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Estimating the Economic and Social Impacts from the Drought in Southern Colorado

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Abstract: Over the course of the 2011 summer, 17 counties in southern Colorado were designated disaster areas due to severe drought conditions. Drought events can have large impacts on the economies of rural communities, not only directly impacting producers, but also having an indirect effect on enterprises and institutions throughout the supply chain. We use an Input-Output model (I-O), an Equilibrium Displacement Mathematical Programming model (EDMP), and a combination of the two to quantify economic impacts and to compare results across modeling techniques. Combining the two approaches allows for a more realistic representation of the agricultural sector (via EDMP), while still allowing us to model the indirect and induced impacts on the non-agricultural (via I-O) sectors of the economy. The estimated impact of the drought for the economy of southern Colorado ranges between $83 and $100 million.

Keywords: *Drought, economic impact, input-output model, equilibrium displacement model*

In the summer of 2011, extreme drought 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 (Farm Service Agency 2012a, 2012b).[1] Drought events can have large impacts on the economies of rural communities, not only directly impacting producers, but also having an indirect effect on enterprises and institutions throughout the supply chain and broader economy.

The primary goal of this paper 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. Additionally, the results will highlight the large difference in losses from irrigated versus non-irrigated crops. Quantifying the economic impact of the drought is important in terms of both informing current efforts to mitigate the impacts of the current drought, as well as designing policy to make these areas more resilient to future periods of drought. Consistent with the literature (see Watson et al. 2007), economic impact is defined as the net change in revenue associated with the drought in the existing regional economy, where net change refers to the fact that only the change in economic activity that can be directly attributed to the drought will be included in the study.

In this study, we consider three approaches to analyzing the economic impact of the 2011 drought in southern Colorado: a traditional Input-Output model (I-O), an Equilibrium Displacement Mathematical Programming (EDMP) based approach, and a combination approach using an EDMP model to determine impacts in the agricultural sector and an I-O model to extend those impacts across all sectors of the regional economy. We are not aware of previous studies that have combined these two modeling approaches to analyze the impact of drought. This three-pronged approach provides us with a range of estimates of potential impacts. As part of the analysis we discuss the pros and cons of each approach, as well as compare results across each of the three approaches illustrating the role that different economic assumptions and methods may have on the results from economic impact models.

How Drought Impacts a Rural Economy

Drought impacts local economies both directly and indirectly. The direct effects of drought come in the form of reductions in output and lost revenues for agricultural producers. Indirect effects are the lost revenues from upstream and downstream entities along the supply chain as a result of the reduced output experienced by the directly impacted producers. The magnitude of the direct impact, in dollar terms, depends on the drought sensitivity of the crops being grown, the ability and cost to provide supplemental irrigation, and how responsive market prices are to change output levels. Here we have defined direct effects as a reduction in output and lost revenues but have not included changes in costs (such as irrigation), which one would assume are likely to have an effect. Although we are able to model changes in costs for indirectly impacted industries (such as increased feed costs for the livestock industry), we are not able to capture changes in costs for the directly impacted industries. This modeling nuance highlights a weakness of this type of analysis in its ability to capture the whole story of the region-wide implications of drought.

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 along the supply chain with other industries within the local economy. We refer to those industries indirectly impacted (via forward and backward linkages) as Secondary Impact Industries (SII). Note that impact to those entities along the supply chain and public sectors are not modeled directly, but rather determined within the model based on impacts experienced by PII.

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 resulting from drought conditions. This paper focuses on two consequences of this shock: (1) the net change in economic activity and (2) the impact on production costs for forward linked industries within the region.

