The Economic Impact of the 2011 Drought on Southern Colorado: A combined input-output and EDMP analysis.

Prepared by

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Executive Summary

Water is a critical input to agricultural activities. Water shortages reduce productivity leading to reductions in yields, harvestable acres and forage for livestock. Since October of 2010, extreme drought has plagued agricultural producers throughout much of Southern Colorado (U.S. Drought Monitor Archive, 2012). Given agriculture's prominent role as a base industry in rural regional economies, the impact of the 2011 drought extends well beyond lost revenues to those producers directly impacted. The primary objective of this research is to describe and quantify the broader economic impacts of the 2011 drought on agricultural productivity and allied economic activity for two Colorado watersheds: the Rio Grande and the Arkansas.

The drought's impact on agricultural productivity was quite different when comparing the Rio Grande and Arkansas River basins. While the drought's onset did not significantly change planted acres in each river basin, two key determinants of overall productivity, harvested acres and yield per harvested acre, were altered. Barley, hay, potatoes and wheat are the primary crops in the Rio Grande. For each of these crops, harvested acreage rates (defined as the percent of planted acres that are harvested) were within two percent of adjusted average.[2] Reported yields were higher relative to average for barley (+1%), potatoes (+6%), and wheat (+2%); whereas hay was six percent below average. By comparison, in the Arkansas, producers reported significant reductions in the percent of planted acres that were harvested; harvested acreage rates for corn, sorghum, sunflowers, and wheat falling 24, 30, 9, and 4 percent respectively relative to normal. Yields were also significantly lower throughout the Arkansas, the productivity of corn, hay, sorghum, sunflowers, and wheat falling 7, 9, 19, 24, and 11 percent respectively. The observed differences in the impact on productivity are in large part due to the nature of the crops grown in each of these two areas. In the Arkansas, dryland farming accounts for roughly 37 percent of total acreage, whereas dryland acreage accounts for less than 10 percent in the Rio Grande.

As part of the study, an impact analysis was conducted to measure the effect of the drought on economic activity across both regions. This analysis was conducted in two parts. First, the change in revenue for those industries directly impacted was estimated by comparing reported revenues in 2011 to estimates of the revenue that would have been earned had producers

[2] Adjusted average refers to average conditions over the period 1998-2010, ignoring the two highest and lowest years in the record.

experienced typical growing conditions. Second, to account for backward linkages with other sectors of the economy, an input-output model was used to estimate the indirect and induced impacts associated with the direct revenue loses/gains. Predominately driven by higher than normal revenues from potato crops, overall economic activity increased by roughly five million dollars in the Rio Grande. By comparison, in the Arkansas, economic activity fell by roughly 105 million dollars, representing a loss of more than 1,000 jobs.

Individual losses are distributed unevenly across the basins, so dryland farmers tended to experience the greatest losses relative to irrigated farmers. At the same time, the broader economic impact to allied agribusinesses was mitigated due to the timing of the drought. It appears that most farmers proceeded with typical planting behavior. Had the drought occurred earlier in the cropping season, especially with winter wheat, then fewer inputs might have been purchased, and greater economic impacts to input suppliers would have resulted.

Many of the commodities discussed previously are primary inputs to value added agricultural sectors such as livestock feeding, dairies and meat packing. A drought's indirect effects may include reduced production and efficiency in forward linked sectors as these businesses must purchase inputs at higher prices, from a further distance and of potentially lower quality. A separate analysis was conducted to capture this. Specifically, a Equilibrium Displacement Mathematical Programming Model (CEDMP), previously built by Davies et al., representing Colorado's agricultural sector was used to model the drought's impact on the livestock producers in Colorado. For the analysis, baseline conditions, reflecting ongoing, external supply shocks associated with widespread drought outside of Colorado, were compared with output from model runs which included reduced productivity on crop and grazing lands associated with the drought. Results suggest that drought conditions in Colorado were responsible for less than a 1% reduction in total revenues for the livestock industry statewide, as the direct impact of local climatic conditions on production levels and prices in these sectors was negligible. While the impact on total revenue was relatively small, production costs (associated with higher prices and the need to provide supplemental feed) increased significantly, statewide feed costs (including both forage and grain) increasing by more than 110 million dollars.

