Estimating the Short and Long-term Economic & Social Impacts of the 2012 Drought in Colorado[1]

James Pritchett, Chris Goemans and Ron Nelson[2]

Abstract: Colorado's ongoing drought is significant in its geographic reach and economic impacts. For farms and ranches, the drought shrinks yields and total crop production, deteriorates pasture condition, reduces cow condition and leads to difficulty in locating critical feed inputs. These production losses generally reduce revenues although declining receipts may be partially offset by higher prices.

Yet, the drought's impacts to the farm or ranch business are not contained within a single season. Much like reservoir levels that are drawn down and may take years to replenish, the impact of a drought can reduce a farm or ranch's equity position making it difficult to service debt or take advantage of future investment opportunities. Equity erosion may take years to rebuild.

In this report, the impacts of the ongoing drought, and the longer term impact to farm and ranch resiliency are characterized. The report includes a description of Colorado agriculture, its history of drought, and responses to a recent drought survey. The survey responses are described in order to characterize the potential longer term impacts of drought, and statistical analysis suggests that the operation's relative debt load is the most important factor in predicting a farm's likelihood of exiting the industry. Further emphasis is placed on production losses due to drought and producers' mitigating actions. While it is difficult to forecast the length of the recovery period for Colorado farmers and ranchers, their adaptations and changing production activities in 2012 do indicate the severity and persistence of financial stress.

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Introduction and Purpose

Drought continues in Colorado causing significant economic losses, widespread crop failures, damaged rangelands, drastically reduced crop yields and diminished livestock productivity. The financial impacts of drought will be felt by agricultural producers for many years to come and may threaten the long-term economic viability of some agricultural operations.

Colorado farms and ranches are an important base industry statewide, but especially in rural areas. Agricultural producers' buying and selling activities also link the drought's production impacts to the rest of Colorado's economy (Gunter, Goemans, Pritchett, & Thilmany, 2012). Impacts are significant enough that federal and state agencies are declaring disaster emergencies and offering millions of dollars in emergency drought relief (USDA, 2013). The purpose of these funds is to improve farm and ranch viability while mitigating negative economic impacts to the general economy.

Intense drought is likely to become more frequent for Coloradoans. Climate models suggest an increased probability of extreme and recurring droughts (Schar, et al., 2004) . Drought response is a growing policy concern as stakeholders seek strategies for mitigating the immediate impacts of drought, as well as improving the resiliency of rural communities, farmers and ranchers in Colorado. Successful drought mitigation and adaptation strategies may be developed if resiliency is better understood.

This document's purpose is to take an initial step in describing farm and ranch resiliency as it relates to drought. Recent trends in Colorado agriculture are described, and the morphology of recent drought events reviewed. The results of a Colorado farmer and rancher drought survey are reported providing insight into the short term economic impacts of the 2012 drought event. These results also suggest key connections between drought and long term farm and ranch resiliency.

An Overview of Colorado Agriculture

Agriculture and drought have an interrelated history in Colorado, and understanding this history is the context under which resiliency is better understood. This section describes the recent history and current status of production agriculture in Colorado. It also introduces drought in a technical sense and briefly summarizes the interrelated history of drought and agriculture in Colorado.

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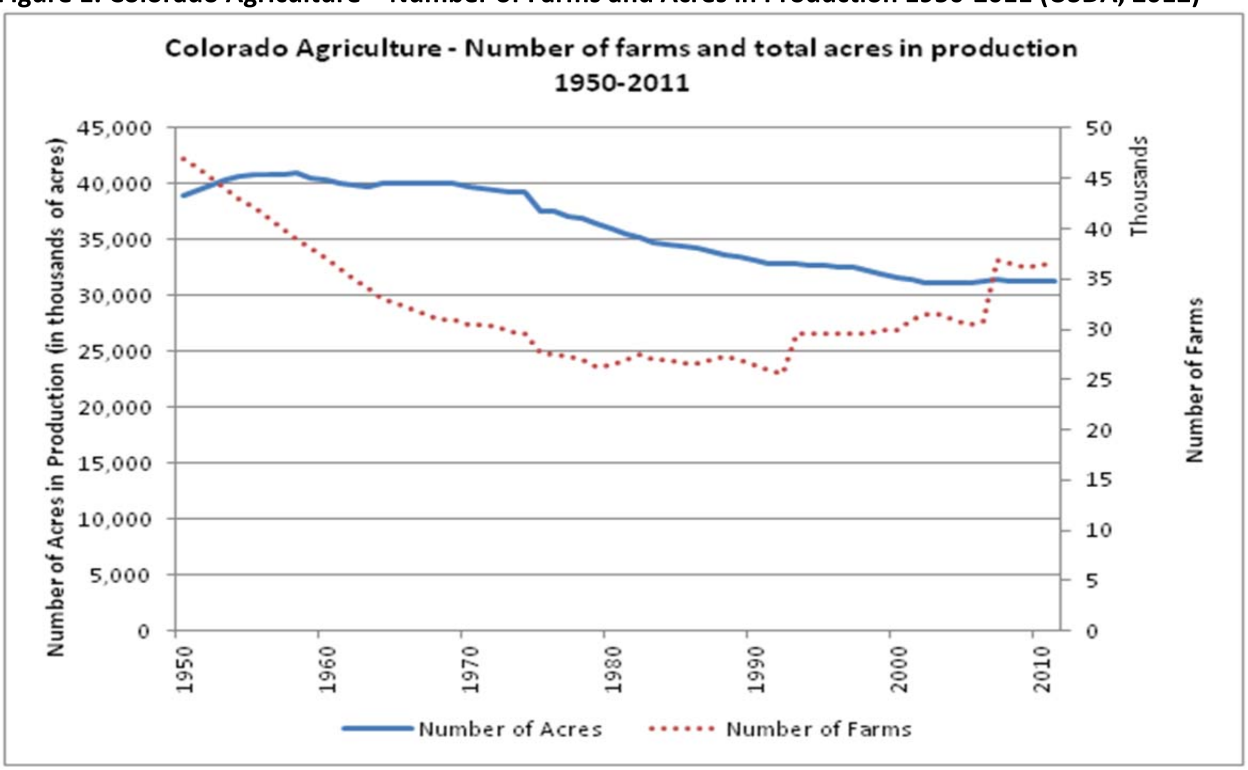
Colorado's recent agricultural trends mirror the evolution of US agriculture. Technological innovation and its adoption following World War II dramatically increased Colorado farm and ranch productivity. Adopted technologies favored capital investment rather than relying more heavily on labor. A byproduct of adoption is a release of labor from farms and ranches to urban environments. Farms and ranches that use more equipment and less labor are linked differently to the local economy than in the past. Currently, farms and ranches generate an increased amount of economic activity with purchasers of equipment and supplies rather than by spending farm labor income. As a result, the impacts of drought may fall disproportionately on input suppliers in the current day when compared to previous years.

Farm and ranch production is heavily weighted toward commodities (e.g., No. 2 yellow corn) rather than branded agricultural products (e.g., Certified Angus Beef). A competitive advantage in a commodity industry is created by investing in technology and services that reduce costs. The adoption of technology and subsequent efficiency gains also mean that fewer, larger farms are needed to produce market clearing agricultural output. Evidence of this is seen in a large reduction in farm numbers, while the number of farm and ranch acres has slowly trended downward to a recent plateau (Figure 1). Since the early 1990's, farm numbers are increasing driven by very small farms whose owner/operators have significant non-farm income. From 2005 through 2010, the decrease in total farm numbers has mainly been due to a loss in mid-sized farms[4] . The decline in mid-sized farms has spurred concern over the viability of rural communities due to the out-migration of rural residences (Hoppe, 2010).