The impact of drought on economic activity occurs through four avenues. 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. 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 1). 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 1). The total change in economic activity resulting from these secondary effects (both backward and forward)

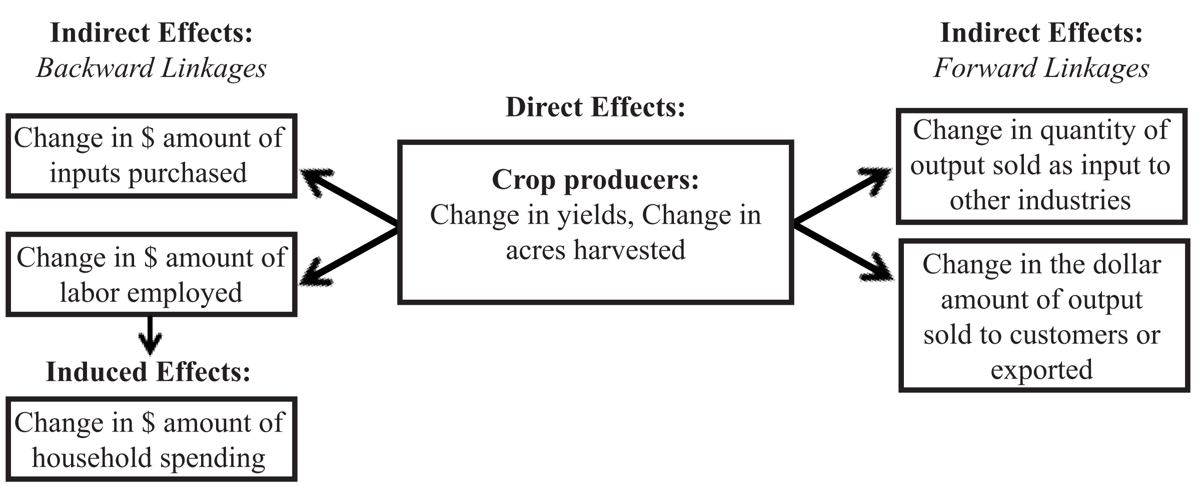

Figure 1. Example economy: forward and backward linkages between crop producers and the rest of the economy are illustrated.

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.

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.[2] 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.

Approach One for Estimating the Impact of Drought: Input-Ouput Model

First developed by Leontief (1936), I-O models estimate the change in economic activity, i.e., a change in total revenues, across all sectors of a local economy resulting from a change in final demand, defined as the value of goods and services produced and sold to final users (MIG 2012). I-O models are one of the main tools utilized to conduct regional impact analysis and have been widely used to look at economic impacts related to water transfers (e.g., Howe and Goemans 2003; Thorvaldson and Pritchett 2006) and droughts in other states (e.g., Diersen and Taylor 2003; Guerrero 2011). The reason for their widespread use is that I-O models provide data on all sectors of a regional economy including the flow of money from one entity to another, and with the availability of data and software packages (such as IMPLAN) results can be obtained relatively easily, at a low cost, and in a timeframe often necessary for these type of studies (where more complex models might take years to build).

For this study, change in economic activity utilizing the I-O approach was estimated in two steps. First, the change in economic activity, including the direct and indirect impacts, was estimated for the PII. The crops model included barley, corn, potato, and wheat producers in the Rio Grande and corn, sorghum, sunflower, and wheat producers in the Arkansas. Basin specific I-O models were then used to estimate the impacts, indirect and induced, of the drought on the SII. The sum of these two parts represents the total change in economic activity, ignoring forward linkages.

The impact to PII was 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. Note that Lost Potential Revenue differs from the change in total revenue. The goal of this analysis is a with-and-without comparison; or a comparison of what would have happened in 2011 had drought conditions not existed to what actually happened. Equation (1) describes the calculation of Potential Revenue for each crop in each region.

Where:

- $Planted\ Acres_{2011}$: total number of acres planted in 2011.
- $Adj\ Ave\%Harvested_{1998\text{-}2010}$: 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.[3]
- $Adj\ Ave\ Yield_{1998\text{-}2010}$: 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.
- $Price_{2011}$: price per unit of output in 2011.

$$Potential\ Revenue = Planted\ Acres_{2011} * Adj\ Ave\,\%\,Harvested_{1998-2010} * Adj\ Ave\,Yield_{1998-2010} * Price_{2011} \quad (1)$$

Potential Revenue represents what producers would have earned if they had experienced typical growing conditions combined with, in most cases, higher commodity prices (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 indicated that no changes to production practices were made prior to April 2011 (Nelson et al. 2012). It is also consistent with reported estimates of planted acres; planted acreage was 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. For example, high feed grain prices are in large part not due to drought in southern Colorado, but the result of an increase in world-wide demand for meat. 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.[4] This assumption is also consistent with output obtained from Approach 2 (discussed below) that determines prices endogenously.

