COMPARISON OF CARBON EMISSION ASSESSMENT USING EXTENSION BUDGETS AND REAL FARM DATA: COTTON IN THE TEXAS PLAINS

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Abstract

Most studies on greenhouse gas (GHG) emissions from agricultural production have used crop production budgets from state extension services as the data source for production inputs. However, the purpose of these budgets is to provide a planning tool to generate farming costs and returns rather than to reconstruct the farming activity or to create carbon emissions estimates. This study uses production data collected from a group of farming operations in the Texas High Plains producing irrigated cotton across a multiyear period, 2005-2010. Carbon emissions from use of diesel, nitrogen, phosphorous, herbicide, insecticide, and water from the sample farms were estimated and used to develop a distribution of carbon emissions, and the amount of carbon emissions for irrigated cotton as estimated from the budget was compared to the carbon emissions distribution from the actual farm operations. Results indicate that the budget-based emission value lies outside the 95% confidence interval of the distribution, which raises questions about reliability of GHG estimates based on crop budgets.

Introduction

Greenhouse gas (GHG) emissions and their potential negative consequences on the environment have raised concerns that continued increases in the atmospheric concentration of CO_2, which constitutes approximately 80% of current GHG emissions (Lashof and Ahuja, 1990), could contribute to changes in climate. Each year the Earth's atmosphere takes up approximately 2.9 billion tons of the 4.8 to 5.8 billion tons of carbon that is emitted from different sources (Sedjo, 1989).

Agriculture contributes to GHG emissions, mostly due to:

1. Fuel consumption for a) farm machinery and field operations (use of fossil fuels in agriculture results in CO_2 emission from the combustion of fuels and the energy consumed in the manufacture, transportation and repair of the machines) and b) irrigation (energy used to power pump and distribute water) .

2. Fertilizer and pesticide usage (herbicides, insecticides, fungicides) – CO_2 emitted during the manufacture and transportation of 1 unit of N as mineral fertilizer corresponds to 1–1.5 units of C emissions from fossil fuels Paustian et al., 1999). Similarly, CO_2 release is tightly linked to pesticide production since they are manufactured from crude petroleum or natural gas products (West and Marland, 2002).

Several studies have been conducted to estimate the carbon emissions from the agricultural sector (e.g., Nalley et al., 2010; Canales et al., 2010; Spreen et al., 2010) and most of them depended on crop production budgets from state extension services as their data source for input use. These budgets offer the advantages of being convenient (accessible) and having a degree of standardization across states and regions. Their disadvantage is that they were not intended to represent "real" farm operations (they provide a "boilerplate" to assist individual producers by providing a point of departure for estimating their own costs and returns) and, as such, cannot capture the inherent variations in operations (and CO_2 emissions) across farms. The objective of this study was to determine how representative this budget value is of carbon estimates from actual farming operations in the Texas High Plains.

Methods and Procedures

This study used a sample of farming operations in Floyd County, Texas, across a multiyear period from 2005 to 2010. Data on the farming operations were collected by the Texas Alliance for Water Conservation (TAWC) project, made up of a group of area producers working in conjunction with the regional water district, industry groups, universities, and government agencies (TAWC, 2011). The project involves collection of data on many aspects of water use and production on the individual farms and fields, among them the use of all production inputs on all of the fields and crops grown, including irrigated cotton. A summary of the conduct of the analysis follows.

Data on irrigated cotton consisted of 62 different sites, resulting in 125 observed input combinations in total for the period (26 in 2005, 27 in 2006, 20 in 2007, 14 in 2008, 18 in 2009, and 20 in 2010). Field level measurements of inputs were collected in several main categories--diesel, nitrogen, phosphorus, herbicides, insecticide, and water, all on a per acre basis.

Each input on each farm in each year was converted to an estimated carbon emissions equivalent using values developed in Lal (2004) (Table 1). These carbon equivalents, or pounds of carbon emitted per unit of input per acre were applied to the gross quantity of each input used within the specific field record. The resulting value specified the total carbon emitted per acre resulting from the use or consumption of an input category. Direct carbon emissions from irrigation were determined assuming electricity as the primary fuel source and were based on the quantity of irrigation water applied in inches per acre. Carbon equivalents for chemicals (herbicides and insecticides) and fertilizers consisted of the energy used and resulting carbon emitted for manufacture and transport (Lal, 2004). The carbon coefficients for nitrogen fertilizer are determined by the amount of natural gas required in the production process.