Figure 1. Colorado Agriculture – Number of Farms and Acres in Production 1950-2011 (USDA, 2012)

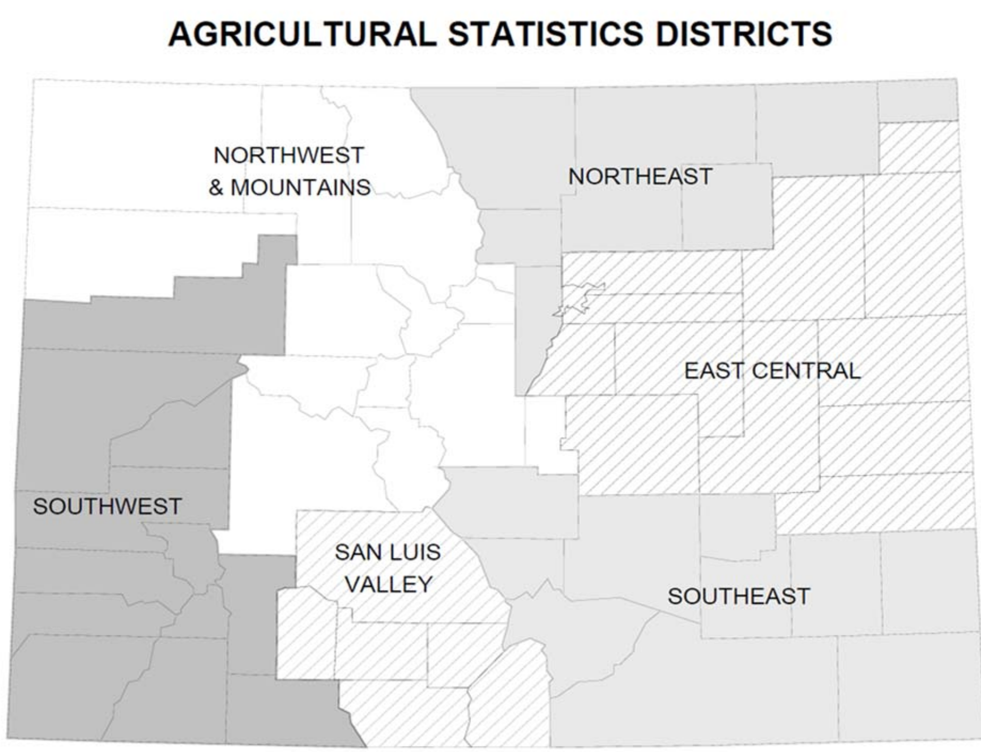


[4] Large farms are consider those that gross over $500,000 and small farms are considered to be those that gross under $10,000 (USDA, 2011).

Colorado's crop mix is being altered by changing consumer preferences and the relative cost effectiveness of producing some crops relative to others. Production of particular crops tends to be regionalized. 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 2). 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 season long precipitation. Dryland crops and irrigated cropping is present on the eastern side, with irrigation water supplies coming from surface diversion, reservoir storage or groundwater from the aquifers (NASS, 2013). The western portion of Colorado has a few areas of intensive production, but for the most part farm production is less intensive. 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.

Regional differences in crop production imply differential links to the local economy. As an example, high value crops grown in the San Luis Valley generate significant receipts locally through the purchase of costly inputs and a relatively high use of labor. These products are most often sold outside the region increasing the flow of outside income to the local community. As a result, the economic activity generated by an irrigated acre of land in the San Luis Valley can easily double that produced in areas with lower value crops that are used locally, such as in the Southeast agricultural reporting district (Thorvaldson and Pritchett, 2006).

Figure 2 NASS Agricultural Statistics Districts (NASS, 2012)



Sub-regions occasionally specialize in commodity production. The eastern portion of Colorado produces large amounts of corn for grain, winter wheat, alfalfa, and livestock in the form of cow-calf ranching (NASS, 2013). The Northeast (NE) region has the largest number of cow-calf operations, and has substantial acreage dedicated to irrigated sugar beets and non-irrigated 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 sugar 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 and malting barley production. The western portion of Colorado specializes in cattle and forages, as well as regionally branded fruits (e.g., Palisade peaches) and vegetables (e.g., Olathe sweet corn). The differences in regional production are due to the different growing conditions that exist throughout Colorado – different climates and drought frequencies, soils, and elevations.

An Historical Overview of 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 use analytical tools that help measure environmental and socioeconomic impacts related to drought. These tools include drought indices[5] and economic impact 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 measure variables 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 compare climate events. Comparisons are useful for policymakers and stakeholders to assess if drought mitigation practices are increasing resiliency. Comparisons also provide context so that advocates can assess the type, duration and intensity of drought response.

A brief description of Colorado's drought history gives some sense of the resiliency of agricultural producers, and comparing the current drought to past history reveals factors impacting resiliency.

The Dust Bowl (1931-1941) was one of the most disastrous droughts in Colorado and U.S. (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 erosion forcing 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 with some counties recording 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 (2013 dollars) (Riebsame, 1991). The extreme economic and ecological impacts suggest early 20th century farmers' production practices and businesses models lacked drought resiliency. Lack of resiliency appears to be created by poor farm management and financial practices, but perhaps also due to government inexperience in responding to widespread drought.

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

After the Dust Bowl, the US government encouraged erosion control and soil conservation with legislation including the 1936 Soil Conservation and Domestic Allotment Act and the 1938 Agricultural Adjustment Act (Hornbeck, 2012). These bills provided incentives that retired highly erodible farmland, restored rangelands, and educated agriculturalists about alternative tilling practices (Baumhardt, 2003). In essence, the legislative goals were to enhance biological and economic resiliency in agriculture.

Colorado farm resiliency was next tested by the 1951-1957 drought. While the 1950's drought was less intense compared to the Dust Bowl, it was 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 agriculture (NOAA, 2003). However, the economic and ecological impacts were much less severe than the Dust Bowl. Specifically, there were fewer exits from the agricultural sector and agricultural land prices were not as greatly impacted[6] (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).

The timing and location of the 1974-1978 and 1981 droughts meant the tourism industry bore the brunt of economic losses (McKee, Doesken, Kleist, & Shrier, 2000). Colorado's state government began drought planning because of the magnitude these losses. In 1981, Colorado passed its first drought related legislation when creating the Colorado Drought Response Plan (currently the Colorado Drought Mitigation and Response Plan) and formed the Water Availability Task Force. These important legislative actions gave the state power to act on drought related hazards, which had previously been initiated and managed at the federal level.

The 1988-89 drought is 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). This drought left Colorado largely unaffected except for the southeastern corner of the state. However, Colorado farmers were not bereft of impacts -- the 1988-89 drought is notable because its national geographic scope made commodities scarce resulting in higher prices benefitting Colorado farmers (Whittaker, 1990). In fact, the drought may have improved the financial standing of many commodity crop farmers in the US because revenue gains from increased prices more than offset losses from decreased yields. 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 wide ranging drought might impact national prices and have differential impacts among agriculturalists. Sellers of scarce commodities benefit from higher prices at the same time that commodity purchasers, such as feedlots, face price shocks.

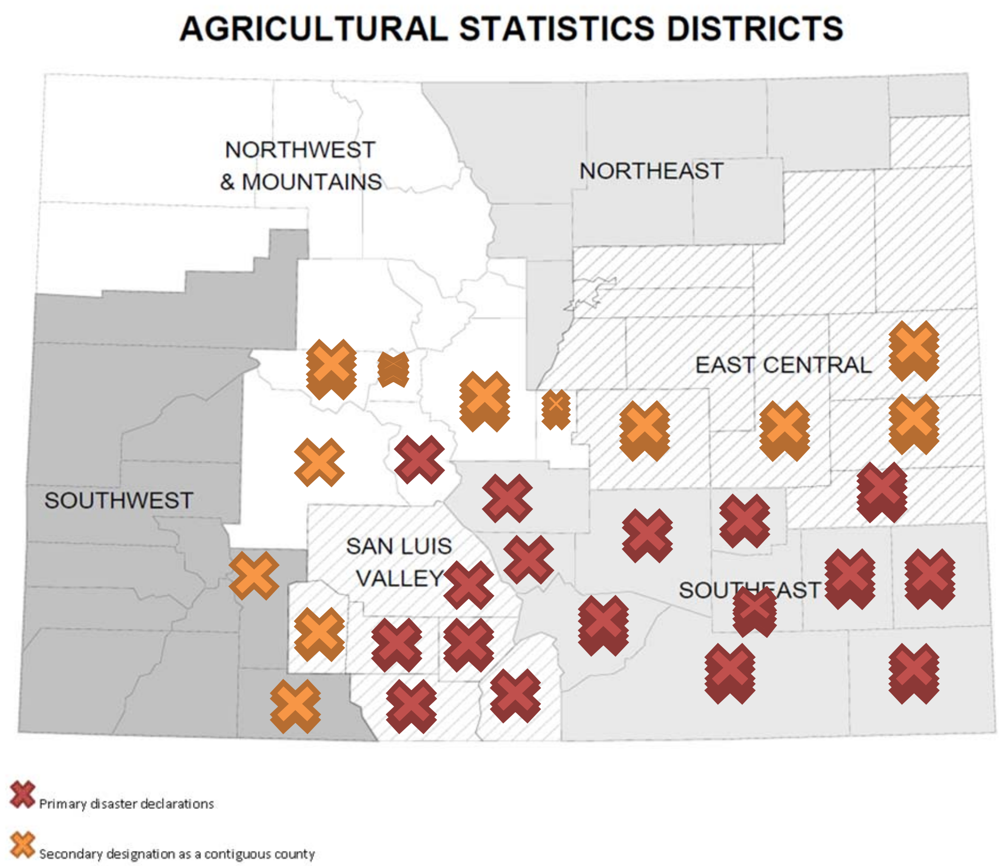
The 2002 drought was one of the most severe droughts in Colorado history when measured by water availability. Low mountain snow accumulation caused critical water shortages for agricultural producers, municipalities and the industrial sector (Pielke, et al., 2005). Precipitation shortages led to a 60% decrease in winter wheat production and 14% decline in the total number of livestock in Colorado (Schuck, Frasier, Webb, Ellingson, & Umberger, 2005). Yet, the scope of the 2002 drought was not sufficiently large to increase national prices for commodities. With small price changes, damages were more localized to the agricultural sector in Colorado (Pielke, et al., 2005).