Estimates of lost potential revenue reflect the direct, indirect and induced impact of the drought to PII. What they do not reflect is economic activity lost in those sectors that were not directly impacted (i.e., SII). To calculate the indirect and induced impacts to SII, I-O models were created for each region using data from IMPLAN.[5]

In this study, we know the change in output for producers as a result of the drought. If we were to simply use this number to determine the economic impact, we would be overstating the impact because we would double count the portion of the output that is used as an input to another production process within the region. In input-output analysis, double counting is avoided by only modeling the change in final demand, i.e., the value of goods and services produced and sold to final users. To model final demand and avoid double-counting, impact multipliers calculated for the SII excluded the indirect and induced impacts to PII; as these impacts are already reflected in the calculation of Lost Potential Revenue. This modification allowed us to model impacts using a change in final demand rather than a change in total revenue generated from a change in sales to both final demand and intermediary sectors. 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 in its implicit assumptions and will lead to estimates of total impacts that are biased upward.

Table 1. Economic Impact Multipliers for Secondarily Impacted Industries. Multipliers (generated from IMPLAN) are multiplied by the estimated direct impact to obtain the indirect and induced impact for those Secondarily Impacted Industries.

	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

Table 1 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 given PII. For example, economic activity decreases in the Arkansas basin by an additional 21 cents for every dollar of lost productivity in corn production.

Approach Two for Estimating the Impact of Drought: CEDMP

Despite their widespread use, I-O models suffer from several shortcomings. Most notably: prices are exogenous, production exhibits constant returns to scale (i.e., a doubling of inputs will always lead to a doubling of output), forward linkages are not included (e.g., the livestock sector), and only changes in revenues, not changes in costs, are modeled.

To overcome these shortcomings, the Colorado Equilibrium Displacement Mathematical Programming model (CEDMP), originally developed as part of collaboration between the Colorado Department of Agriculture and Colorado State University, was also used to estimate the impacts of the drought on the agricultural sector. The CEDMP was modified from an EDMP model originally developed by the USDA Economic Research Service (Harrington and Dubman 2008), which provides a sector-wide comparative static analysis of the U.S. agricultural sector. The CEDMP combines an equilibrium displacement modeling approach, which can be traced back to Muth (1964), with positive mathematical programming, outlined by Howitt (1995).

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. This feature allows us to model the effect of reduced yields on grazing lands, another aspect not reflected in the input-output analysis. Additionally, the CEDMP captures both forward and backward linkages whereas input-output models only capture backward linkages.

To model the impacts of the drought using the CEDMP, a "baseline" was established by calibrating the model to reflect conditions outside of the study area in 2011, assuming normal, non-drought growing conditions in Colorado. This approach is consistent conceptually with the I-O approach adopted which utilized 2011 prices for the with-and-without comparison. This baseline represents what would have occurred had Colorado experienced normal climatic conditions in 2011. Baseline output was compared to model output generated assuming changes in yields and percentage of acres harvested that resulted from drought conditions. One difference between the two approaches is that using the CEDMP model we can reflect the impact of changes in yields on grazing lands which impact the demand for forage crops.

Approach Three for Estimating the Impact of Drought: Linking the I-O Model and CEDMP

The major shortcoming of the CEDMP is its limited scope; only changes to agricultural sectors are modeled. To overcome this, as illustrated in Figure 2, we link the two models using estimates of the change in economic activity within the agricultural sector from the CEDMP as inputs into the I-O model to determine the change in economic activity across non-agricultural sectors throughout the region.

