October 2011

EDR 11-01

Economic Development Report

Colorado State University Extension

Department of Agricultural and Resource Economics, Fort Collins, CO 80523-1172
http://dare.colostate.edu/pubs

AGRICULTURE ECONOMIC IMPACT OF ENERGY ALTERNATIVES AND CLIMATE CHANGE IN COLORADO: EVIDENCE FROM AN EQUILIBRIUM DISPLACEMENT APPROACH

Stephen Davies,[1] Eihab Fathelrahman,[2] Amalia Davies,[3] and James Pritchett[4]

Overview

Colorado agriculture has blossomed with the development of water resources that are used for growing crops, which, in turn, spurs value-added production in the meat, sugar and dairy sectors. Increasing urban development is expected to spur the reallocation of an additional six hundred thousand to one million acre feet of agricultural water to new municipal, industrial and energy demands by 2040. Reallocation and climate change will likely to lead to large scale fallowing of agricultural lands. The purpose of the modeling effort summarized in this document is to better understand the impacts borne by the agricultural economy that result from large scale fallowing.

Methodology

Agriculture is an important base industry in Colorado generating more than $6 billion dollars of farm gate receipts and contributing broadly to the state's economic activity – nearly 20% of Colorado's gross domestic product can be traced to agriculture or allied industries. It is also a sector in transition with new markets developing, technological innovations improving efficiency, laws and institutions evolving and, importantly, agriculture is seeing increasing competition for key resources such as land and water. In the midst of these structural changes, we created a state-of-the-art model to help develop 'what-if' scenarios related to issues arising from the multiple dynamics affecting the agricultural sector of Colorado. This model is called the Colorado Equilibrium Displacement Mathematical Programming (CEDMP) model.

The underlying model is a positive mathematical programming model first developed by Howitt (1995) and then improved by Preckel et al. (2002) for the entire US. The model further modified to simulate agricultural sector policy scenarios by Harrington and Dubman (2008). We extend the approach to consider water as a productive resource in Colorado agriculture with specific primary shocks to the South Platte Basin and linked impacts to the Arkansas River basin and the Rio Grande basin. The equilibrium displacement approach maximizes an objective function of social net benefits by allocating resources such as land, labor, capital and other inputs through market mechanisms and assuming

[1] Professor, Dept. of Agricultural and Resource Economics, Colorado State University.
[2] Economist, USDA, Animal and Health Inspection Service, Fort Collins, Colorado.
[3] Research Associate, Dept. of Agricultural and Resource Economics, Colorado State University.
[4] Associate Professor, Dept. of Agricultural and Resource Economics, Colorado State University.

profit maximizing behavior by business owners (Figure 1). We re-create the status quo of economic activity using the most recent economic data that captures the implicit relationships between final products such as cheese, meat and milk and important inputs such as feeds. We then "shock" the model by changing available resources, such as irrigated farmland, and see how outputs are changed when social net benefits are re-optimized. Specific details of the model can be obtained from the authors upon request.

Simulations

Fallowing of irrigated cropland is anticipated as agricultural water right holders voluntarily release water for use by the energy and municipal sectors. Extensive fallowing will lead to a reallocation of resources and income streams in the agricultural and rural regional economy. Climate change including its impact on available irrigation water, average temperature and length of the growing season and the occurrence of extreme weather events - is an important factor in determining the intensity and duration of these impacts. Thus, the intent of this document is to describe a 'what-if' scenario analysis in which the relative size of the resource reallocation is quantified at the same time -the substitutions among land, labor and water are described and the potential mitigating impact of interstate commerce is captured.

To narrow the scope of possible results, we focus on the following simulations:

Base Simulation: This simulation shifts water resources from agricultural to municipal uses in the South Platte and Arkansas River basins by reducing water availability by 22% and 18% respectively so that available irrigated cropland is reduced by the same proportion (Pritchett et al. 2008). The scenario increases ethanol production from 175 million gallons annually to 308 million gallons in anticipation of increasing local demand.

Simulation 1 (Poor Climate): The first simulation is a "poor" climate outcome in which season-long agricultural water availability is reduced from the base scenario by an additional 14.0%. In this scenario, it is assumed that groundwater resources are depleted and seasonal precipitation is less available for cropping.