The drought's timing played an important mitigating role in livestock production as well. In general, ranchers had sufficient carryover hay and forage stocks to feed cattle as the drought intensified, and profits gained prior to the drought meant that ranchers had cash resources with which to purchase higher cost feedstuffs. The forage stocks and cash resources were sufficient to avoid a large scale liquidation of breeding livestock in fall 2011, but anecdotal evidence suggests that ranchers have begun liquidating herds in 2012 in the face of ongoing drought. The impact analysis does not include liquidation of cattle during this calendar year.

The drought resulted in significant reductions in harvestable acres and yields, primarily in the Arkansas Basin. In total, the drought resulted in more than 100 million dollars in lost economic activity throughout the Rio Grande and Arkansas Basins, producers in the Arkansas suffering the most. In additional to lost revenues, the drought resulted in roughly 110 million dollars in additional feed costs. It should be noted that the estimates reported here only reflect the short-term impacts associated with drought conditions experienced in 2011. For example, the long-run impacts associated with short-term decisions to cull herds are not reflected. This report also does not reflect impacts associated with drought conditions experience in 2012, which appear to be more severe and widespread.

Introduction

Water is a critical input to agricultural activities. Water shortages reduce productivity leading to reductions in yields, harvestable acres and forage for livestock. Since October of 2010, extreme drought has plagued agricultural producers throughout much of Southern Colorado (U.S. Drought Monitor Archive, 2012). Over the course of the 2011 summer, 17 counties throughout the Arkansas and Rio Grande River basins were designated disaster areas due to the severity of the drought (FEMA Colorado Declarations, 2012). The importance of agriculture in these areas (Davies and Sullins, 2011) suggests that the direct (agricultural production) and more community wide impacts from this climatic event are likely significant.

The Colorado Water Conservation Board (CWCB), Colorado Department of Agriculture (CDA), and the Department of Agricultural and Resource Economics at Colorado State University (DARE-CSU) began work on a project in the fall of 2011 aimed at developing a better understanding of drought's impact on Colorado in 2011. The project consisted of three parts: (1) a preliminary look at the evolution of agriculture activity in the Arkansas and Rio Grande River basins from 1998-2011, (2) a survey of producers in the impacted regions, and (3) an analysis of the impact of the drought on economic activity throughout the areas primarily impacted in 2011. This document reports on the economic impact analysis conducted as part of the project. The primary objective of this portion of the study was to estimate the economic impacts of the 2011 drought on agricultural productivity and allied economic activity for two Colorado watersheds: the Rio Grande and the Arkansas.

The remainder of this report is organized as follows. The next section provides background information on the drought and study area. This is followed by a discussion of the impact of the drought on economic activity and production costs in the impacted areas. The final section provides an overview of the findings.