A summary of each of the three approaches, in terms of the linkages captured, the scope, model inputs and outputs are presented in Table 2.

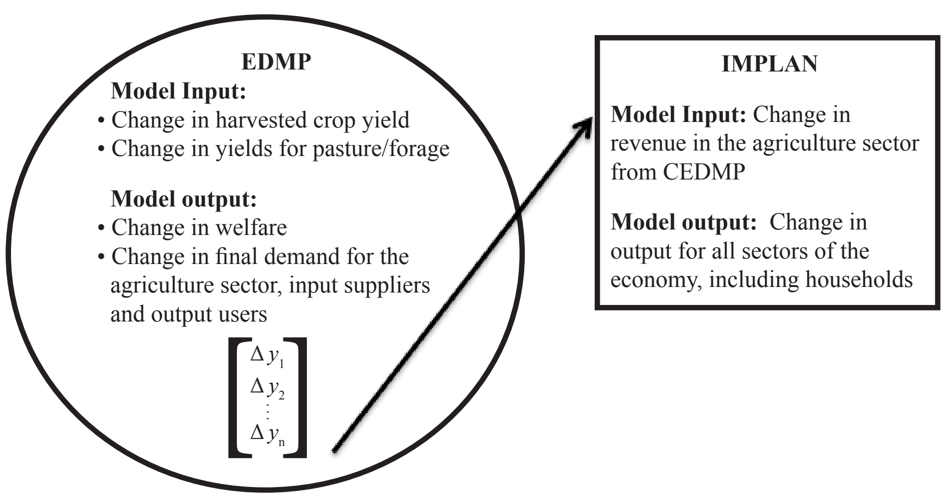

Figure 2. Overview of Approach 3- Linking the I-O Model and EDMP.

Table 2. Three Modeling Approaches for Estimating the Economic Impact of the Drought.

Approach	Linkages	Scope	Model input	Model output
1: I-O	Backward	All sectors of the economy in the 17-drought impacted counties	Change in revenue to PII attributed to drought due to decreased yields and fewer harvested acres	Change in output for all sectors of the economy, including households
2: EDM	Forward/Backward	Agricultural sector in the 17-drought impacted counties	Change in harvested crop yield +change in harvested acres	Change in output for the agriculture sector, input suppliers and output users
3: Linked	Forward/Backward	All sectors of the economy in the 17-drought impacted counties	Change in revenue in the agriculture sector from EDMP	Change in output for all sectors of the economy, including households

Results

The results section is split into two sub-sections. The first provides comparisons of the estimates of the change in total economic activity across each of the three modeling approaches. The second focuses on comparing, across each of the three approaches, estimates of the total economic impacts stemming from the impacts of the drought on each of the PII. Each sub-section refers to Table 3, which contains estimates across each of the three approaches of the total economic impacts stemming from each PII and in total.

Comparison of Total Economic Impacts

Using I-O alone, the estimated total economic impact of the drought is approximately $100 million. By comparison, both Approach 2 and 3 produced total estimates that are 30 and 16 percent less, respectively. These differences reflect two factors. First, the scope of the I-O model includes all sectors within each of the regions, whereas the CEDMP only traces the impact of lost productivity through the agricultural sector. Second, unlike the case with the I-O, the CEDMP allows prices to adjust and producers to mitigate impacts by changing their input mixes; both of which act as mitigating factors, dampening the impacts calculated in the linking approach.

Interestingly, the forward linkages included in the EDMP model, but not in the I-O model, did not produce smaller results in the former, as would have been expected. This result is due to the very small impact of forward linkages. In Colorado, the feedlots import both feed and cows (the most significant inputs based on cost shares).

Table 3. Total Economic Impacts in the Arkansas and Rio Grande River Basins for each Modeling Approach.