Simulation 2 (Forages Benefit)**:** This simulation builds on the *base simulation* of water transfer from agriculture to energy and municipal use. A potential climate outcome is increased temperature and decreased precipitation during the reproductive period for corn. The agronomic consequence of this outcome will be a negative impact on irrigated corn yields but improved yields for important crops such as winter

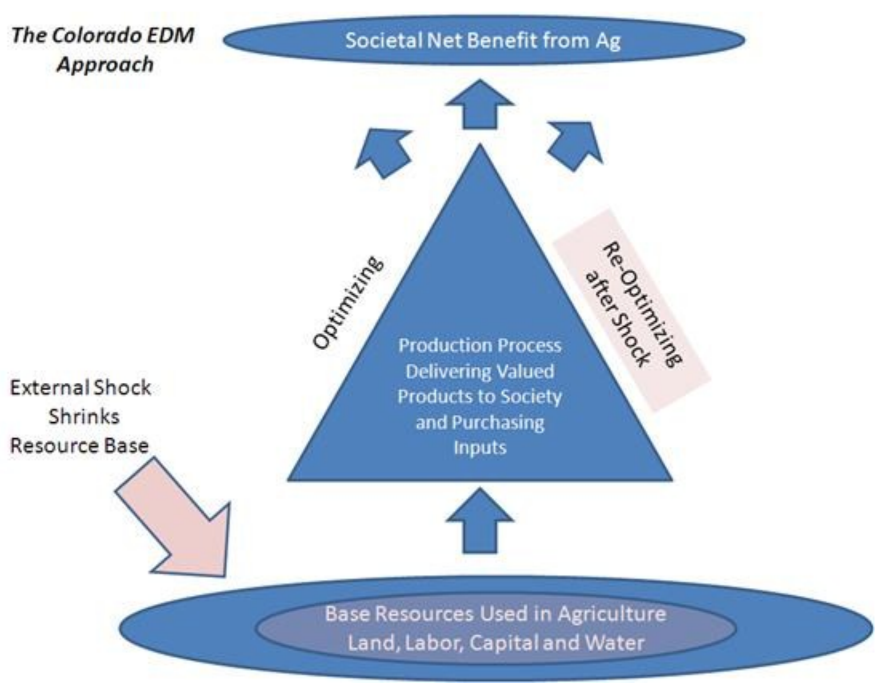


Figure 1. Colorado Equilibrium Displacement Approach

wheat, corn silage, irrigated hay, range and pasture. Under these conditions, irrigated corn production declines by 8% as higher temperatures arise during the pollination period reducing yields, while the production of corn silage for forage increased by 13% as biomass growth is encouraged. Other direct impacts include the production of dryland winter wheat increasing by 13% assuming sufficient moisture to support seed germination; reduced milk output from dairy cows due to heat stress (-18%), increased production of irrigated hay associated with a longer growing season and potentially more cuttings (+18%); and increased range and pasture production (+8%) assuming sufficient season long moisture.

Simulation 3 (Drought Year)**:** This simulation also builds on the *base simulation* of water transfer from agriculture to energy and municipal use. In contrast to *simulation 2*, a drought year is assumed leading to reduced dairy output and harvested corn and wheat acres. Yields are reduced for wheat and corn for grain, and range and pasture conditions suffer. The total production of hay and corn silage is increased assuming that biomass production benefits from a longer growing season and higher temperatures, while corn intended as a grain crop is instead harvested for silage.

More specifically, in *Simulation 3* the harvested acres of dryland wheat and corn decline by 60% from the *base simulation*. Dryland wheat yields decline by 13% as insufficient rainfall exists for seed germination. Irrigated corn yields are reduced by 15%, dry land corn yields suffer an 18% reduction, and range and pasture forage biomass production is reduced by 15%. Increased temperatures stress dairy cows so that milk production is reduced by 18%. Net increases occur for corn silage production (+18%) and irrigated hay production (+18%).

These scenarios are treated as exogenous shocks to the equilibrium depicted in the description of the Colorado EDMP that is illustrated Figure 1. As the resource base for agriculture shrinks due to climate change and competition for water resources, substitutions among primary factors of production are made and opportunities to import factors and products via interstate commerce are realized. The net result is a change in overall production, income and prices that is described in the next section.

