THE EFFECT OF CARBON REDUCING POLICIES ON PRODUCTION ON THE TEXAS HIGH PLAINS

Andrew P. Wright
Darren Hudson
Texas Tech University
Lubbock, TX

Abstract

Increased interest in the connection between greenhouse gases and climate change has lead to several attempts to implement policies meant to limit the amount of carbon emitted in the United States. Given these efforts, along with the attitude of the current administration toward energy and climate issues, it is necessary for both policy makers and producers to understand the effect that carbon reducing policies will have on agricultural production at the regional level. This paper develops a model that measures carbon emissions for the Texas High Plains region and estimates the effect of restricting carbon emissions on net revenue, acres planted, and the amount of water used. A representative farm was developed using data from NASS, extension service budgets, and previous studies, and a linear programming model was developed that maximized net revenue. Using carbon equivalents based on data from extension budgets, the amount of carbon emitted in the baseline scenario was calculated, and by restricting the amount of carbon emitted to ninety-five percent and eighty-five percent of the baseline calculation, the effect of reducing carbon was analyzed. Results show that while the number of acres planted in the region would not change, the amount of water applied to crops for irrigation would decrease significantly; thus, carbon reduction policies tend to act as water conservation policies as well.

Introduction

Concerns about climate change have led to efforts to enact policies meant to curb the production of green house gases, such as carbon, by humans. In the United States, the most recent effort by the legislature to do so was the American Clean Energy and Security Act of 2009, which was approved by the House of Representatives but did not pass in the Senate. In addition, the EPA maintains that it has the right to regulate carbon emissions through the Clean Air Act, and has shown its willingness to enforce their own regulations.

As the debate about climate change continues, so will efforts to limit green house gas emissions by those who control policy. So far, agricultural production has not been targeted, but this may not always be the case; therefore, the possible impact of climate change policies need to be studied now so that the information is available should the debate ever include agriculture. In the past, efforts along these lines have focused on the overall impact such policies will have on total emissions (Pop et al., 2010 and Nalley et al., 2010). This study will focus on the effect of carbon restrictions on producer net income, acres planted, and the amount of water used.

Materials and Methods

The study area chosen for this project was the Texas High Plains, an area of forty counties in the Northwest part of the state. The total shaded area in Figure 1 illustrates the layout of these counties. The blue shaded area depicts the Northern High Plains and the red shaded area depicts the Southern High Plains. For each of these counties, a representative farm was established where corn, cotton, peanuts, sorghum, and wheat were grown. For corn and peanuts, only irrigated production was considered, while for cotton, sorghum, and wheat both dryland and irrigated production was allowed; thus, there were eight different crops considered in the study.

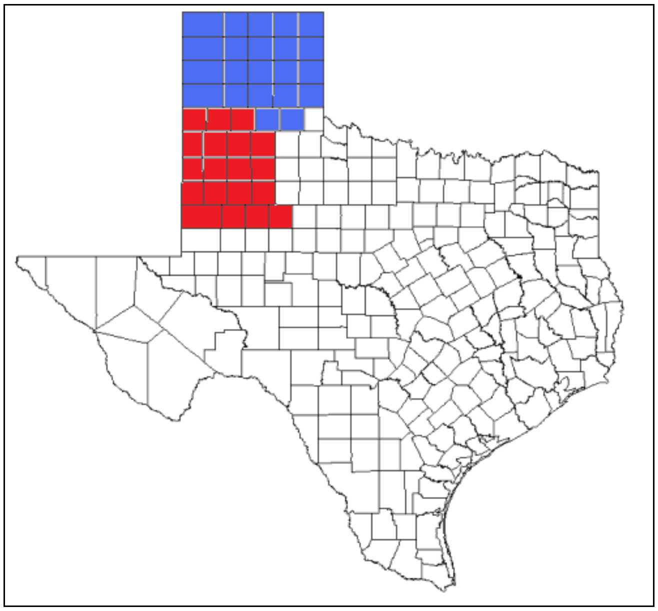

Figure 1. The Texas High Plains

Information for the crops and counties came from three primary sources. First, crop budgets published by the Texas A&M Extension Service for the years 2008 to 2010 provided information on crop prices, per acre costs, and per acre input quantities. For the price and input cost data, the average over all three budgets was used. Second, to calculate per acre yield, functions were obtained from previous studies that had been performed on the High Plains (Wheeler et al., 2006). Finally, NASS statistics for the years 2000 to 2009 planted acres, harvested acres, and yields for each crop in each county were used to provide realistic bounds for our calculations.