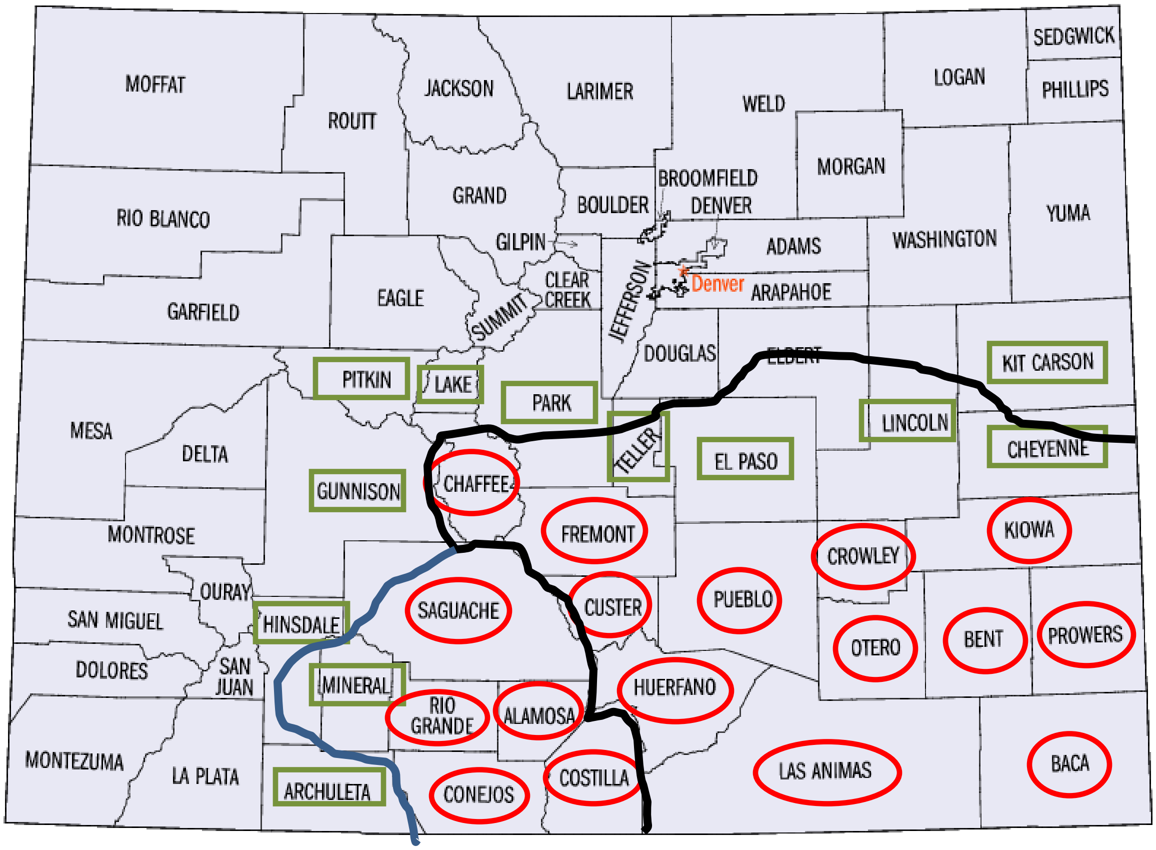
Background

Study Area

Over the course of the summer of 2011, ongoing drought conditions resulted in seventeen counties receiving primary disaster designations and twelve, due to their proximity with those counties, receiving secondary designations (FEMA Colorado Declarations 2012).[3] The seventeen counties that received a primary designation include: Alamosa, Baca, Bent, Chaffee, Conejos, Costilla, Crowley, Custer, Freemont, Huerfano, Kiowa, Las Animas, Otero, Prowers, Pueblo, Rio Grande, and Saguache. This report focuses on these counties. For the analysis, two economic regions were identified loosely corresponding to the Arkansas and Rio Grande River Basins. Figure 1 shows the seventeen counties with primary disaster designations in red circles, the twelve counties with a secondary designation as a contiguous county in green squares, the Arkansas River basin outlined in black, and the Rio Grande River Basin outlined in blue.

[3] The geographic scope and severity of the drought has increased since 2011. As of July 2012, 62 of 64 counties in Colorado had received primary designations.

Figure 1: Map of Counties Included in the Study Area



Primary disaster declarations

Secondary designation as a contiguous county

Arkansas River basin

Rio Grande Basin

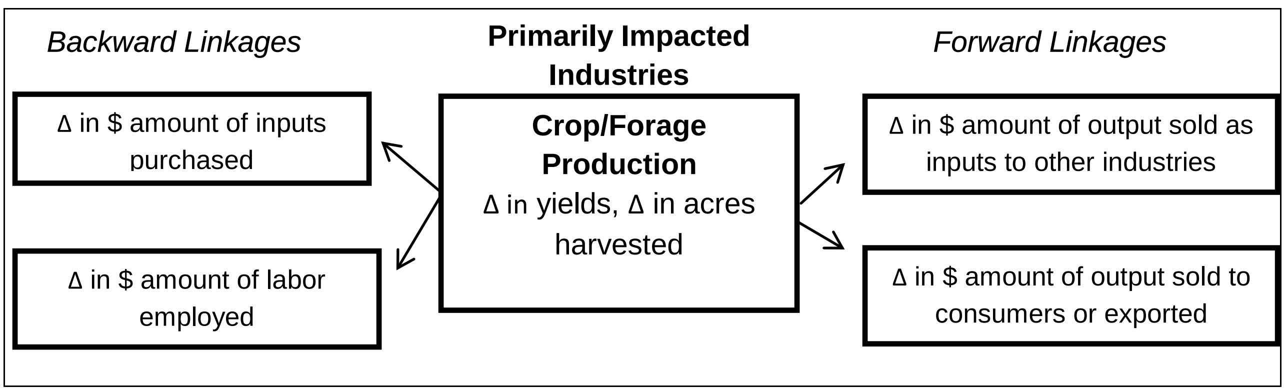
How Drought Impacts a Rural Community's Economy