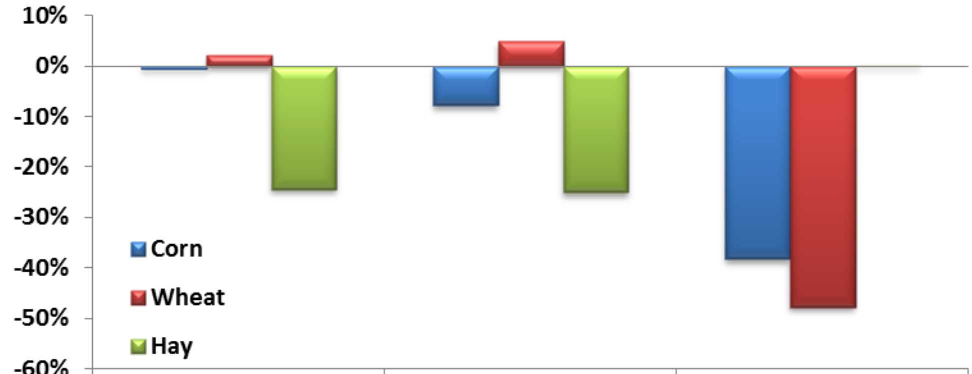
Results

In the subsequent text, the *Base Simulation* is treated as a benchmark, and the three simulations are compared to that benchmark. Comparisons are made according to productive capacity (total acres and number of livestock), agricultural prices, production of livestock feed, exports of agricultural goods from the state of Colorado to other regions, and imports of agricultural good from other regions.

Productive Capacity**:** Shifting water from the agricultural industry to the energy and municipal sectors will reduce irrigated acres. Likewise, shrinking available water due to climate change will also reduce production of crops. Facing fewer irrigated acres and less precipitation, farmers will respond to the price received for farm products and the cost of farm inputs by altering their crop rotation (Figure 2). More specifically, the acreage allocated to hay production declines by 24% and 25% in *Simulation 1 (Poor Climate)* and *Simulation 2 (Forages Benefit)* when compared to the *Baseline Simulation*. In contrast, a simulation in which a drought year occurs (*Simulation 3)* leads to nearly the same hay production as the *Base Simulation*. The difference in hay production occurs because in *Simulation 3* corn prices increase by a sufficiently high amount to induce corn imports. Imports displace local production of corn, and hay can be used as a replacement crop on these acres. Import substitution and poor precipitation explain why corn and wheat production decline by 38% and nearly 48% respectively in *Simulation 3.* Other factors that influence the change in acres include the demand for feed and costs of production.

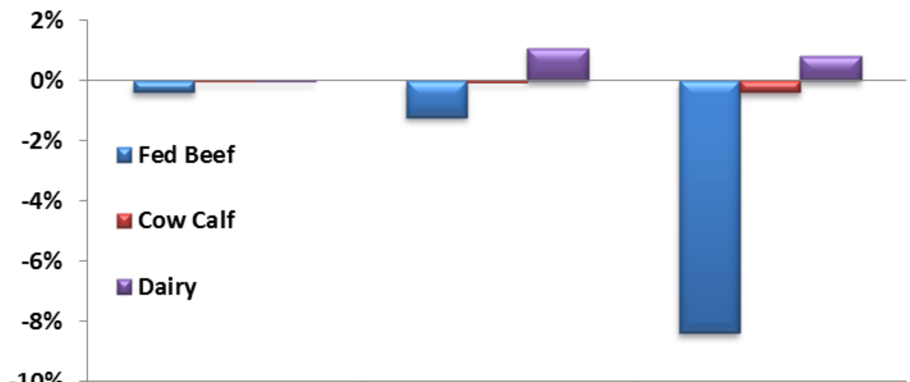
Livestock production responds to climate change, but to a lesser extent when compared to acres of crop production. *Simulation 3* indicates the most dramatic changes from the *Base Simulation* with fed beef production declining by 8.4% (Figure 3) as a result of higher corn grain prices escalating feedlot production costs. Importing feedstuffs is one reason why changes to the livestock sector are less dramatic.