Using the above information, the net revenue for each county was calculated as

(1) $NR_i = \sum_j (R_j - C_j)$,

where R_j is the revenue from crop *j*, C_j is the total cost to produce crop *j*, and NR_i is net revenue in county *i*. Cost in the function is defined as

(2) $C_j = a_j (c_j + w_j x_j)$,

where a_j is the number of acres of crop *j* planted in a county and c_j is the per acre specified costs for crop *j* according to the extension service budgets, excluding irrigation costs. In our calculations, c_j is reduced to sixty percent of the amount in the extension budget for two reasons. First, our calculations do not include government supports, therefore, reducing the costs account for this. Second, the extension service budgets tend to overestimate the amount of inputs that farmers will use during production; therefore, reducing the specified cost accounts for this as well. The second term in the parenthesis is the irrigation cost per acre, where w_j is the cost associated with irrigation and x_j is the number of acre-inches applied. Irrigation costs are calculated separate from other costs so that the amount of water applied to each crop can be calculated later.

Revenue is defined as

(3) $R_j = h_j (y_j p_j)$,

where H_j is the number of acres of crop *j* harvested in a county. Harvested acreage is itself calculated using the ratio of the mean harvested acres to the mean planted acres for each crop in each county according to NASS data. Y_j is the per acre yield for crop *j*. The yield functions for each crop are quadratic functions that relate crop yield to water use in each county. Since we used yield functions from previous studies, there were some counties for which yield functions did not exist. In such a case, the functions from an adjacent county were used. It is assumed that neighboring counties would share enough of the same characteristics that the two county's yield functions would be similar. P_j is the unit price for crop *j*.

Using this specification, a non-linear programming model using the Excel Premium Solver add-in was specified that maximized net revenue in each county. The model was constrained so that the yield for each crop in each county in the solution was at least as much as the minimum yield found in NASS data and the planted acres of each crop in each county was no higher than the maximum amount according to NASS. Further constraints on the model include restricting the amount of water applied to dryland crops to zero, bounding the amount of water applied to irrigated crops between zero and twenty-three acre-inches, and maintaining that the sum of the planted acres for each crop in a county be at least equal to the sum of the average amount of planted acres for each crop according to NASS.

The model was initially run to provide a baseline estimate for net revenue, planted acres, and water use. These results allowed for the calculation of carbon emissions using information provided by Lanier Nalley at the University of Arkansas. This information essentially equates inputs in the extension budget to an equivalent per acre carbon emission. Using these equivalents, it was possible to calculate the carbon emissions by multiplying the carbon equivalent for a crop by the number of acres planted. Since water as an input is calculated separately from the rest of the budget, the carbon emission associated with irrigation was also calculated separately. Once total carbon emissions in each county were calculated, the effect on net revenue, planted acres and water use was determined by restricting carbon emissions in two different scenarios, one scenario where carbon is restricted to ninety-five percent of the baseline, and one with an eighty-five percent restriction.

Results and Discussion

How much net revenue is affected by carbon restrictions varies over the study area. Figures 2 and 3 are maps of the High Plains that illustrate the percentage change in net revenue in each county as carbon is restricted to ninety-five percent and eighty-five percent of the baseline respectively. Lighter shaded counties were not affected as heavily as darker shaded counties. When carbon is restricted to ninety-five percent, the most affected counties tended to be in the center of the region, where irrigation is more prominent, and counties in the southern part of the High Plains tended to see a greater percentage change in net revenue than counties in the Northern High Plains. When carbon is further restricted to eighty-five percent of the baseline the effect on net revenue is even greater with about half of the counties experiencing at least a thirty percent change in net revenue and three quarters experiencing at least a twenty percent change.

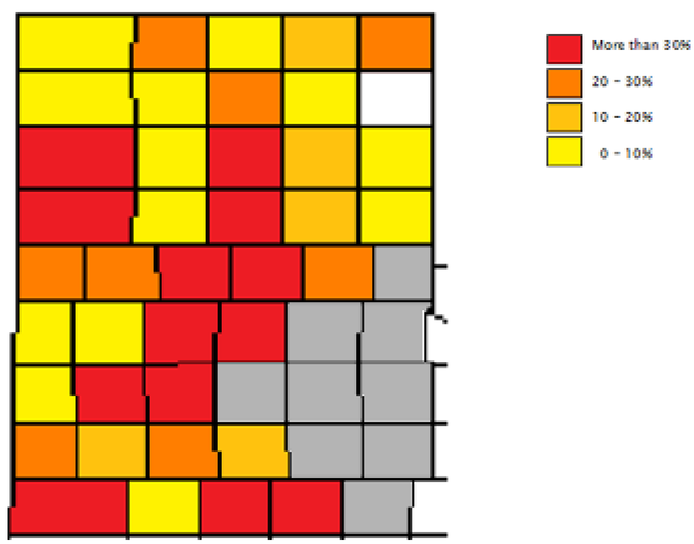

Figure 2. Percent change in net revenue when carbon is restricted to 95% of the baseline