The direct effects of the drought in these counties come in the form of reductions in output and lost revenues for agricultural producers. The magnitude of the direct impact, in dollar terms, depends on the sensitivity of the crops being grown to drought, the ability to provide supplemental irrigation, and how responsive prices are to changing output levels. Throughout the remainder of this report we refer to those industries for which productive capacity (e.g., yields) was directly impacted as Primary Impact Industries (PII).

The direct impacts experienced by PII represent only a portion of the true impact due to forward and backward linkages with other industries within the local economy. We refer to those industries indirectly impacted (via forward and backward linkages) as Secondary Impact Industries (SII).

Figure 1 presents an example economy where the forward and backward linkages between crop producers and the rest of the economy are illustrated. The initial "shock" corresponds to a change in yields and/or harvested acreage for those industries directly impacted by the drought. This report focuses on two consequences of this shock: (1) the change in economic activity and (2) the impact on production costs for forward linked industries within the region.

Figure 2: Example Economy



Economic Activity

Following Watson et al. (2007), economic activity is defined as the total number of dollars spent within a region. Economic impact analysis measures the change in economic activity, or dollars spent within a region, associated with a particular event.

Drought impacts economic activity in four ways. The first is the direct effect on total revenues for PII. Second, these direct impacts lead to a reduction in the amount of inputs and labor purchased from backward linked industries and households (illustrated on the left hand side of Figure 2). Third, the loss of output may lead to a reduction in economic activity for those industries that utilize output from PII as inputs to production (upper portion of right hand side of Figure 2). The total change in economic activity resulting from these secondary effects (both backward and forward) is commonly referred to as "indirect impacts". Finally, losses in household income, associated with the reduction in employment, results in a third round of impacts, as household expenditures on goods and services within the region fall. These are commonly referred to as “induced effects”.

The total impact to economic activity within a region is equal to the change in total revenue to those industries directly impacted by the drought plus the indirect and induced impacts to households and industries not directly impacted by the drought.

Production Costs

In addition to potential changes in total revenue, drought is also likely to impact production costs in forward linked industries. In Colorado, this includes value added sectors such as livestock feeding, dairies, and meat packing.[4] Production costs are impacted in two ways. The drought results in a decrease in the supply of key inputs to production as yields and harvestable acres decrease for forage and grain products. This shift in supply coincides with an increase in demand for feed products resulting from reduced productivity on grazing lands. Both factors contribute to an increase in feed costs, leading to an overall increase in production costs for these industries.

Estimating the Impact of Drought

In this section we present estimates of the drought’s impact on economic activity and production costs, as well as an overview of the methodology used to derive them. Two distinct modeling approaches were utilized. Input-ouput models were constructed for each basin and serve as the foundation of the economic impact analysis. Limitations of input-output models include the inability to capture the impact on forward linked industries, both in terms of economic activity as well as production costs. To account for this, a separate analysis was conducted to analyze the impact of lost productive capacity on forward linked industries. Specifically, a Mathematical Programming Equilibrium Displacement Model (CEDMP), previously built by Davies et al. (2010), representing Colorado’s agricultural sector was used to model the drought’s impact on the livestock producers in Colorado.

Changes in Economic Activity

The impact of the drought on economic activity is calculated in two parts. We first examine the impact of the drought on productivity and total revenue for those industries identified as PII, this

[4] In Colorado, livestock receipts account for roughly two-thirds of total receipts to Colorado agriculture NASS (2008).

includes barley, corn, potato, and wheat producers in the Rio Grande and corn, sorghum, sunflower, and wheat producers in the Arkansas. Input-output models, specific to each basin, are then used to estimate the impact of the drought on SII. Estimates for SII include both the indirect and induced impacts associated with the impacts to PII. The sum of these two parts represents the total change in economic activity, ignoring forward linkages.

