reduce irrigation later in the season (2)	❑	❑	❑	❑	❑	❑	❑
Plant perennial forage crops that can better withstand	❑	❑	❑	❑	❑	❑	❑

reduced irrigation (3)							
Reduce water conveyance losses (e.g., lining ditches) (4)	❑	❑	❑	❑	❑	❑	❑
Upgrade the irrigation system (5)	❑	❑	❑	❑	❑	❑	❑
Measure applied water more accurately with a flow meter or other device (6)	❑	❑	❑	❑	❑	❑	❑
Schedule irrigation based on an evapotranspiration (ET) balance sheet or soil moisture monitoring (7)	❑	❑	❑	❑	❑	❑	❑
Fallow (non-irrigated) a portion of your irrigated land and fully irrigate the remainder (8)	❑	❑	❑	❑	❑	❑	❑

Q24 Farm managers might have altered their production practices prior to and during the cropping season due to the drought. Did you alter your cropping practices prior to OR during the cropping season?

- ❍ Yes (1)
- ❍ No (2)

Q25 How did you change your production practices in anticipation of the drought? (Check all that apply)

- ❑ Changed my crop mix to less water using crops. (1)
- ❑ Reduce my purchase of production inputs such as fertilizer and chemical. (2)
- ❑ Chose to fallow some acres that I would normally irrigate. (3)
- ❑ Chose to plant a dryland crop rather than an irrigated crop (4)
- ❑ Leased additional irrigation water (5)
- ❑ I did not change practices in anticipation of the drought. (6)
- ❑ I did not change my production practices in anticipation of the drought. (7)
- ❑ Other Changed Practice (8) ____________________

Q26 How did you change your cropping practices during the cropping season? (Check all that apply)

- ❑ I chose not to harvest some acres and did not graze these acres. (1)
- ❑ I harvested my crop for silage or hay rather than grain. (2)
- ❑ I grazed my crop rather than harvesting it for grain. (3)
- ❑ I devoted irrigation water to some of my acres and reduced water supplies to other acres. (4)
- ❑ I did not change cropping practices during the season. (5)
- ❑ Reduced my irrigation amount per application (6)
- ❑ Reduced number of irrigation's (7)
- ❑ Scheduled irrigation based in an evapotranspiration (ET) balance sheet (8)
- ❑ Scheduled irrigation based on soil moisture modeling (9)
- ❑ Leased my water to someone else (10)

Answer If Please indicate the source of your irrigation water in 20... Direct River Diversion Is Selected Or Please indicate the source of your irrigation water in 20... Reservoir Water Delivered Through Canal Is Selected Or Please indicate the source of your irrigation water in 20... Canal/Ditch Water from Direct River Diversion Is Selected

Q27 If you receive water from a canal or reservoir, how much of your TYPICAL diversion did you receive? Please slide the bar to indicate how much you received. By sliding the bar to the middle, you received the same amount as in a TYPICAL year.

______ Water received (1)

Answer If Please indicate the source of your irrigation water in 20... Groundwater Well Is Selected

Q28 During a drought, the energy costs of extracting groundwater can increase. Please use the slider below to indicate the degree to which your energy costs for irrigation were different than in a TYPICAL year.

______ 0 (1)

Q29 The 2012 drought may have caused a decrease in dryland crop yields compared to expected yields, and/or may cause fewer acres to be harvested. Please type in what you expected on average for dryland yields and acres in 2012 (no commas or labels are needed), and then what you actually experienced at harvest. Please estimate average yields including "0" yields for abandoned acres. If you do not grow the crop, please leave the boxes blank. If you purchased crop insurance for crops listed below, please indicate so by checking the appropriate box in the far right column. Also check the space in the last column if you received an indemnity payment or expect to receive a payment.

	Expected Yield (Numbers Only)	Actual Yield (Numbers Only)	Planted Acres (Numbers Only)	Harvested Acres (Numbers Only)	Did you buy an insurance product for this crop? Please check if so.	Did you (or will you) receive an indemnity for this crop? Please check if so.
	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)
Dryland Wheat (1)					❍	❍
Milo/Sorghum (2)					❍	❍
Millet (3)					❍	❍
Sunflower (4)					❍	❍
Dryland Corn (5)					❍	❍
Other Crop (6)					❍	❍

Q30 We would like to know a little more about how the drought might have changed the forage available to your sheep operation. Please indicate the TYPICAL amount of AUM's of forage that you use in your operation by the source, such as owned pasture. Next indicate the number of AUM's used in your operation in 2012.

	Please indicate the annual AUM's needed by your operation in a	Please indicate the forage resources that you USED in 2012.	Did the drought cause the difference? If so check the box below.