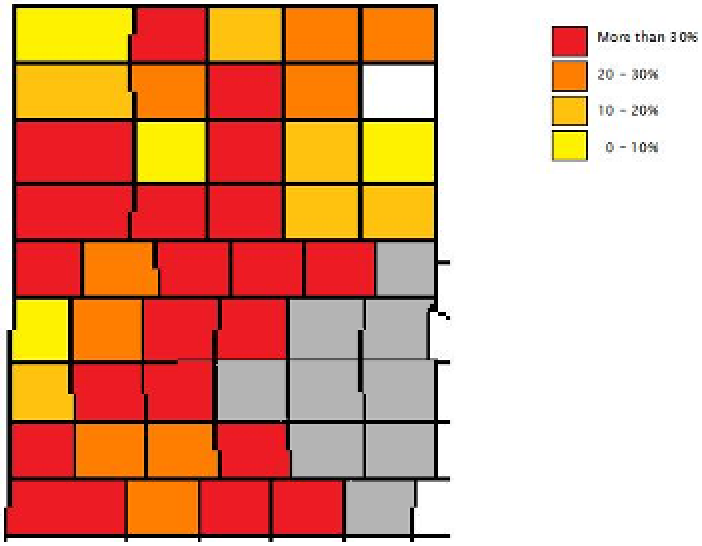

Figure 3. Percent change in net revenue when carbon is restricted to 85% of the baseline

Tables 1 and 2 show how net revenues, planted acres, and water use changed in a typical county in the study area. Not every crop is included in the table since the county grows no corn and very few peanuts, and dryland sorghum and dryland wheat never changed from the baseline. The results that are reported show what was typically seen in each county as carbon was restricted. Table 1 shows the net revenue and the planted acres for dryland and irrigated cotton, sorghum, and wheat. While net revenue does decrease significantly as carbon is restricted, this is only in part due to a reduction in the number of acres planted. The only crop to see a significant reduction in planted acres in this county is irrigated cotton, which indicates that something else must be happening. The information from Table 2 is required to understand why net revenue is decreasing.

Table 1. Results from a typical county: net revenue and acreage

Lubbock County					
	Net Revenues	Dry Cotton	Irr. Cotton	Irr. Sorghum	Irr. Wheat
Baseline	$71,394,792	109,100.0	206,300.0	42,800.0	9,600.0
95%	$40,956,264	109,100.0	109,240.9	42,787.9	9,520.6
85%	$37,273,110	106,958.5	106,958.5	42,799.9	9,600.0

Table 2. Results from a typical county: water use in acre-inches

Lubbock County				
	Total for County	Per Acre of Cotton	Per Acre of Sorghum	Per Acre of Wheat
Baseline	4,914,970.76	19.52	18.18	11.49
95%	2,202,894.02	15.74	8.72	5.89
85%	1,809,657.47	14.20	4.85	3.57

Table 2 shows how water use in the county changes as carbon is restricted. These numbers decrease significantly with the county reducing its water use by more than half when moving from the baseline to a ninety-five percent constraint on carbon. Reducing the amount of water reduces the crop yield, which is related to revenue. It can be concluded from this table that the decrease in net revenue is caused in part by both the reduction in irrigated cotton acres in the county and in reduced yields resulting from decreased water use.

Tables 3 and 4 show the aggregate change in net revenue, water use, and planted acres for the entire study area as carbon is restricted. Fewer than ninety-five percent restriction net revenue for the entire high plains decreases to about seventy percent of the baseline, while an eighty-five percent restriction reduces net revenue to about sixty percent of the baseline. Water use is restricted to about sixty percent of the baseline and fifty percent of the baseline under a ninety-five percent and eighty five percent restrictions respectively. As shown in table 3, the two crops most affected in terms of the number of acres planted are irrigated and dryland cotton. The next largest change is in the acres of irrigated wheat. The number of acres planted of the other crops in the study does not change significantly.