	I-O	EDMP	Linking I-O and EDMP
Barley	($753,682)	$261,330	$313,595
Corn	($48,087,345)	($46,000,000)	($55,468,909)
Hay	($32,908,131)	($3,942,083)	($5,085,850)
Potatoes	$16,579,019	$2,293,781	$3,050,729
Sorghum	($14,750,428)	($716,877)	($864,443)
Sunflowers	($3,178,128)	$996,399	$1,198,842
Wheat	($16,888,350)	($22,000,000)	($26,528,609)
Total	**($99,987,045)**	**($69,107,450)**	**($83,384,644)**

Due to high beef prices and a reliance on imports, feedlots ran at capacity and did not feel the impacts of the drought on their revenue streams. Note that the numbers presented here only reflect changes in revenue and do not reflect changes in costs. Increased costs were one of the main areas where livestock producers were impacted, but those impacts are not captured in an economic impact analysis.

Results from the linking approach are about 20 percent higher than when the CEDMP model is used alone, highlighting both the importance of the agricultural sectors within these regions and the importance of extending the analysis beyond just those industries immediately impacted.

Comparison of Total Economic Impacts by PII: Irrigated vs. Non-Irrigated Activities

Comparing results of economic impacts of potato producers (irrigated) versus those of wheat producers (mostly non-irrigated), we see profoundly different results. Drought impacts resulting from potato production were positive, ranging between \$3 million and \$16.6 million. The better than average revenues for potato producers resulting from the drought could be attributed to favorable growing conditions (warmer and sunnier weather) and high commodity prices, with the drought having no negative impact because potatoes in this region are irrigated, and potential "drawdowns" of soil moisture will not impact yields until subsequent growing seasons (if moisture is not replenished through natural precipitation).[6]

Drought impacts resulting from wheat production, on the other hand, were negative ranging between \$16.8 million and \$26.5 million. Wheat production in the region is dominated by dry land acres, relying only on rainfall for crop production. The significant difference between impacts of irrigated versus non-irrigated crops demonstrates the heterogeneity in drought impacts; some producers can see large, negative impacts while others can actually see positive impacts. When talking about drought impacts it is important to remember that, although total impacts are often presented, these impacts are rarely evenly distributed.

Conclusion

The estimated economic impact of the drought for the economy of southern Colorado ranges between \$83 and \$100 million. Moreover, two key stories emerge from this study that should inform future research and policy decisions. First, the results highlight the variability in the impacts of drought across producer types and regions. Specifically, producers able to minimize yield losses by irrigating (especially from ground water where availability is not susceptible to climatic variation), benefited from the drought due to higher commodity prices. This highlights the need for policies that address the wide variation in impacts felt by irrigated versus non-irrigated producers.

Second, three different approaches to estimating the impacts of drought are presented: I-O, CEDMP, and a combination of the two. Linking the CEDMP model and the I-O model provides a lower estimated impact because the CEDMP model allows producers to augment input mixes and allows for prices to vary. Allowing for these changes to occur within the model provides a smaller impact than described when the I-O model is used alone, which does not enable any flexibility. Theoretically, the linking approach provides a better estimate of the impacts of the drought because of the CEDMP's ability to more accurately model how producers respond to drought conditions. In reality, the true impact of the drought most likely falls somewhere between the two estimates, so the value of this approach is likely framing that range. However, because we are not able to model all aspects of the drought, true impacts could be either higher or lower than those estimated here.

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Notes

1. 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.
2. In Colorado, livestock receipts account for roughly two-thirds of total receipts to Colorado agriculture National Agricultural Statistics Service (2012).
3. 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 times the price in 2011.
4. The one exception to this is hay (both in terms of observed prices and output from the CEDMP model). Because of relatively high transportation costs, the market for hay is more localized. The price of hay increased by roughly 50% in 2011 relative to 2010.
5. Input-output models have been widely used to look at economic impacts related to water transfers in Colorado (Howe and Goemans 2003; Thorvaldson and Pritchett 2006), as well as to analyze drought impacts in other states (Diersen and 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).
6. In the 2011 growing season, there were no water restrictions as the previous winter had provided plenty of snowpack.

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