The total economic impact of the 2011-2013 drought will not be fully known until it ends. However, studies (e.g. Gunter et al., 2012; WWA and NIDIS, 2012; NOAA, 2013) assess the initial economic impacts, make meteorological comparisons, and describe qualitative impacts provide insights. More specifically, the drought first began in Fall 2010 with primary disaster designations made in 2011 for 17 counties of Colorado (Figure 3). Estimates for the Southeastern agriculture statistics reporting district suggest decreased economic activity by $105 million and a job equivalent loss of more than over 1,000 full time labor equivalents. Economic activity actually increased by $5 million in San Luis Valley

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

(Gunter, Goemans, Pritchett, & Thilmany, 2012) in spite of the drought. Differential impacts occur because of a greater availability of irrigation water in the San Luis Valley (SLV), less dryland production and higher prices for primarily SLV grown potatoes (Gunter, Goemans, Pritchett, & Thilmany, 2012).

Figure 3. Primary and Secondary Disaster Designations by NASS Districts in 2011



By the summer of 2012, the drought extended northward resulting in 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 increased nationally so that 80% of the contiguous US experienced some level of drought during August 2012 according to the US Drought Monitor (Folger, Cody, & Carter, 2013). National corn yields decreased by 26% and soybeans yields fell by 10% (Henderson & Kauffman, 2013). Thousands of commodity crop acres were not planted or were abandoned prior to harvest. A similar curtailment in corn production had 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. Commodity price increases along with the fact that 70% of the pastures in the US were designated as poor to very poor decreasing the return on cow-calf pairs by $100 per head in spite of strong calf and feeder cattle prices. Net effects 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).

Economic Impact of the 2012 Drought

Overall Economic Impacts: Table 1 summarizes an estimate of crop revenues in 2012. The values are calculated from data reported by the US Department of Agriculture, National Agriculture Statistics Service (NASS) including estimates of planted acre harvested acres, yields and marketing year prices.

Table 1. 2012 and Average Revenues for Selected Colorado Crops

	2012 Revenues	2000 - 2010 Average Revenue	What Might Have Been Revenues[a]	Difference Between 2012 Revenues and What Might Have Been
Crops				
Barley	$45,663,750	$29,513,530	$46,967,828	-$1,304,078
Corn Grain	$947,026,500	$514,752,255	$1,201,519,061	-$254,492,561
Corn Silage	$166,400,000	$62,668,182	$183,040,000	-$16,640,000
Dry Beans	$32,457,600	$26,968,564	$30,009,411	$2,448,189
Hay (alfalfa & other)	$885,198,000	$473,898,618	$960,408,099	-$75,210,099
Millet	$22,848,000	$20,393,591	$63,542,169	-$40,694,169
Potatoes	$150,678,450	$188,995,952	$145,700,620	$4,977,830
Sorghum	$20,328,000	$14,940,581	$34,285,537	-$13,957,537
Sunflower	$18,313,120	$22,091,421	$28,005,838	-$9,692,718
Wheat	$602,482,930	$301,562,112	$606,979,514	-$4,496,584
Total	$2,891,396,350	$1,655,784,805	$3,300,458,076	-$409,061,726

[a] What Might Have Been Revenues are 2012 prices multiplied by historical average yields multiplied by 2012 planted acres multiplied by the historical ratio of harvested acres to planted acres.

While not an exhaustive list, the crops listed in the first column of Table 1 represent more than ninety percent of crop production in the state and includes both irrigated and non-irrigated cropping. The second column represents an estimate of revenues in which the 2012 marketing year price is multiplied by the 2012 statewide average yield and 2012 harvested acres. Corn grain production represents the greatest revenue generator ($947 million) followed by hay production ($885 million) and wheat production ($602 million). Total crop sales are approximately $2.9 billion.
In spite of the drought, total revenues are significantly higher than the ten year average of 2000 through 2010 that is reported at the bottom of the third column as $1.65 billion. The difference between 2012 revenues and the average amounts are very strong commodity prices in 2012. Persistently high prices were also observed in 2011.

Higher prices mitigate some drought impacts, but farmers experiencing yield losses and/or abandoning planted acres did miss an opportunity to sell some of their crop at higher prices. The fourth column is an estimate of this “foregone” potential – values represent the 2012 marketing year price multiplied by average yields (year 2000 to 2010) multiplied by planted acres for 2012 multiplied by the historical average ratio of harvested to planted acres. More simply, if farmers had an average year in producing crops, but sold at 2012 prices, they would have received $3.3 billion, or about $409 million more than was actually received.

The $409 million of foregone revenues may also be spent on crop inputs or as labor income, both of which might have contributed to other economic activity in the local community. This indirect and induced economic activity is based on an economic concept called a "multiplier." In this context, a multiplier is the total reduction in economic activity divided by the amount of foregone revenues. In sum, the $409 million of foregone revenues (second column of Table 2) resulted in more than $726 million in foregone economic activity (last column of Table 2).

Table 2. Economic Activity Lost as a Result of Foregone Revenues

Crop	Difference Between 2012 Revenues and What Might Have Been	Foregone Indirect and Induced Economic Activity	Sum of Foregone Revenues, Indirect and Induced Economic Activity
Barley (bu/ac)	$1,304,078	$988,322	$2,292,400
Corn Grain (bu/ac)	$254,492,561	$192,872,377	$447,364,938
Corn Silage (tons/ac)	$16,640,000	$12,610,963	$29,250,963
Dry Beans (lbs/ac)	-$2,448,189	-$1,855,410	-$4,303,598
Hay (tons/ac)	$75,210,099	$66,040,493	$141,250,592
Millet (bu/ac)	$40,694,169	$30,840,906	$71,535,074
Potatoes (cwt/ac)	-$4,977,830	-$3,801,866	-$8,779,697
Sorghum (bu/ac)	$13,957,537	$10,578,004	$24,535,541
Sunflower (lbs/ac)	$9,692,718	$5,483,312	$15,176,030
Wheat (bu/ac)	$4,496,584	$3,407,828	$7,904,411
Total	**$409,061,726**	**$317,164,929**	**$726,226,655**

Planted acres are abandoned when the revenues from the crop are smaller than harvest costs. Abandoned acres are one explanation for the $409 million of foregone revenues, but not for every crop. When examining Table 3, large proportions of traditionally non-irrigated crops were not harvested: sunflower, millet and sorghum. The exception is wheat, most of which is grown as a non-irrigated crop in Colorado. Note that sunflower, millet and sorghum are crops sown in the Spring and harvested in the Fall, whereas wheat is planted in the previous September/October and harvested in the July. The full impact of the drought was not realized statewide until mid to late summer 2012 ***after*** wheat had been harvested. Thus wheat would not be as affected by the 2012 drought when compared other crops.

Table 3. Comparison of Planted vs. Harvested Acres for Selected Crops

	2012		2000 - 2010 Average	
Crops	Planted Acres	Harvested Acres	Planted Acres	Harvested Acres
Barley	58,000	55,000	76,818	72,091
Corn Grain	1,420,000	1,010,000	1,184,545	995,455
Corn Silage	N/A[a]	160,000	N/A[a]	108,182
Dry Beans	50,000	45,000	76,636	68,545
Hay	N/A[b]	1,460,000	N/A[b]	1,529,091
Millet	210,000	120,000	261,818	226,818
Potatoes	60,500	59,900	68,173	67,700
Sorghum	245,000	150,000	251,818	155,455
Sunflower	86,000	70,000	151,000	132,727
Wheat	2,363,000	2,182,000	2,438,455	2,122,909

[a]Corn silage acres are reported as "Corn" for planting, but separated into "grain" and "silage" categories at harvest.

[b] Hay is alfalfa and other, but are only reported as harvested acres by USDA-NASS.