Feed Crops: Climate change scenarios generally suggest a decrease in feed available for local livestock consumption as is illustrated in Figure 4. In S*imulation 1* (Poor Climate), hay production declines from the base simulation by 41.5%, and similarly for *Scenario 2* and



	Simulation 1 (Poor Climate)	Simulation 2 (Forages Benefit)	Simulation 3 (Drought Year)
Corn	-0.6%	-7.8%	-38.2%
Wheat	2.3%	4.9%	-47.7%
Hay	-24.4%	-25.0%	0.2%

Figure 2. Percent Change in Major Crop Production Acres from Base Simulation

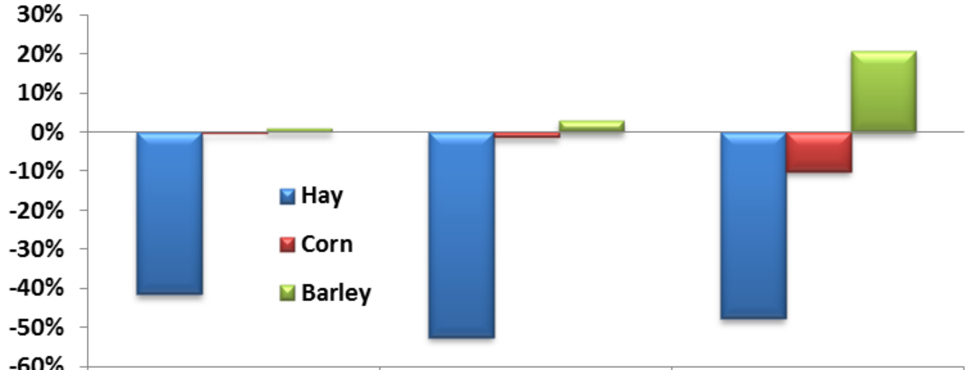


	Simulation 1 (Poor Climate)	Simulation 2 (Forages Benefit)	Simulation 3 (Drought Year)
Fed Beef	-0.4%	-1.2%	-8.4%
Cow Calf	0.0%	-0.1%	-0.4%
Dairy	0.0%	1.1%	0.8%

Figure 3. Percent Change of Livestock Production from Base Simulation

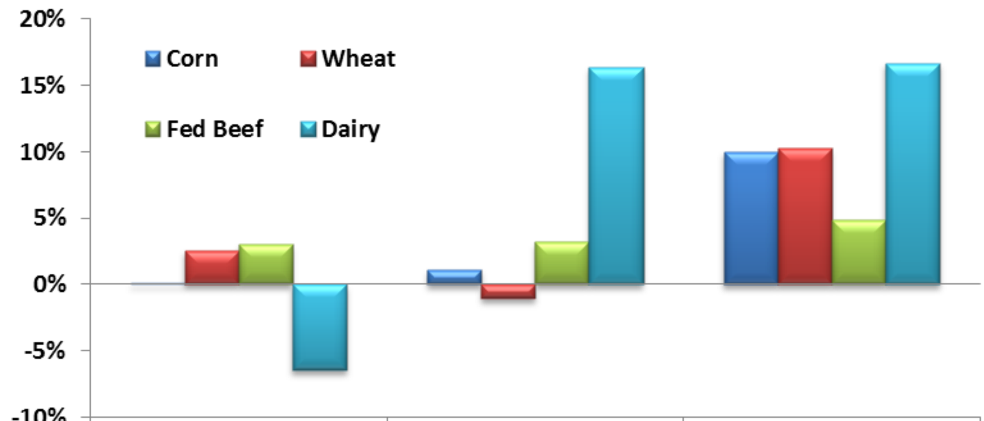
Scenario 3. In part this is due to reduced acreage, but also because more range and pasture is available. Corn is a more frequently utilized feedstuff, and its production is relatively constant in *Scenario 1* and *Scenario 2*, but declines in Scenario 3 because of very low moisture. Barley production increases about 21% in *Simulation3* relative to the baseline. Note that barley makes a very small production of all feed, just 7.7% of the total feed produced in *Simulation 3.*

Prices: Declining crop acres will tend to increase crop prices if sufficient substitutes are not available. As illustrated in Figure 5, model simulations indicate that prices almost universally increase. Both corn and wheat prices increase by about 10%, fed beef prices increase nearly 5%, and dairy products prices increase up to about 17% in *Simulation 2* and *3*. These results indicate that consumers may suffer as less product is sold and at higher prices.