Table 3. Changes in net revenue and water use aggregated across the region

	Baseline	95% Constraint	85% Constraint
Net Revenue			
Texas High Plains	$1,273,964,348	$880,148,639	$777,073,011
Northern High Plains	$396,361,273	$314,260,938	$281,369,849
Southern High Plains	$877,603,074	$565,887,700	$495,703,162
Water Use			
Texas High Plains	80,298,596	50,364,535	42,909,096
Northern High Plains	26,756,814	19,198,342	16,192,607
Southern High Plains	53,541,782	31,166,193	26,716,488

Table 4. Changes in planted acres aggregated across the region

Change in Irrigated Cropping Patterns

	Corn	Irr. Cotton	Peanuts	Irr. Sorghum	Irr. Wheat
Baseline	896,494.02	1,943,359.55	158,700.00	724,154.69	1,222,678.39
95%	868,523.61	1,370,856.18	125,551.91	727,750.89	1,065,453.64
85%	792,839.17	1,279,154.67	154,584.42	710,329.45	1,072,690.93

Change in Dryland Cropping Patterns

	Dry Cotton	Dry Sorghum	Dry Wheat
Baseline	1,404,217	1,140,493	1,404,826
95%	1,231,684	1,153,865	1,416,992
85%	1,078,101	1,210,007	1,371,455

Summary

The results of this study show that reducing the amount carbon that producers are allowed to emit on the Texas High Plains will result in significant decreases in net revenue for the region. While some of this decrease will come from a reduction in the amount of land devoted to cotton production, the results indicate that the amount of acres planted in the region will not significantly change. Instead, most of the reduction in net revenue appears to be a result of smaller yields due to decreasing the amount of water used in irrigating crops. This is an important fact to keep in mind when considering the consequences of carbon policies.

Irrigation requires energy derived either from natural gas or electricity, both of which greatly contribute to carbon emissions, so it makes sense that when faced with carbon restrictions producers will reduce the amount of water they use. This means that carbon policy results in the same effect as that of water conservation policies, less water is used, and that water conservation policies will contribute to reduced carbon emissions. As the debate about carbon policy continues, and as carbon policy is formulated, the link between these two issues must be kept in mind.

The ongoing debate about climate change will result in future attempts to limit carbon emissions. While agricultural production has not been targeted at this time, the possibility exists; therefore, understanding the implications of such restrictions for producers is important. This study represents a first step in this direction. Including different production techniques, physical characteristics such as soil type, and sequestration calculations to the way this study considers the problem will help researchers to further our knowledge of the problem and provide a clearer picture of the issue.

References

Extension Agricultural Economics. 2008. *2008 Texas Crop and Livestock Budgets.* http://agecoext.tamu.edu/resources/crop-livestock-budgets/by-district/district-2/2008.html. Accessed August 2, 2010.

Extension Agricultural Economics. 2009. *2009 Texas Crop and Livestock Budgets.* http://agecoext.tamu.edu/resources/crop-livestock-budgets/by-district/district-2/2009.html. Accessed August 2, 2010.

Extension Agricultural Economics. 2010. *2010 Texas Crop and Livestock Budgets.* http://agecoext.tamu.edu/resources/crop-livestock-budgets/by-district/district-2/2010.html. Accessed August 2, 2010.

Nalley, Lanier, Mike Popp, Kris Brye, Corey Fortin, and Zara Niederman. 2010. "A Carbon Sequestration and Emissions Life Cycle Analysis for County Level Cotton Production in the United States." Center for Agricultural and Rural Sustainability Project 09-634, University of Arkansas Division of Agriculture.

New, L. Personal Communication. 2010. Former Professor and Extension Agricultural Engineer in Irrigation for the Texas AgriLife Extension Service, Amarillo, Texas.

Popp, Michael, Lanier L. Nalley, Kristofor R. Brye, Corey J. Fortin, and Aaron S. Smith. 2010. "A Life Cycle Approach o Estimating Net Carbon Emissions and Agricultural Response to Potential Carbon Offset Policies." Working Paper, Dept. of Agr. Econ. and Agribuisness, University of Arkansas.

Wheeler, Erin A., Eduardo Segarra, Phillip N. Johnson, Jeffery W. Johnson, and David B. Willis. 2006. Policy Alternatives for the Southern Ogallala Aquifer. *Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orlando, FL, February 5-8, 2006.*

U.S. Department of Agriculture, National Agricultural Statistics Service. 2010. *Quick Stats: U.S. and All States County Data- Crops.* http://www.nass.usda.gov/QuickStats/Create_County_All.jsp. Accessed June 10, 2010.