Declining yields might also account for foregone revenues, though these could be partially offset by higher prices. Table 4 compares averages yields (irrigated and non-irrigated) for selected Colorado crops. Table 5 illustrates the prices received for these crops relative to their historical averages.

Table 4. Selected Colorado Crop Yields in 2012 and on Average (2000 – 2010)

Crops	2012 Yield	Average Yield (2000 - 2012)
Barley (bu/ac)	123	119
Corn Grain (bu/ac)	133	143
Corn Silage (tons/ac)	20	22
Dry Beans (lbs/ac)	1,840	1,712
Hay (tons/ac)	2.6	2.7
Millet (bu/ac)	14	26
Potatoes (cwt/ac)	387	373
Sorghum (bu/ac)	20	33
Sunflower (lbs/ac)	788	1,116
Wheat (bu/ac)	34	32

Table 5. Marketing Year Price Received for Selected Crops

	2012 Price Received	Average Price Received (2010-2010)
Crops		
Barley ($/bu)	$6.75	$3.45
Corn Grain ($/bu)	$7.05	$3.04
Corn Silage ($/ton)	$52.00	$26.41
Dry Beans ($/cwt)	$39.20	$24.39
Hay ($/ton)	$235.00	$114.95
Millet ($/bu)	$13.60	$3.81
Potatoes ($/cwt)	$6.50	$7.73
Sorghum ($/bu)	$6.78	$2.74
Sunflower ($/lb)	$0.33	$0.15
Wheat ($/bu)	$8.05	$4.21

Notable reduction in yields is observed for sunflowers, sorghum, millet and corn for grain. Tremendously improved prices can be observed for all crops except potatoes. While the high prices offset revenue losses for farmers, they represent a severe price shock for the buyers of these inputs such as cow-calf producers, feedlots and millers.

The 2012 drought is with few precedents in its intensity and geographic reach. Drought impacts include sharply reduced yields and substantial abandoned acres. Losses were mitigated by historically high prices. These prices are the direct result of short supplies because the drought's reach extended to much f the United States. As a result, the revenues generated by Colorado crop production were well above the historical average of years 2000 through 2010. However, these revenues also represent a missed opportunity – Colorado farmers would have benefitted tremendously if production had been closer to the average. Indeed, foregone revenues total $409 million that would have generated more than $317 million of additional spending in local communities.

The previous analysis is one narrative describing the drought – it represents single year estimated impacts. However, the drought's impacts may multiple year effects eroding farm and ranch owner equity in their business. Equity erosion and sale of capital assets may lead to reduced future profitability and difficulty servicing debt. As a result, a survey of Colorado farm and ranch operations was conducted to gain an understanding of agriculture resiliency.

Although the2011-2013 drought is among the most intense, high commodity prices caused by the large spatial range of the drought may offset the impact of the drought for some producers. For other producers, increased prices represent a significant cost shock that may lead to increased debt burden and inability to service debt. To better understand the differential effects of the drought and the impact to agricultural resiliency, a survey of agricultural operations is performed.

Internet Survey of Colorado Farmers and Ranchers

Drought disrupts rural economies as farmers and ranchers adopt mitigating strategies to cope with precipitation and water shortages. Agricultural producers absorb the direct economic impacts of a drought by reducing production and bearing 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 and instead substitute more expense feed from outside of the region. Ranchers may reduce the herd size by culling cows more aggressively. All told, less calf revenue is available with which to purchase other production inputs like fuel, services, equipment and supplies. The ranch manager's actions strain allied firms who do business with agricultural producers.

In Fall 2010, southern Colorado began to experience drought conditions, which spread to engulf the entire state by the summer of 2012. The impacts are significant but distributed unevenly, so much so that stakeholders and policymakers seek more detailed information so they can target assistance. In addition, a more concrete understanding of impacts will influence policies meant to improve agricultural and rural economic resiliency in the face of drought.

To this end, the Colorado Water Conservation Board, Colorado Department of Agriculture and Colorado State University initiated a collaborative survey effort. The survey's goal was to describe and quantify the impacts of the 2012 drought to Colorado. Objectives include describing how farm and ranch managers changed their business practices in the face of a persistent drought, the direct impacts of the drought in terms of production losses, and the reduced resiliency of agricultural operations. The following section describes the survey scope, questionnaire type, sampling strategy, development, and distribution. It is followed by a summary of responses to the survey questionnaire.

Survey Scope, Type, and Sampling Strategy

The survey's scope included all Colorado agricultural operations. An internet based questionnaire was designed to fulfill survey objectives, and the internet location of the questionnaire was advertised to agricultural operations via stakeholders that include commodity organizations, farm advocacy groups and CSU Extension. All types and sizes of producers had the opportunity to participate in the survey.

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 to completion, 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.

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 county location, operation characteristics such as size, input buying and marketing behavior, crop and livestock production type(s), the impact of the drought on farm finances, available water resources, use of drought/climate information and personal demographics.

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 previously 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. The questionnaire was available from November 2012 to February 2013, and 550 responses were collected.

Of the 550 individuals that opened the survey, 530 chose to begin the survey and 276 answered the last question the survey. Not every participant responded to each question, rather internal logic within the questionnaire routed respondents to appropriate questions. As an example, a subset of respondents indicated that they grew irrigated crops, and these respondents were asked to provide information about irrigated crop production. Those that did not agree that they grew irrigated crops did not answer these questions.

Demographics

Respondents to the questionnaire represent a diverse cross-section of Colorado agriculture. Respondents are primarily comprised of adult households with no children. Respondents are experienced managers with an average of more than 31 years of experience in farming or ranching. Nearly half report 75% to 100% of their household income comes from farming, with a smaller portion (25%) reporting that one-quarter or less of their household income is derived from agricultural operations. Gross revenues from farming are of three general categories: those with less than $50,000 in receipts (43%), between $50,001 and $150,000 of receipts (28%) and those with more than $500,000 in receipts (13%). Nearly one-half of respondents organize their business as a sole proprietorship followed by limited liability corporations (24%) and corporations (12%). Almost all (91%) reported serving as the owner and operator of their business.

Drought Assistance and Information

Drought assistance at the state and federal level are relatively well known by these respondents – 2/3 indicate knowledge of the programs. Interesting only 15% of respondents received state and federal assistance. An interesting question is why so few respondents too advantage of the assistance.

Many sources of information are available when planning for drought or responding to the impacts of drought. In order to better understand how farmers and ranchers view these resources, they are asked to indicate sources on which they rely. Table 6 summarizes the responses.

Table 6. **Responses to Information Source of Drought Forecasts**

Question: Where do you get extended forecasts and seasonal climate outlooks? (Check all that apply)		
Information Source	# of Checked Responses	Percent of all Checked Responses
USDA	104	17%
The Weather Channel	141	23%
Local TV	136	22%
Local Radio	73	12%
University of Nebraska, Lincoln	9	1%
Colorado Climate Center (CSU)	62	10%
Print News	88	14%

The first column of Table 6 lists the information sources, while the second column lists the number of times an information source was checked. The last column details the percentage of total checked responses that an information source makes (e.g., USDA receives 17% of all the checked responses). The Weather Channel and local television broadcasts comprise close to ½ of all checked responses followed by USDA and print news.

The agriculture producers responding to this survey monitor several drought specific measures when planning and adapting to conditions including those listed in Table 3.

Table 7. Drought Indicator Information Monitored

Question: Which of the following types of information do you monitor? (Check all that apply)		
	# of Checked Responses	Percent of Checked Responses
Snowpack	215	16%
Reservoir Level	147	11%
Temperature	178	14%
Accumulated Precipitation	199	15%
Soil Moisture	166	13%
Groundwater Level	72	5%
Streamflow	112	9%
Palmer Drought Index	71	5%
Crop health	155	12%

Indicators receiving the least amount of checked responses are for groundwater levels, streamflow levels and the Palmer drought index. Respondents keep their collective eyes on snowpack levels, reservoir levels, accumulated precipitation, soil moisture and crop health.

Producers seek accurate forecast of potential drought, but the optimal time at which the forecast is released may differ according to the type of operation (livestock vs crop, winter wheat versus spring crop). Respondents selected the date category in which a drought forecast would be the most useful, and this summarized in Table 8.

Table 8. Respondents Preference for the Release of an Accurate Drought Forecast

Question: What is the latest date an accurate drought forecast would be useful? (Check one category)	
Latest Date of Forecast	Percentage of Responses
Before March	33%
March	22%
April	26%
May	13%
June	1%
July	2%
August	1%
September	0%
October	1%
November	0%
Never	1%

In Table 8, it is clear that most forecasts are useful if they are released prior to planting for spring crops (i.e., May) and cow-calf producers still have opportunities to find additional pasture or hay stocks for summer grazing. More than ½ of respondents would like to see an accurate forecast prior to April 1st.