Primary Impact Industries

The impact to PII is calculated as the difference between actual, reported revenue (Actual Revenue) earned in 2011 and what they would have earned in 2011 had the drought in Colorado not occurred (Potential Revenue). This difference is referred to as Lost Potential Revenue.[5] Equation (1.1) describes the calculation of Potential Revenue for each crop in each region.

$$\begin{aligned} &\textit{Potential Revenue} = \\ &\quad \textit{Planted Acres}_{2011} * \textit{Adj Ave}\,\%\,\textit{Harvested}_{1998-2010} * \textit{Adj Ave Yield}_{1998-2010} * \textit{Price}_{2011} \end{aligned} \tag{1.1}$$

Where:

$\textit{Planted Acres}_{2011}$: total number of acres planted in 2011.

$\textit{Adj Ave}\,\%\,\textit{Harvested}_{1998-2010}$: adjusted average percent of total acres planted which are harvested, calculated as the average rate of harvest over the period 1998 to 2010 excluding the two highest and lowest harvest rates over that period.[6]

$\textit{Adj Ave Yield}_{1998-2010}$: adjusted average yield per harvested acre, calculated as the average yield over the period 1998 to 2010 excluding the two highest and lowest reported yields over that period.

$\textit{Price}_{2011}$:price per unit of output in 2011.

Potential Revenue represents what producers would have earned if they had experienced typical growing conditions combined with, in most cases, higher commodity prices which were

[5] Note that Lost Potential Revenue differs from the change in total revenue across, for example, 2010 and 2011. The goal of this analysis is a with-without comparison; or a comparison of what would have happened in 2011 had drought conditions not existed to what actually happened.

[6] The total number of acres planted for hay is not reported. For this crop Potential revenue is calculated as the actual number of harvested acres times the adjusted average yield time the price in 2011.

largely a product of outside forces. Calculating Potential Revenue in this fashion rests on two assumptions. First, it is assumed that the drought was largely unanticipated and planting decisions were not impacted by the drought. This assumption is consistent with survey responses; the majority of producers indicating that no changes to production practices were made prior to April. It is also consistent with reported estimates of planted acres; planted acreage being greater in 2011 than the average over the previous two years in both regions.

Second, we assume that given the magnitude of recent trends in commodities prices and severe drought conditions experienced throughout the surrounding region, local prices would have been similar to those observed had the drought not occurred in Colorado.[7] This assumption is only relevant to the calculation of impacts to PII. That said, it is consistent with observed trends in commodities prices over the last decade. With few exceptions the difference in prices between 2010 and 2011 were small compared to observed price increases over the last decade.[8] This assumption is also consistent with output obtained from the CEDMP which determines prices endogenously.

Given the assumptions outlined above, differences between Potential and Actual Revenues are a result of the drought's impact on productivity. Analysis of planted acreage data suggests that the drought's onset did not significantly impact planted acres in each river basin. However, harvested acres and yield rates were altered. Table 1 presents the adjusted average and actual harvest rates for the Rio Grande and Arkansas River Basins across each of the major crops impacted by the drought.

[7] For example, high feed grain prices are in a large part due to an increase in world-wide demand for meat.
[8] One possible exception is hay. The price of hay increased by roughly 50% in 2011 relative to 2010; however, this increase is largely a result of the drought in Texas and Oklahoma.

Table 1: Actual and Adjusted Average Harvest Rates

	Rio Grande			Arkansas		
	Actual	Adjusted Average	% Difference	Actual	Adjusted Average	% Difference
Barley	95.49%	97.38%	-1.94%	-	-	-
Corn (grain)	-	-	-	67.93%	89.36%	-23.98%
Hay	-	-	-	-	-	-
Potatoes	99.81%	99.48%	0.33%	-	-	-
Sorghum	-	-	-	48.73%	69.38%	-29.77%
Sunflowers	-	-	-	85.31%	93.55%	-8.81%
Wheat	95.48%	93.98%	1.59%	82.02%	85.07%	-3.59%

Table 2 presents the adjusted average and actual yields for the Rio Grande and Arkansas River Basins across each of the major crops impacted by the drought.