	TYPICAL year.		
	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)
Owned Pasture/Range (# of AUM's) (1)			❍
Private Lease (# of AUM's) (2)			❍
Federal Lease/Permit (# of AUM's) (3)			❍
State Lease Permit (# of AUM's) (4)			❍
Purchased Hay (# of Tons) (5)			❍
Hay Grown for Feed (# of Tons) (6)			❍

Q31 We would like to learn a little more about your Sheep operation. Please indicate the number of sheep and herd performance in a TYPICAL Year.

	My herd in a TYPICAL year ... (Please input numbers without labels or commas) (1)
Number of Sheep (1)	
Culling Percentage (2)	
Weaning Percentage (3)	
Average Weaning Weight (4)	
Average Sheep Cost per Year (5)	

Q32 Please rate your number of Sheep and herd performance for 2012

______ Number of sheep (1)
______ Sheep Condition at the Present (2)
______ Culling Percentage (3)
______ Weaning Percentage (4)
______ Average Weaning Weight (5)
______ Average Sheep Cost (6)

Q33 We would like to know a little more about how the drought might have changed the forage available to your cow-calf operation. Please indicate the TYPICAL amount of AUM's of forage that you use in your operation by the source, such as owned pasture. Next indicate the number of AUM's used in your operation in 2012.

	Please indicate the annual AUM's needed by your operation in a TYPICAL year.	Please indicate the forage resources that you USED in 2012.	Did the drought cause the difference? If so check the box below.

	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)
Owned Pasture/Range (# of AUM's) (1)			❍
Private Lease (# of AUM's) (2)			❍
Federal Lease/Permit (# of AUM's) (3)			❍
State Lease Permit (# of AUM's) (4)			❍
Purchased Hay (# of Tons) (5)			❍
Hay Grown for Feed (# of Tons) (6)			❍

Q34 We would like to learn a little more about your cow/calf operation. Please indicate the number of cows and herd performance in a TYPICAL Year.

	My herd in a TYPICAL year ... (Please input numbers without labels or commas) (1)
Number of Cows (1)	
Culling Percentage (2)	
Weaning Percentage (3)	
Average Weaning Weight (4)	
Average Cow Cost per Year (5)	

Q35 Please rate your number of cows and herd performance for 2012

_______ Number of Cows (1)
_______ Cow Condition at the Present (2)
_______ Culling Percentage (3)
_______ Weaning Percentage (4)
_______ Average Weaning Weight (5)
_______ Average Cow Cost (6)

Q36 When did you first make changes in your production practices because of the 2012 drought? Please check one.

- Before April 1st, 2012 (1)
- During April 2012 (2)
- During May 2012 (3)
- During June 2012 (4)
- During July 2012 (5)
- After August 1st, 2012 (6)
- The drought did not impact my operation (7)

Q37 If you had known that you would experience a drought earlier than your answer in the previous question, would you have made different production decisions than those you actually made?

- Yes (1)
- No (2)

Answer If If you had known that you would experience a drought earl... No Is Selected

Q38 Did you attend a CSU Extension drought workshop in 2011 or 2012?

- Yes (1)
- No (2)

Answer If If you had known that you would experience a drought earl... No Is Selected

Q39 Did you use CSU Extension information or tools when making decisions about how to respond to the drought?

- Yes (1)
- No (2)

Answer If If you had known that you would experience a drought earl... Yes Is Selected

Q40 What is the latest date an accurate drought forecast for Colorado would have been useful to you for making production decisions in 2012?

- Before March (1)
- March (2)
- April (3)
- May (4)
- June (5)
- July (6)
- August (7)
- September (8)
- October (9)
- November (10)
- Never (11)

Q41 Where do you get extended forecasts and seasonal climate outlooks (Check all you use)?

- ❑ USDA (1)
- ❑ The Weather Channel (2)
- ❑ Local TV station (3)
- ❑ Local radio station (4)
- ❑ University of Nebraska Lincoln (5)
- ❑ Colorado Climate Center at CSU (6)
- ❑ Print news media (7)

Q42 Which of the following types of information do you monitor (Check all that you use)?

- ❑ Snowpack (1)
- ❑ Reservoir level (2)
- ❑ Temperature (3)
- ❑ Accumulated precipitation for your area (4)
- ❑ Soil moisture (5)
- ❑ Ground water levels (6)
- ❑ Stream flow (7)
- ❑ Palmer Drought Index (8)
- ❑ Crop health (9)

Q45 How much did your farm or ranch REVENUES change in 2012 compared to a TYPICAL year?

______ Revenues (1)

Q46 How much did your farm or ranch PROFITS change in 2012 compared to a TYPICAL year?

______ Profits (1)

Q47 Some farms or ranches need to finance their assets with more debt following a drought. Could you please indicate the percentage of your assets financed by debt BEFORE and AFTER the drought?