The information in Table 8 can be juxtaposed against when respondents first began to respond to the drought. As mentioned in the previous discussion, the 2012 drought began and intensified from late Spring 2012 and into the summer of 2012 for three-quarters of Colorado's land mass. The lat onset meant little planning time was available for many farmers and ranchers. In contrast, drought continued for producers in the southeastern part of Colorado, and this is why some may have responded early to the drought. The timing of production response is categorized in Table 9.

Table 9. Respondents' Timing of Changing Production Practices Because of Drought

Question: When did you first make changes in your production practices because of the 2012 drought?	
Timing	Percent of Respondents
Before April 1	28%
During April	10%
During May	18%
During June	18%
During July	12%
After August 1	7%

Interestingly, 55% of respondents indicate they would act earlier to drought conditions had they been notified of its onset earlier.

Location and Regional Drought Impacts

Respondents were asked to provide the zip code in which they performed most of their operation's production practices. This zip code was then mapped into the appropriate agricultural statistics reporting districts as indicated by Figure 3. Survey responses for the agriculture reporting districts are the following:

Table 10. Respondents by Agriculture Reporting District (N=411)

NASS Reporting District	Number of Responses	Percent of Total Responses	Percent of Region Impacted by Drought
Northwest	47	11%	53%
Southwest	75	18%	57%
San Luis Valley	19	5%	84%
Northeast	146	36%	78%
East Central	74	18%	80%
Southeast	50	12%	96%
Total	**411**	**100%**	**74%**

The Northeast reporting district was the most heavily represented among total responses with nearly twice as many responses as those in the Southwest and East Central reporting district. The San Luis Valley was the least represented with only 19 responses.

The last column of Table 10 indicates the proportion of respondents within a region that reported being impacted by the drought. Nearly all of the respondents in the Southeast reporting district reported being impacted by the drought (96%), while the fewest respondents affected by the drought were in the northwest (53%). In total, 74% of respondents indicated being impacted by the drought.

Yield losses, higher prices, increased costs and abandoned acres are all direct impacts that result from a drought. At the same time, production agriculture is linked to input providers and output purchasers via backward and forward linkages. As an example, a rancher's purchase of fencing materials and feed is a backward linage to input suppliers, and their sale of weaned calves to a feedlot represent forward linkages. When drought reduces productivity, the broader economy may be negatively impacted as well.

For this reason, producers were asked where they sold most of their agricultural products (Table 11) and where they purchased inputs (Table 12). As indicated by survey respondents, significant shares of output are sold within 50 miles of the operation and within Colorado's borders. It's interesting that a significant share of livestock sales, mostly likely cattle and calves, are made outside of the state's borders. Inputs also tend to be purchased locally with easily transported inputs purchased outside Colorado followed by capital expenditures and then local services. The combination of results suggests drought will have significant impacts on rural Colorado's "Main Street" businesses.

Table 11. Proportion of Respondents Sales Made Within 50 Miles of their Operation and Outside Colorado

	Percent Sold within 50 Miles	Percent Sold Outside Colorado
Crop Sales	78%	23%
Livestock Sales	58%	43%
Milk/Dairy Sales	19%	< 1%
Custom Farming for Others	63%	9%

Table 12. Proportion of Respondents Expenses that Are Purchased 50 Miles of their Operation and Outside Colorado

	Proportion of Inputs Purchased within 50 miles	Proportion Inputs Purchased Outside Colorado
Capital Expenses (e.g., tractors)	87%	21%
Direct Expenses (e.g., feed, seed)	77%	30%
Services	91%	17%

Drought Impacts of Agricultural Operation Revenues and Profits

The 2012 drought profits and revenues impacts are mixed: the vast majority of producers are negatively impacted because of yield decreases or input cost increases, but higher prices for some commodities partially offset losses. Respondents are asked to compare revenues and profits in 2012 to a "typical" Year, and these responses are summarized in the following two tables.

Table 13. Respondents' Revenue Changes in 2012 Compared to Typical Year

How much did your farm or ranch REVENUES change in 2012 compared to a TYPICAL year?		
	Number of Responses	Percent of Responses
Lower Revenues	175	76%
Greater Revenues	56	24%
Average Percentage Change of All Responses	*-34%*	

Table 14. Respondents' Profit Changes in 2012 Compared to Typical Year

How much did your farm or ranch PROFITS change in 2012 compared to a TYPICAL year?		
	Number of Responses	Percent of Responses
Lower Profits	195	84%
Greater Profits	38	16%
Average Change Across All Responses	*-43%*	

More than ¾ of respondents suffered a decrease in revenues during 2012 (Table 13), and the average revenue change was -34% across all responses who received greater or lower revenues. A larger percentage (84%) realized lower profits – the increase in affected parties is primarily due to ranchers who faced higher forage costs from increased costs. The average decline in profits is -43%.

Diversity of Enterprises

Respondents engaged in many forms of agricultural production including forage crops, non-irrigated production, irrigated production and livestock operations (Table 9). Prominent among these were 175 forage crop production enterprises with a small number of dairy enterprises (only 7 in Table 14). The "Other" category primarily consisted of fruit and vegetable production, equine production, outfitting and goats.

Table 14. Enterprises Reported by Respondents During 2012

	Number of Respondents
Forage Crops	175
Non-Irrigated Crops	92
Irrigated (Not Forage)	153
Livestock Feeding	113
Cow-Calf	137
Sheep Production	31
Dairy Production	7
Other[a]	80

Once a producer responded to a particular enterprise, skip logic is utilized to ask more detailed questions about production characteristics including typical yields, actual 2012 yields, etc. to ask the producer what types of crops or livestock were involved in the production process. The following sections summarize responses for particular commodity groups.

Forage Production

Livestock, dairy and equine production are important sectors in the agriculture economy. These enterprises rely on forage production – alfalfa hay, grass hay, range/pasture – in order to provide important feed inputs. When drought occurs, forage production is adversely impacted creating a primary loss for forage producers and a cost shock to livestock producers.

A total of 165 survey respondents answered the subset of questions directed at forage production. Respondents were asked to rate their forage yield and forage quality against a benchmark of a typical year. The benchmark year was considered to be 100% of normal production, and then respondents used a slider bar to indicate their crop's productivity as a percent of the typical year. As indicated by Table 15, drought significantly impacted production quality and yield on average, but standard deviation of responses indicated significant variability among producers.

Table 15. Respondents' Characterization of 2012 Forage Yield and Quality as a Percent of a Typical Year (Typical = 100%)

	Forage Production	Forage Quality
Mean Percent Forage Outcome for 2012 Compared to Typical Year	50%	67%
Standard Deviation Percent Forage Outcome for 2012 Compared to Typical Year	27%	31%

As illustrated in Table 15, average forage production as just 50% of what it would be in a typical year, and forage quality was just 67% of a typical year.

Respondents provided specific information for forage yields in 2012 and in a typical year (Table 16). Alfalfa hay production was down from 4.4 tons per acre to 2.7 tons per acre for questionnaire respondents, and grass hay producers realized reductions from 3 tons per acre to 1.3 tons per acre.

Table 16. Acreage and Yield Information For Forage Produced by Respondents

Crop	*Avg. Irrigated Forage Acres*	*TYPICAL Yield (avg. tons/ac)*	*2012 Yield (avg. ton/ac)*	*Percent Difference*
Alfalfa Hay	207	4.4	2.7	-40%
Grass Hay	58.6	3	1.3	-50%

In addition, approximately 42% of forage respondents reported harvesting their hay acres 2 to 4 weeks early in 2012. Respondents also estimated that it would take a little more than 2 years of normal precipitation conditions for their hay pastures to return to typical production levels.

Irrigated Crop Production

Respondents were asked to report yields and acres for a variety of non-forage crops. Additionally, respondents were asked if they purchased crop insurance and if they anticipated an indemnity based on 2012 actual versus guaranteed crop value. Summaries of responses to these questions are found in Tables 17 and 18. Note that to avoid disclosing farm specific information, dry beans, potato and barley results are not reported.