	Simulation 1 (Poor Climate)	Simulation 2 (Forages Benefit)	Simulation 3 (Drought Year)
Hay	-41.5%	-52.6%	-47.8%
Corn	-0.5%	-1.4%	-10.1%
Barley	1.0%	3.0%	20.8%

Figure 4. Percent Change in Feed Consumption from Base Simulation

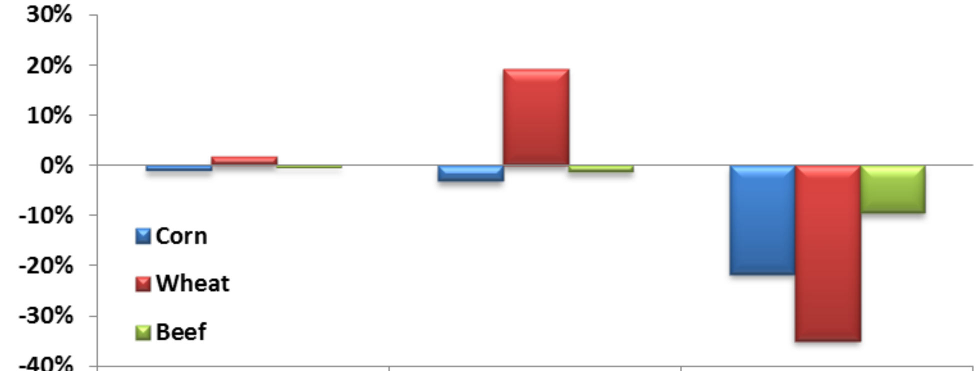


	Simulation 1 (Poor Climate)	Simulation 2 (Forages Benefit)	Simulation 3 (Drought Year)
Corn	0.1%	1.1%	10.0%
Wheat	2.6%	-1.1%	10.2%
Fed Beef	3.0%	3.2%	4.8%
Dairy	-6.4%	16.4%	16.7%

Figure 5. Percent Changes in Sale Prices from the Base Simulation

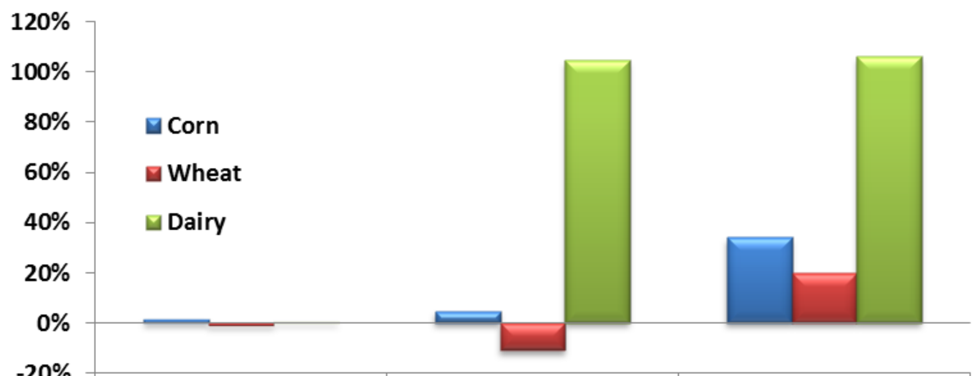
Interstate commerce is an important revenues source for Colorado farmers as well as a mitigating factor for local shortfalls in livestock and ethanol production. All things being equal, exporting goods will tend to enhance farm income, while imports will tend to reduce prices when shortages exist. The following subsections delineate climate change impacts on the exports of agricultural goods and imports that are meant to replace local production.

Export of Colorado Agriculture Products: As illustrated by Figure 6, exports of corn decline slightly from the *Baseline Simulation* in *Simulation 1* and *Simulation 2*. Wheat exports tend to increase in *Simulation 2,* in no small part due to increased winter wheat acreage. Beef exports are relatively unchanged except under the more extreme conditions of *Simulation 3*, in part because of very high feed prices.