______ Before the Drought (1)
______ After the Drought (2)

Q48 In direct response to the drought, what additional actions did you undertake in managing the financial aspects of your operation, and which options did your agricultural lender suggest? (Check all that apply)

	I took this action ...	I will take this action if drought continues ...
	Answer 1 (1)	Answer 1 (1)
Custom farmed for others (1)	❍	❍
Took off-farm employment (2)	❍	❍
Reduce family living expenses (3)	❍	❍
Pursue federal/state assistance (4)	❍	❍
Sold breeding livestock (5)	❍	❍
Sold equipment (6)	❍	❍
Sold land (7)	❍	❍
Paid interest only on loans (8)	❍	❍
Put up more collateral for loans (9)	❍	❍
Rolled the operating note into next year (10)	❍	❍

Q49 If drought conditions continue in 2013, how likely are you to leave farming/ranching in the next five years?

______ Certainty of Leaving (1)

Q50 If conditions return to normal in 2013, how likely are you to leave farming/ranching in the next five years?

______ Certainty of Leaving (1)

Q51 Regardless of the weather, are you planning on leaving/retiring from farming within the next five years?

❍ Yes (1)
❍ No (2)

Q52 When it comes to your farm or ranch operation, you are the

- Owner/Operator (1)
- Manager (2)
- Absentee owner (3)
- Employee (4)
- Other (5)

Q53 How many years of farming or ranching experience do you have?

______ Years of Experience (1)

Q54 How long have you been farming or ranching in Colorado?

______ Years Farming or Ranching in Colorado (1)

Q55 Were you aware that state and federal assistance for drought was available?

- Yes (1)
- No (2)

Answer If Were you aware that state and federal assistance for drou... Yes Is Selected

Q56 Did you receive state or federal drought assistance in 2011 or 2012?

- Yes (1)
- No (2)

Q57 How many people are there in your household?

	# in Household
	Answer 1 (1)
Number of people OVER age 18 (1)	
Number of people UNDER age 18 (2)	

Q58 Check your form of business organization.

- Sole Proprietorship (1)
- Partnership (2)
- Limited Liability Corporation (3)
- Limited Liability Partnership (4)
- Corporation (5)

Q59 Check your highest level of education.

- ❍ High School (1)
- ❍ Bachelors degree (2)
- ❍ Some college (3)
- ❍ Graduate or Professional degree (4)
- ❍ Technical/Vocational Degree (5)

Q60 Please use the slider to indicate your operation's gross revenues in a TYPICAL year.

______ Gross Revenues (1)

Q61 In a typical year, what percentage of your household net income comes from farming/ranching?

______ Percent of Income from Farming (1)

Q62 Thank you for taking the time to complete the Colorado State University Department of Agriculture's and the Colorado Water Conservation Board's 2012 Drought Survey! Look for a summary of the results on the Department of Agriculture and Resource Economics website at http://dare.colostate.edu/index.aspx in the Spring of 2013. Your responses will be kept confidential and are completely anonymous.

Q63 If you have any additional comments or suggestions we would like to hear from you in the box below.

APPENDIX C: DROUGHT INDICES, MONITORS, AND PLANNING

Colorado has a long history of disruptive droughts. In fact, 93% of the time at least 5% of Colorado is experiencing some level of drought (McKee, Doesken, Kleist, & Shrier, 2000). However, the level of disruption caused by a drought and the impact subsequently felt by agricultural producers depends on many variables, such as the duration, intensity, and scale of the drought, that combine to define the type of drought (Figure 3). For this reason, researchers and policy makers have developed tools that help measure environmental and socioeconomic impacts related to drought. Drought indices are used to measure variables that are related to the intensity and duration of drought such as soil moisture and precipitation. Economic impact analysis is used to quantify the socioeconomic effects that drought has on regional economies and specific economic sectors. By defining, categorizing, and economically quantifying the impacts of droughts, it is possible to begin to assess how one drought compares to another. Comparing different droughts using these classification and economic impacts is difficult because droughts and economic activity take place within dynamic political and ecological systems. However, comparisons are necessary because it allows policy makers and the stakeholders impacted by drought to see if they are becoming more or less resilient over time. This subsection will discuss drought types and indices, and how they are used by policy makers to plan for, respond to, and mitigate drought.