Table 17. Respondents' Reported Yields, Acres Planted and Harvested, Insurance Participation and Expected Indemnity for Selected Irrigated Crops

Crop	No. of Responses	Expected Yield	Actual Yield	Percent Difference	Average Planted Ac.	Average Harvested Ac.	Percent Abandoned	No. Reporting Insurance Purchase	No. Expecting Indemnity
Corn Grain	51	184 bu/ac	129 bu/ac	-30%	364.9	297.3	-19%	42	20
Corn Silage	18	37 tons/ac	25 tons/ac	-33%	244.5	205.4	-16%	13	5
Irrigated Wheat	31	89 bu/ac	59 bu/ac	-33%	154.3	145.2	-6%	0	0

Table 18. Respondents' Reported Yields, Acres Planted and Harvested, Insurance Participation and Expected Indemnity for Selected Non-Irrigated Crops

Crop	No. of Responses	Expected Yield	Actual Yield	Percent Difference	Average Planted Ac.	Average Harvested Ac.	Percent Abandoned	No. Reporting Insurance Purchase	No. Expecting Indemnity
Dryland Wheat	57	38 bu/ac	27 bu/ac	-28%	1,177	1,117	-5%	51	22
Milo/Sorghum	7	31 bu/ac	11 bu/ac	-65%	331	123	-63%	7	5
Millet	19	34 bu/ac	8 bu/ac	-75%	446	258	-42%	18	14
Sunflower	7	1,071 lbs/ac	483 lbs/ac	-55%	343	193	-44%	5	3
Dryland Corn	25	58 bu/ac	8 bu/ac	-86%	504	174	-65%	22	20

When comparing the two tables, it is true that every crop experienced both yield reductions and planted acre abandonment because of the drought. On a percentage basis, dryland crops experienced larger shocks due to the drought, but the overall value of these crops may differ because of the relative productivity of irrigated cropping.

Cow-Calf Production

Sixty-eight (68) respondents completed questions regarding their forage requirements for the year (Table 19). The potential sources of forage included owned land, private leases, state leases purchased hay and hay grown for own feeding. As indicated in the table, the drought meant that cow-calf producers shifted their forage resources from grazed land to grown or purchased hay. The shift is not surprising, but it is clear that many ranchers fed hay that they grew rather than selling surplus hay or storing for the winter months – grown hay fed to cattle was 186% greater than normal.

Table 19. Source of Forage for Cow Calf Production in Typical years and 2012

AUM Source	AUMs Required by the Operation in a TYPICAL year	Forage Resources Used in 2012	Percent Difference
Owned Pasture/Range	1,136	690	-39%
Private Lease	821	762	-7%
Federal Lease	1,313	909	-31%
State Lease	300	198	-34%
Purchased Hay	121	188	55%
Grown Hay	400	1,143	186%

The performance of the cow-calf herd may diminish under drought conditions as cattle receive inadequate nutrition or are otherwise stressed by climate conditions. Survey respondents also reported their typical performance measures and the performance measures during the 2012 drought. Table 20 indicates how 90 cow-calf producers rated their performance of their herd. In general, the drought did not adversely impact the weaning and culling percentages of the herd, but it appears respondents did wean and perhaps place their calves in the feedlot at lighter weights. Also notable is the significant decrease in the overall size of the cow herd – from 203 cows to 105 cows on average.

Table 20. Cow-Calf Performance Measures During the Drought

Performance Measure	Avg. Performance Measure in a Typical Year	Percent of Normal Performance Measure in 2012
No. of Cows in Herd	203	105
Culling Rate	10%	12%
Weaning Pct.	95%	94%
Avg. Weaning Weight	550	460
Average Cow Cost	$534	$745

Previous sections indicate the production impacts of the drought that include yield reductions, crop abandonment, increased costs of production, reduced revenues and declining profits. The following section addresses the actions that survey respondents took in order to mitigate or adapt to these production shocks.

Operator Adaptation to Drought

Significant production losses severely impacted some, but not all, agriculture operations in Colorado as a result of drought. Affected operations adapted to/mitigated these economic losses with diverse strategies. Some of these strategies are very disruptive to the long term viability of the operation, and may indicate a lack of farm or ranch resiliency. The following section provides insights into some of these adaptations.

More aggressive culling is an example of a disruptive drought mitigation strategy. The selling of assets, such as breeding livestock, can be very disruptive to the agricultural operation because it reduces revenue generated in subsequent years, and asset replacement significant capital investment in the future. For these reasons, asset sales can signal significant financial stress for the farm or ranch operation.

More generally, a hierarchy of mitigation strategies exists ranging from the least to most disruptive for the operation:

- Managing Cash Flow: Agriculture producers will seek to increase household income by generating more revenue from the existing asset base and reducing expenses. From a business perspective, farm and ranch managers critically evaluate whether a production input will "pay its way" by matching revenues and expenses. The exceptions are longer term assets whose revenues may extend beyond the current accounting cycle. Examples of managing cash flow include performing soil tests so that nutrient application is more precisely matched to crop needs, custom farming for others and reduced household expenses.

- Managing Debt: A drought can reduce cash flow to the operation, and for the leveraged producer, reduced cash flows may result inability to service debt. If debt service is a problem, debt management strategies include refinancing existing loans for longer terms, paying only interest on term notes, pledging more collateral as security, cross-collateralization and amortizing an operating note from a single year to multiple year payback. These strategies are less desirable than adjusting managing cash flow because they influence the farm/ranch's ability to service and acquire future investment capital. In addition, the strategies may improve cash flow in the short term, but increase the overall cost of financing assets in the long term via increased total interest expense.

- Managing Assets: Assets are converted to cash for the operation by sale or may be used more intensively to increase revenues. Initially, farm and ranch mangers sell short term assets (e.g., grain inventories) or place calves in a feedlot early in order reduce expenses and increase revenues to the operation. These actions may be poorly timed, but are less disruptive then leasing assets or more intensive use of assets (e.g., custom farming with own equipment) that hastens the depreciation of assets. The most disruptive asset strategy is to sell noncurrent assets such as breeding livestock and land.

Survey results indicate that Colorado producers are using a mix of these mitigation strategies in response to drought, but are generally focused on managing cash flow and managing debt. As indicated in Figure 4, respondents sought to reduce family expenses first (59% of respondents) while relatively few took advantage of federal drought assistance (18% of respondents), even though more than 4 out of 5 were aware that federal assistance was available. Perhaps the participation can be explained by a lack of eligibility, a shortfall of federal funds, or an unwillingness to complete the sign up process. Respondents were also asked to indicate if they would adopt a practice if the drought continues. A smaller proportion selected reducing family living expenses (41%) as strategy, likely because it is difficult to cut expenses that have already been reduce. An increasing percentage will adopt custom farming, seek off farm employment and obtain federal assistance.

Figure 4. Respondents' Approaches and Participation Rates for Managing Cash Flow

	In response to drought our operation …	*If the drought continues our operation will …*
Custom Farm(ed)	12%	14%
Sought/ Seek Off-Farm Employment	25%	26%
Reduce(d)Family Expense	59%	40%
Sought/ Seek Federal Assistance	18%	25%

Respondents are managing debt to mitigate drought impacts (Figure 5) The most popular debt management is rolling an operating note into the next year (17%) followed by paying the interest only for a scheduled debt payment (15%) or putting up more collateral (9%). If the drought persists, more operations will seek all debt management strategies.

Figure 5. Respondents' Approaches and Participation Rates for Managing Debt

	In response to drought our operation …	*If the drought continues our operation will …*
Paid / Will Pay Interest Only	15%	16%
Put Up More Collateral	9%	11%
Roll Operating Note Into Next Year	17%	18%

It is clear that survey respondents are depopulating their cow herd with more aggressive culling in order to cope with drought (Figure 6). Among survey respondents, 41 % indicate they have sold breeding livestock and 29% indicate they will do so if the drought continues. Relatively few have sold land in response to drought (2%) but more will consider doing so if the drought continues (9%).