Table 2: Actual and Adjusted Average Yields

	Rio Grande			Arkansas		
Crop	Actual	Adjusted Average	% Difference	Actual	Adjusted Average	% Difference
Barley	135.10	133.86	0.93%	-	-	-
Corn (grain)	-	-	-	136.00	147.00	-7.48%
Hay	2.72	2.90	-6.21%	2.70	2.97	-9.09%
Potatoes	393.00	372.10	5.62%	-	-	-
Sorghum	-	-	-	28.00	34.70	-19.31%
Sunflowers	-	-	-	945.00	1242.69	-23.96%
Wheat	102.00	100.00	2.00%	27.00	30.19	-10.57%

In the Rio Grande, harvested acreage rates were within two percent of adjusted average. Reported yields were higher relative to average for barley (+1%), potatoes (+6%), and wheat (+2%); whereas hay was six percent below average. By comparison, in the Arkansas, producers reported significant reductions in the percent of planted acres that were harvested; harvested acreage rates for corn, sorghum, sunflowers, and wheat falling 24, 30, 9, and 4 percent respectively relative to normal. Yields were also significantly lower throughout the Arkansas Basin, the productivity of corn, hay, sorghum, sunflowers, and wheat falling 7, 9, 19, 24, and 11 percent respectively. The observed differences in the impact on productivity are in large part due to the nature of the crops grown in each of these two areas. In the Arkansas, dryland farming accounts for roughly 37 percent of total acreage, whereas dryland acreage accounts for less than 10 percent in the Rio Grande.

Table 3 shows the impact to producers, in terms of Lost Potential Revenue, resulting from the climatic conditions experienced in 2011. These estimates represent the direct, indirect, and induced impacts on PII. Negative (positive) numbers indicate that potential revenue was less (greater) than actual revenue, i.e. that producers, all else constant, were worse (better) off.

With the exception of potato and wheat producers in the Rio Grande, Lost Potential Revenue was negative for all producers.[9] In the Arkansas, revenues for PII were roughly $85 million less than what they would have been had they experienced typical harvest and yield rates. Alternatively, in the Rio Grande, driven by higher than expected revenues for potatoes and wheat, Potential Revenue was roughly $12 million more than Actual Revenue in 2011.

The difference in outcomes across the Rio Grande and Arkansas is largely driven by the difference in the drought's impacts on irrigated versus non-irrigated crops. Dryland crops account for roughly 47 percent of total acreage in the Arkansas; whereas dryland crops account for less than 5 percent of total acreage in the Rio Grande (NASS, 2008). [10] While data detailing differences between irrigated and non-irrigated crops is no longer reported, survey respondents indicated that yields for dryland crops were less half of what was expected, two to three more times the reduction in yields reported for irrigated crops (Nelson et al. 2012).[11]

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[9] Note that LPR was positive for potatoes despite the fact that total revenues were lower in 2011 relative to 2010. The decrease in total revenues between 2010 and 2011 was largely driven by a fall in prices; whereas the positive LPR was a result of better than normal harvest and yield rates.
[10] Data collection of irrigated and non-irrigated acres in the region was last reported in 2008, the numbers listed above are an average from the time period 1998-2008 and are only an approximation of current conditions.
[11] Respondents indicated that potato yields were actually higher than expected in 2011. This is consistent with the NASS data presented in Table 2.

Table 3: Lost Potential Revenue by Crop

	Rio Grande	Arkansas
Barley	(628,068)	-
Corn (grain)	-	(39,878,518)
Hay	(9,311,169)	(16,413,731)
Potatoes	12,465,428	-
Sorghum	-	(12,232,433)
Sunflowers	-	(2,641,452)
Wheat	550,070	(14,552,800)
Total	3,076,261	(85,718,935)

Secondarily Impacted Industries

The totals presented in Table 3 reflect only the changes in economic activity associated with lost productivity in the PII. Impacts to SII are commonly estimated using IMPLAN, an input-output modeling software suite. IMPLAN can be used to estimate the direct, indirect and induced effects across all industries resulting from a change in final demand. Final demand is that portion of the change in total revenue that is generated from sales outside the region (Watson et al. 2007).

Here the shock was not in the form of a change in final demand, rather a change in total revenue generated from a change in sales to both final demand and intermediary sectors (i.e. producers in those industries which use output from PII as inputs to production). While it is not uncommon to observe studies using changes in revenue as a proxy for the change in final demand, this approach is incorrect and will lead to estimates of total impacts which are biased upward.