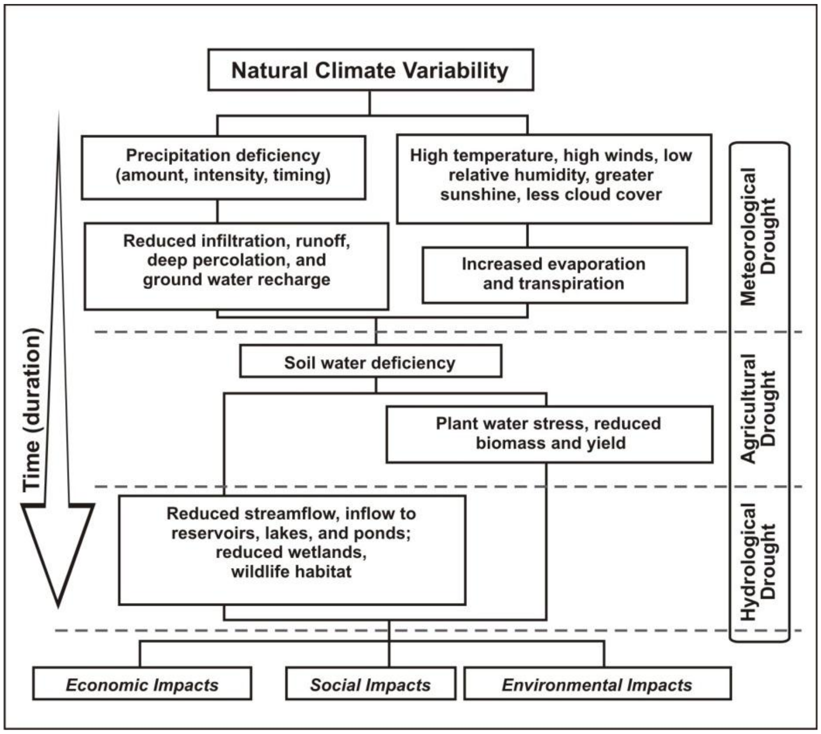

FIGURE 8. National Drought Mitigation Center's drought categories. Source: NDMC, 2013

Drought indices can be used individually or aggregately to define and categorize drought. The Palmer Drought Severity Index (PDSI) is one of the most widely used and known meteorological drought indices in the world (Wilhite & Glantz, 1985). The PDSI categorizes the severity of droughts by standardizing and comparing temperature and precipitation data as well as information on the available water supply within the soil (NDMC, 2013). Wilhite and Glantz (1985) used the PDSI along with other indices, such as the Water Supply Index and the Crop Moisture Index, to define drought into four distinct types; 1) meteorological drought is a measure of the dryness and duration of a period, 2) agricultural drought indicates insufficient moisture to meet short-term crop requirements, 3) hydrological drought indicates that surface and subsurface hydrology has been compromised, and lastly 4) socioeconomic drought indicates that the drought has caused a decrease in the supply or demand of an economic good. Drought categories are used as proxies to estimate how severely the resiliencies of the different ecological and human systems are being comprised. The different types of drought are indicators that the resiliencies of different systems are being impacted. For example, meteorological drought indicates that the ecological resiliency of native plants and animals is being compromised by lower moisture levels. Similar comments can be made for each type of drought. This is important because it indicates that different types of drought may only impact certain systems, while leaving other systems relatively unaffected. The different types of droughts do not have to happen individually. In fact, meteorological drought is the only drought type that commonly occurs on its own because it often the first type of drought to be designated and therefore is often the least severe in the early stages of drought (Wilhite and Glantz, 1985). Defining and categorizing droughts helps policy makers to identify the systems at risk and estimate the severity of their decreased resiliency. By identifying and estimating the loss in resiliency, decision makers are better able to plan for, respond to, and mitigate the impacts of drought.

State and the federal governments use drought indices to construct drought mitigation and response plans. These plans determine which farmers and ranchers have had their resiliency compromised to the point when financial assistance is required. The federal government relies on the US Drought Monitor to aid in much of its decision making. The US Drought Monitor incorporates information from five separate drought indices to create a nationwide drought indicator map that includes categorizes of drought from mild, moderate, severe, extreme, and exceptional drought (Table 1) (NDMC, Drought Monitor: State-of-the-Art Blend of Science and Subjectivity, 2013). The US Drought Monitor helps determine how and when federal aid is distributed for drought events (FSA, 2012). For example, after a county has been in the severe category of drought for eight consecutive weeks or extreme drought for any period within the growing season it is declared a disaster area (FSA, 2012). After a county has been designated a disaster area, producer are eligible for emergency loans (FSA, 2012). Colorado's Drought and Mitigation Response Plan (DMRP) incorporates information from the Standardized Precipitation Index (SPI), Surface Water Supply Index, and the Colorado Modified Palmer Drought Severity Index (CMPDSI) (CWCB, 2010). The Colorado's DMRP helps determine whether or not those impacted by drought receive state aid and when. For example, the state also provides emergency loans and some grants to agricultural producers for drought purposes (CWCB, 2011). The reason for creating the different indices, monitors, and plans is to be able to effectively provide assistance to and increase the resilience of business sectors that suffer from drought.

TABLE 3. Drought severity classification

Category	Description	Ranges: Possible Impacts	Palmer Drought Index	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short and Long-term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	3-5	-1.6 to -1.9	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0-2	0-2	-2.0 or less	0-2

Source: US Drought Monitor, 2008.