	Simulation 1 (Poor Climate)	Simulation 2 (Forages Benefit)	Simulation 3 (Drought Year)
Corn	-1.0%	-3.1%	-21.7%
Wheat	1.7%	19.3%	-34.9%
Beef	-0.4%	-1.3%	-9.5%

Figure 6. Percent Change of Colorado Agriculture Exports from the Baseline Simulation



	Simulation 1 (Poor Climate)	Simulation 2 (Forages Benefit)	Simulation 3 (Drought Year)
Corn	1.6%	4.8%	34.0%
Wheat	-1.0%	-11.0%	19.9%
Dairy	0.1%	104.7%	106.1%

Figure 7. Percent Change of Colorado Agriculture Exports from the Baseline Simulation

Imports of Agriculture Products to Colorado: Figure 7 illustrates the changes in imports in *Simulations 1, 2 and* 3. In general, imports tend to increase when local prices are high as a result of stable demand and decreased supplies of agricultural goods. Corn imports are moderate relative to the baseline in *Simulation 1* and *Simulation* 2, and wheat imports decline in the same simulations. Imported dairy products see significant increases in *Simulation 2 and 3* as local production declines due to animal stress and feedstuffs become expensive, but it should be noted that the imports still only comprise 25% of Colorado's consumption of dairy products.

Conclusions: This study demonstrates potential effects of the transfer of water resources from agricultural use to municipal use juxtaposed against climate change in Colorado. The agricultural economy in Colorado is dominated by livestock, which accounts for 67 percent of total receipts. Crops, including feed grains and forages, accounts for 33 percent of production receipts. Most of Colorado's agriculture is based on irrigated production, which depends on both groundwater and surface water sources. The water available from these sources for agricultural irrigation is expected to decrease.

In order to gain a foothold on the combined impacts of water transfers and climate change, a Colorado Equilibrium Displacement Model was created. The model is first calibrated to current economic conditions. The model is then "shocked" by decreasing the available water supplies and/or land available for agriculture production. The model then achieves a new equilibrium with associated prices and production levels of agricultural goods.

The initial baseline for the model is the titled *Baseline Simulation* and other model simulations are measured as departures from the baseline. *Simulation 1* reduces season long precipitation from the baseline by 14%, *Simulation 2* is a situation in which forage crops are favored relative to grain producing crops and *Simulation 3* characterizes very limited water availability.

In general, the impact of a changing climate and water transfers is to decrease the amount of agricultural goods produced, and consumers pay higher prices for these goods. These negative impacts are most pervasive in *Simulation 3*. Importantly, the livestock sector does not suffer as dramatic a downturn as the crops sector. In this case, interstate commerce is the mitigating source that provides inputs for livestock production. In general, importing agricultural goods will tend to put a cap on price increases to consumers and provide feedstuffs needed to continue production. The dairy industry faces significant downturn, but this is a consequence of the decreased productivity of stressed animals rather than access to local feed inputs.

Future opportunities to enhance this effort modeling the watersheds' "upper" and "lower" portions as the distributional impacts of reduced cropping are not expected to be spread homogenously. Indeed, municipal growth is generally contained in the upper portion of the watershed, and crop production is not equally distributed across the basin. The agricultural productivity relationships in the modeling effort can be improved; specifically by understanding how crop consumptive use will be altered by climate change. Notably, the net benefits of municipal growth are not considered in this analysis, rather attention is only focused on the agricultural economy.

References

Harrington, David H. and Robert Dubman. (2008). "Equilibrium Displacement Mathematical Programming Models: Methodology and a Model of the U.S. Agricultural Sector," Technical Bulletin No. (TB-1918). http://www.ers.usda.gov/publications/tb1918/

Howitt, R.E. (1995). "Positive Mathematical Programming," *American Journal of Agricultural Economics,* Vol. 77, No. 2. pp. 329:3412

Preckel, P.V., D.H. Harrington, and R. Dubman. (2002) "Primal/Dual Positive Math Programming: Illustrated Through an Evaluation of the Impacts of Market Resistance to Genetically Modified Grains," *American Journal of Agricultural Economics*. Vol. 84, No. 3. pp. 679-690.

Pritchett, James, Jennifer Thorvaldson, and Marshall Frasier. (2008). "Water as a Crop: Limited Irrigation and Water Leasing in Colorado," *Review of Agricultural Economics*, Vol. 30. No. 3. pp. 435-444.