Estimates of lost potential revenue presented in Table 3 reflect the direct, indirect and induced impact of the drought to PII. What they do not reflect is economic activity lost in those sectors which were not directly impacted (i.e. SII). To calculate the indirect and induced impacts to SII, input-output models were created for each region using data from IMPLAN.[12] To avoid

[12] Input-output models have been widely used to look at economic impacts related to water transfers in Colorado (Howe & Goemans, 2003; Thorvaldson & Pritchett, 2006), as well as to analyze drought impacts in other states (Diersen & Taylor, 2003; Guerrero, 2011). With the exception of the modifications made to avoid double counting, the approach adopted here is conceptually consistent with these earlier studies and the original work of Leontief (1936).

double-counting, impact multipliers for the SII were calculated which excluded the indirect and induced impacts to PII- already reflected in Table 3.

Table 4 presents the estimated adjusted indirect and induced impact SII multipliers for each of the PII. These multipliers represent the total change in economic activity across all SII associated with a one dollar loss in total revenue in any give PII. For example, economic activity decreases in the Arkansas by an additional 21 cents for every dollar of lost productivity in corn production.

Table 4: SII Multipliers

	Rio Grande	Arkansas
Barley	0.20	-
Corn (grain)	-	0.21
Hay	0.26	0.29
Potatoes	0.33	-
Sorghum	-	0.21
Sunflowers	-	0.20
Wheat	0.20	0.21

The indirect and induced impacts to SII associated with the change in productive capacity in the PII are reported in Table 5. These represent additional lost economic activity (relative to that presented in Table 3) due to linkages with other sectors of the economy.

Table 5: Indirect and Induced Effects in SII

	SII Indirect + Induced	
	Rio Grande	Arkansas
Barley	(127,752)	-
Corn (grain)	-	(8,208,827)
Hay	(2,379,346)	(4,762,327)
Potatoes	4,075,776	
Sorghum	-	(2,517,995)
Sunflowers	-	(536,676)
Wheat	111,887	(2,995,633)
Total	1,680,566	(19,021,458)

Tables 6 and 7 present total lost economic activity across all industries by basin. Estimates of losses (gains) in employment opportunities associated with the change in economic activity are also reported.

Table 6: Total Change in Economic Activity and Employment Across Sectors in the Rio Grande

	Total Impact	Employment Loss
Barley	(755,819)	(20)
Corn (grain)	-	-
Hay	(11,690,515)	(50)
Potatoes	16,541,204	94
Sorghum	-	-
Sunflowers	-	-
Wheat	661,957	18
Total	4,756,827	42

Table 7: Total Change in Economic Activity and Employment across Sectors in the Arkansas

	Total Impact	Employment Loss
Barley	-	-
Corn (grain)	(48,087,345)	(630)
Hay	(21,176,058)	(236)
Potatoes	-	
Sorghum	(14,750,428)	(193)
Sunflowers	(3,178,128)	(21)
Wheat	(17,548,434)	(230)
Total	(104,740,393)	(1,309)

Predominately driven by higher than normal revenues from potato crops, overall economic activity increased by roughly five million dollars in the Rio Grande. By comparison, in the Arkansas, economic activity fell by roughly 105 million dollars, representing a loss of more than 1,000 jobs.

Forward Linkages and Increased Production Costs

The analysis above does not include the impact on economic activity and production costs to forward linked industries. To estimate these additional impacts a second analysis was conducted using the Colorado Equilibrium Displacement Mathematical Programming Model (CEDMP), originally developed by Davies et al. (2010). Following the Harrington and Dubman ERS-EDMP (2008), researchers at Colorado State University developed a model focused on Colorado's agricultural economy. The main objectives of the model are to explore welfare effects for producers and consumers and the change in final demand associated with an exogenous change in the market.[13]

The CEDMP has several advantages over traditional input-output analysis. In addition to the ability to reflect changes in forward linked industries (i.e. the right hand side of Figure 2), the CEDMP is able to capture more sophisticated economic relationships such as managerial responses (e.g., the substitution of inputs) and the potential influence of interstate trade. Unlike input-output models, where the initial impact to total revenue is exogenously determined, changes in economic activity and final demand are endogenous responses to changes in internal and external supply and demand conditions. The latter includes the ability to model the effect of reduced yields on grazing lands, another aspect not reflected in the input-output analysis.