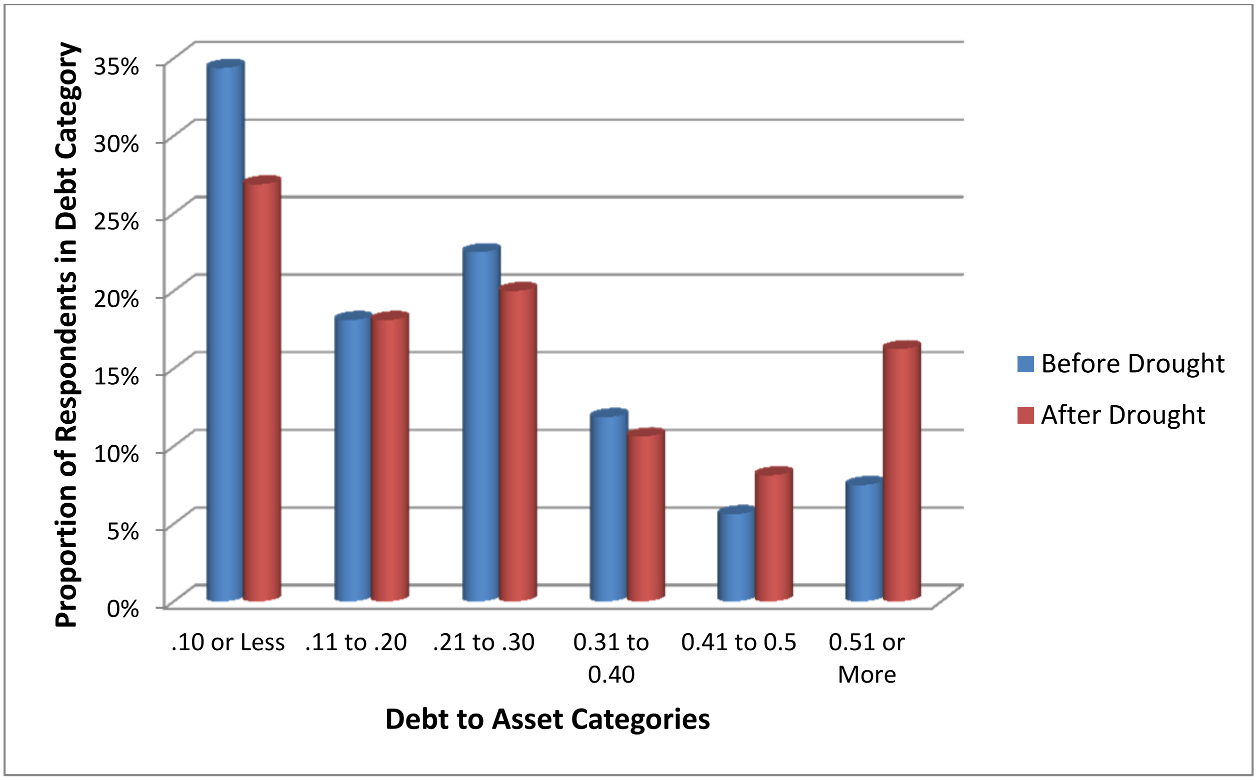
Figure 6. Respondents' Approaches and Participation Rates for Managing Assets

	In response to drought our operation …	*If the drought continues our operation will …*
Sold / Will Sell Breeding Livestock	41%	29%
Sold / Will Sell Equipment	13%	19%
Sold / Will Sell Land	2%	9%

Based on survey responses, farm and ranch operations are experiencing financial stress due to the drought, but the hierarchy of strategies represented in Figures 4through 6 suggests that the most intense stress is borne by those who are culling breeding livestock. If the drought persists, financial stress will likely increase, but respondents do not anticipate drastic changes to current efforts.

One caveat applies to the previous statement. Survey respondents are predicting slight changes if drought continues, but these same respondents are adding debt to the operation. As illustrated in the "Before Drought" and "After Drought" debt to asset percentages in Figure 7, the proportion of operations with very little debt has decreased substantially, and those in the highest debt category – 50% or more of assets financed with debt – has increased significantly. If the drought continues through 2013, more drastic management practices may be adopted than those suggested by survey respondents.

Figure 7. Respondents' Percentage of Assets Financed by Debt Before and After the Drought



Farm and Ranch Resiliency Following the Drought

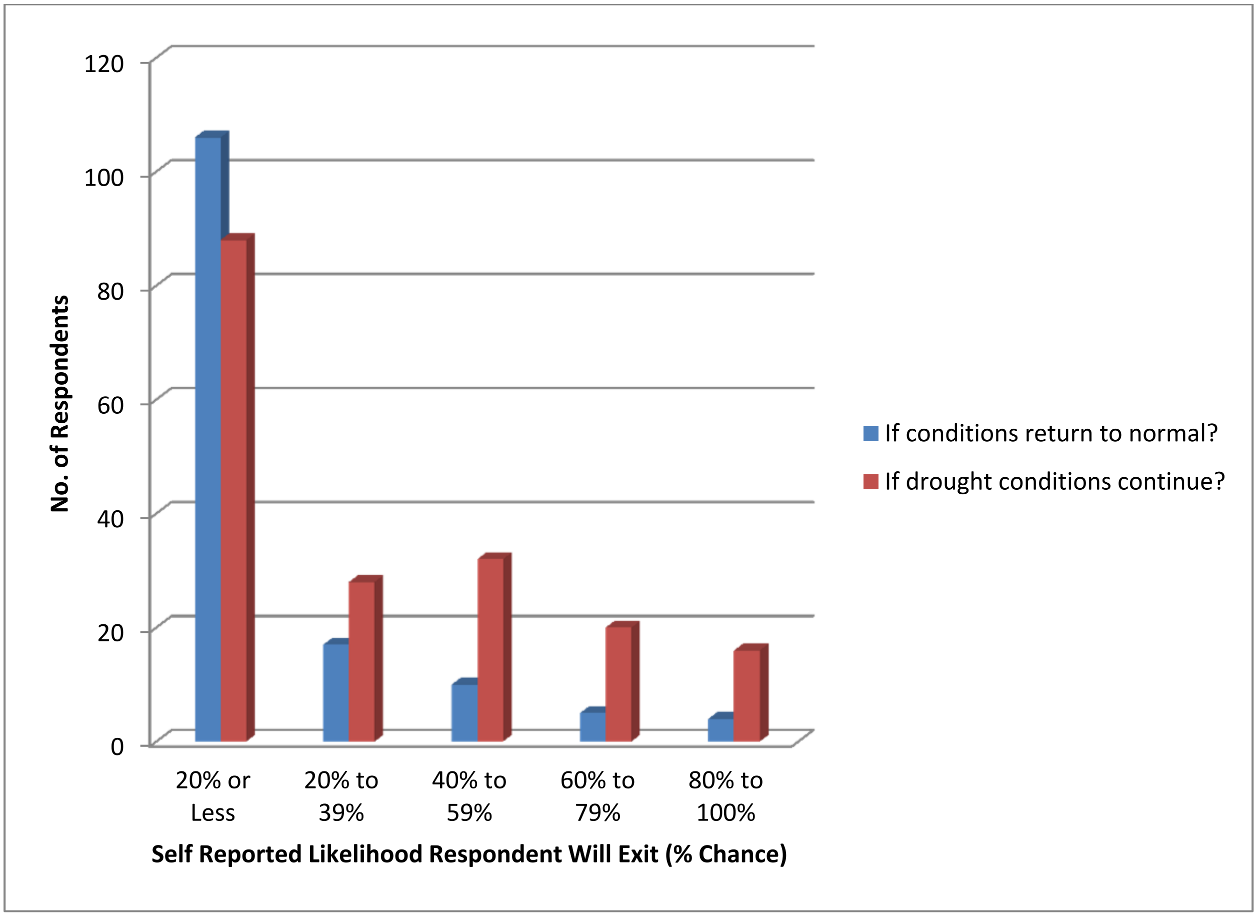
Resiliency is the ability of the agricultural operation to return to a similar state of production after enduring a stressor such as a drought. The similar "state" includes biological and physical production characteristics, as well as a level if financial assets and performance. Understanding resiliency of agricultural producers is useful because it includes:

- Understanding how adaptable agricultural producers are to extreme and changing climatic conditions.
- Indicating how long farmers and ranchers can endure an environmental stressor such as drought until they are ultimately forced to exit the agricultural sector.
- Designing assistance to help agricultural producers adapt to the challenges presented by natural hazards such as drought.
- Quantifying broader impacts to a rural economy. Farmers and ranchers are key components of rural communities, their resiliency is directly correlated with the resiliency of rural communities.
- Assessing impacts to local feed, food and fiber systems. Small and mid-sized farms and ranches have been found to be less resilient than large farms to drought, which many believe decreases the adaptability of the domestic food sector and may lead to food security concerns in the future.

By investigating resiliency, this section provides insights into the efficacy of current drought relief policies and identifies ways to decrease economic impacts felt by agricultural producers and regional economies.

One means for measuring resiliency is to ask producers how likely it is that they will exit the industry if the drought continues, and then compare this to the likelihood of exit if conditions return to normal

Figure 8. Self Reported Likelihood of Exiting the Industry in the Next Five Years



Responses to these questions are illustrated in Figure 8. The vertical distance of Figure 8 measures the number of respondents and the categories along the horizontal axis is the self reported likelihood of exit for those respondents. Blue bars represent the likelihood if conditions return to normal, and red bars represent the likelihood if the drought continues. As an example in the left-hand corner, 106 respondents indicate that there is a 20% chance or less of exiting the industry if conditions return to normal in 2013. Should the drought continue, only 88 respondents indicate a 20% chance or less of exiting (red bar).