Why not just use the CEDMP? The model was originally developed as part of an effort to better understanding the potential impacts of increased demand for ethanol on Colorado's agriculture and extends only to the agricultural sector. Indirect and induced impacts to sectors outside of agriculture are not reflected in the results. To develop a complete picture of the economy wide impacts to economic activity it was necessary to incorporate input-ouput techniques into the analysis. Combining both approaches allows for a more complete understanding of the drought's impact, including the impacts to the livestock industry (both in terms of economic activity and increased production costs) associated with the drought.

The following steps were taken to isolate, independent of external supply shocks associated with widespread drought outside of Colorado, the impact of reduced productivity on crop and grazing lands on the livestock sector. The model was first calibrated to a baseline reflecting conditions at the time of the 2007 Agricultural Census. Second, "2011 Baseline" conditions were then established that reflected ongoing external supply shocks associated with widespread drought outside of Colorado. Output from the 2011 Baseline represents what would have happened had drought conditions not existed in 2011. Finally, yields on crop and grazing lands were adjusted to estimate the combined effect of the external and internal supply shocks.[14]

[13] For a more detailed description of the model, including its theoretical foundation see Pritchett et al. (Draft 2011).
[14] The reduction in grazing yields was based on Nelson (2012).

To estimate the impact of the drought livestock producers, 2011 Baseline conditions were compared to output from the 2011 drought model runs.[15]

Results suggest that drought conditions in Colorado were responsible for less than a one percent reduction in total revenues for the livestock industry statewide[16], as the direct impact of local climatic conditions on production levels and prices in these sectors was negligible. This is consistent with expectations (in the short-run) and reported changes in production for the state of Colorado between 2010 and 2011.[17]

While the impact on total revenue was relatively small, production costs increased significantly as producers were forced to provide supplemental feed and faced higher feed costs. Table 9 presents the estimated change in feed costs to the livestock feeding, dairy and beef production industries associated with the drought.

Table 8: Estimated Change in Total Feed Costs for the Livestock Industry

	Change in Total Cost
Forage	$98,720.459
Grain	$12,014,243
Total	$110,734,702

The overall increase in feed costs exceeds 110 million dollars, representing a roughly 10-15 percent increase over the period 2005-2010 (CAS 2011).

[15] Note that this approach is conceptually similar to that adopted in the previous section, where Potential Revenue (reflected here as 2011 Baseline) is compared to Actual Revenue (2011 Drought).
[16] While crop production is modeled at the basin level, the livestock industry is modeled at the state level. While the internal supply shocks represent changes in conditions in each basin, changes in economic activity and production costs are only available for the entire state.
[17] http://www.nass.usda.gov/Statistics_by_State/Colorado/Publications/Ag_Update/agup0112.pdf

Conclusions and Caveats

This report presents estimates of the impact of the 2011 drought on economic activity and production costs. The drought resulted in significant reductions in harvestable acres and yields, primarily in the Arkansas Basin. In total, the drought resulted in more than 110 million dollars in lost economic activity throughout the Rio Grande and Arkansas Basins, producers in the Arkansas suffering the most. In additional to lost revenues, the drought resulted in roughly 110 million dollars in additional feed costs.

These figures do not reflect insurance payments. In the counties impacted, livestock and crop producers received slightly less than 50 million dollars in insurance payments (USDA FSA Disaster Assistance Programs). While these payments help to offset the direct losses experienced by PII, the extent to which these payments impact overall economic activity is unclear.

The drought's timing played an important role in mitigating the impact on livestock production. In general, ranchers had sufficient carryover hay and forage stocks to feed cattle as the drought intensified, and profits gained prior to the drought meant that ranchers had cash resources with which to purchase higher cost feedstuffs. The forage stocks and cash resources were sufficient to avoid a large scale liquidation of breeding livestock in fall 2011, but anecdotal evidence suggests that ranchers have begun liquidating herds in 2012 in the face of ongoing drought. The impact analysis does not include liquidation of cattle during this calendar year.

Finally, it should be noted that the estimates reported here only reflect the short-term impacts associated with drought conditions experienced in 2011. For example, the long-run impacts associated with short-term decisions to cull herds are not reflected. This report also does not reflect impacts associated with drought conditions experience in 2012, which appear to be more severe and widespread.

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