Clearly, respondents are more likely to exit if the drought continues, as the probability of exit increases in nearly every category. At the far right hand side of Figure 8, the number describing a 80% or better exit likelihood grows from 4 respondents to 16 respondents, a four- fold increase. An important question remains: what characteristics are the most often associated with the likelihood of exiting the industry? If these can be determined, then assistance for these producers may be better targeted, and better mechanisms designed to address declining resiliency.

Other economists have sought to explain farm/ranch resiliency in the face of many stressors, but none have looked at Colorado in particular. These studies found that off-farm income, the size of the operation, experience, and age influence resiliency and the likelihood of exit. Characteristics related to drought induced exits include decreased crop yields, number of acres fallowed, the duration of drought, access to irrigation, and decreased profit. Most recently, a theoretical model was developed that suggested proxies for a farmers' /ranchers' overall wealth, such as groundwater supplies, since these supplies can be thought of as a saving account during drought. These types of hedges against drought may be an important determinant of resiliency. In the section that follows, the determinants of Colorado farmer and rancher resiliency are considered.

Farmer Resiliency: Analytical Framework and Empirical Methodology

In this section, an analytical framework describing resiliency and an empirical methodology are explained. Parameters of the empirical model are estimated and the results are reported. Conclusions regarding Colorado farmer and rancher resiliency are discussed along with the targeting of assistance. Limitations of the analysis are also described.

This analysis 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 of household consumption data to create a drought resiliency index for farmers in Indonesia. The author's 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.

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. The research objective is focused on 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 for an individual producer is dependent upon the operation's asset base and an individual manager's 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.

$$E = f(Human\ Capital, Natural\ Capital, Economic\ and\ Financial\ Capital, Shock) \qquad Eq\ 2$$

A producer's likelihood of exit changes from one point in time to another so long as 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). This is also represented by the individual differences comprising the red and blue bars of Figure 8.

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

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

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.

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

The determinants of E^1 and ΔE were derived[7]. 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.

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.

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

Table 21. Summary Statistics of Variables Used in Resiliency Parameter Estimation

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
$\Delta\mathbf{E}$	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 self-reported debt-to-asset ratio after the 2012 drought had ended and is illustrated in Figure 7. 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 in the regression analysis. 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 as it corresponds to an increase in the probability that the producer exits the industry. 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.

Resiliency Model Parameter Estimation

Model 1 is estimated as follows:

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

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:

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

Eq 9

Resiliency Results and Discussion

Table 17 displays results for both the GLM and OLS models. Marginal effects[8] 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 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

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

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.

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 9 illustrates 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 9 Average marginal effects of debt to asset ratio with respect to E^1

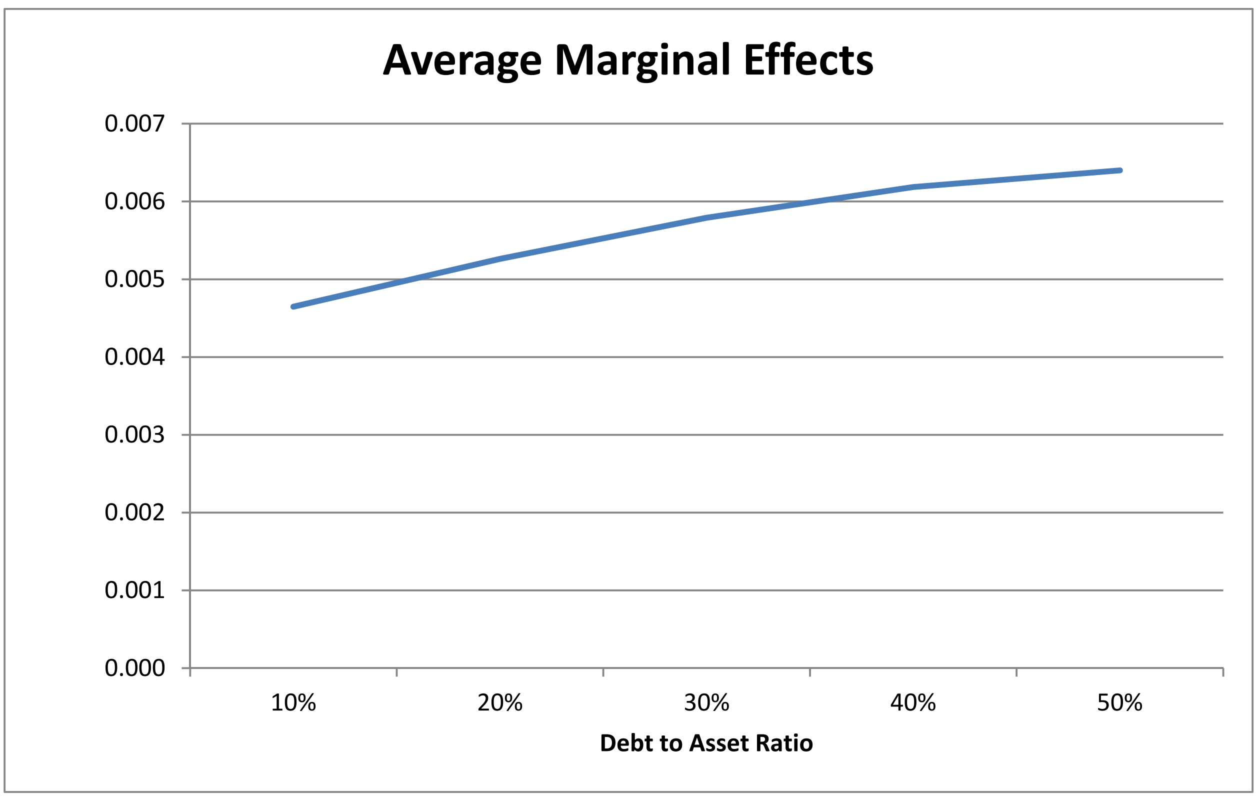

Table 22. Parameter Estimates for Variables of Model 1 and 2

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		

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.

Concluding Remarks on Resiliency

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 research 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 multiyear 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 analysis 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.

These findings 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.

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Appendix 1: Drought Questionnaire

Text introducing the survey included the following:

“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”

Question: 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.
	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)	Answer 1 (1)
Corn Grain (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 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)			❍

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)

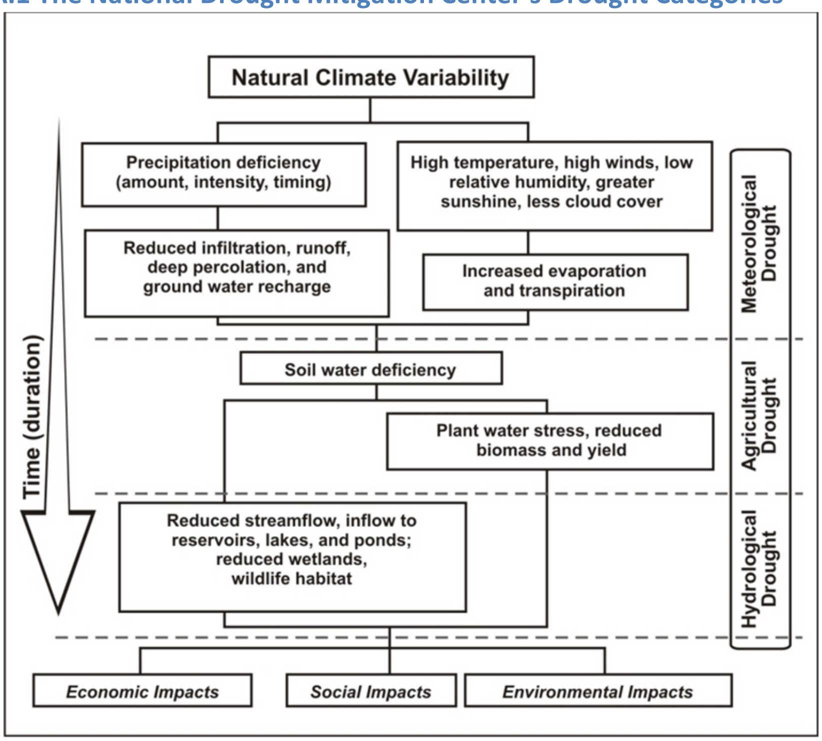
Q62 Thank you for taking the time to complete the Colorado State University Department of Agriculture's and the Colorado Water Conservation Board's 2012 Drought Survey! Look for a summary of the results on the Department of Agriculture and Resource Economics website at http://dare.colostate.edu/index.aspx 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 2: 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 A.1 The 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 A.2 Drought Severity Classification

		Ranges					
Category	Description	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)