Total carbon emissions from irrigated cotton per acre for each farm in each year were estimated by summing the estimated carbon emissions per acre from each input. Using total carbon estimates from the entire set of farms across time, a probability density function (pdf) was estimated for the six year period using the Easy Fit (2011) program. This program examines a variety of probability density functions and chooses the function that best fits the data.

The Statistical Analysis System (SAS) 9.2 (2008) was used to calculate confidence intervals based on the estimated pdf for irrigated cotton. The mathematical forms tested were: Lognormal, Fatigue Life, Dagum, Log-Gamma, Generalized Extreme Value, Inverse Gaussian, Log-logistic, Gumbel Max, Burr, Gamma, Generalized Gamma, Pearson, Johnson, Log-Pearson, Generalized Pareto, Nakagami, Triangular, Erlang, Rice, Weibull, Frechet, Pert, Beta, Logistic, Chi-Squared, Normal, Error, Cauchy, Rayleigh, Hypersecant, Uniform, Laplace Kumaraswamy, Power Function, Exponential, Reciprocal, Pareto, Levy, and Student's t. The carbon emissions estimated from the budgets (one for each of the six years) was compared to the distribution to determine whether this amount was statistically different from the farm-based values (using the 95% confidence interval).

Results

Table 2 indicates carbon estimates (in lbs. per acre) for, diesel, nitrogen, phosphorous, herbicide, insecticide, and water in irrigated cotton for the period 2005-2010. Two points become clear from the data: (1) the largest sources of carbon emissions from the sample farms was from nitrogen fertilizer and irrigation and (2) the carbon emissions from most inputs varied from year to year. Weather conditions affect use of several of the inputs, likely some more than others, thus affecting carbon emissions. Using the total carbon emissions per acre data from each data site, the Lognormal Distribution was selected as the pdf that best fits these data (Figure 1). The probability distribution lacks normality and is skewed to the right, indicating that the bulk of the values lie to the left of the mean (309.3899, shown in red in Figure 1). Thus, more of the acres in the sample of farms used in the study produced carbon emissions below the mean than above. Note also that a relatively high standard deviation (110.31) indicates that the carbon emissions per acre are quite variable, even in this confined sample. Goodness-of-fit tests, which determine how well the distribution is, all indicated that the lognormal distribution was appropriate. (See Table 3 for technical results of the tests).

Finally, the budgeted amount for cotton (547.06) was compared to the lower bound (166.56 lbs. C/acre) and upper bound (533.52 lbs. C/acre) of the calculated 95% confidence interval (Table 5). These limits are shown as the green dashed lines in Figure 1. Results of this analysis indicated that budgeted amount lay outside the 95% confidence interval quantiles of the distribution, signifying that there is a less than 5% probability that the budgeted value for carbon emissions is representative of the carbon emissions from the sample of farms. The budgeted amount of carbon emissions for irrigated cotton was significantly higher than the emissions observed on the sample farms.

Conclusion

This analysis provides evidence that the carbon emissions from 62 cotton production sites in Floyd County, Texas, over a 6-year period are significantly lower than carbon emissions as estimated using the Extension budgets as the source of production inputs used. While the farms used are not a representative sample of farms in the Texas Plains, or of the U.S. cotton production sector, the study raises a valid question as to the accuracy of the carbon emissions estimates for cotton production, and overall agricultural commodity production, made to date. More carefully (scientifically valid) collected data on actual levels of production inputs used, at a minimum, is needed for reliable estimates of carbon emissions to be made, both at the farm level and the aggregate level.

A further reminder from this conclusion is that if carbon emissions are to be a public and policy concern, and if policy decisions are to be made regarding carbon emissions, reliable information about carbon emissions is important. Although reliable information does not assure good decisions, bad decisions are assured without it.

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Table 1.Carbon values used to estimate carbon emissions of production inputs.

Input	Carbon-equivalent
Diesel	6.1 lbs C/gallon
Nitrogen	1.3 lbs C/lb
Phosphorous	0.2 lbs C/lb
Herbicide	6.3 lbs C/lb
Insecticide	5.1 lbs C/lb
Water	11.7 lbs CO2/acre-inch

Source: Lal, 2004.

Table 2. Pounds of carbon per acre estimates for cotton, by carbon source, by year.

Year	Diesel	Nitrogen	Phosphorous	Herbicide	Insecticide	Water	Total
2005	22.84	125.38	6.28	27.09	1.51	103.93	287.03
2006	21.35	122.51	2.34	30.28	0.27	180.09	356.85
2007	21.33	123.37	4.53	23.01	3.28	140.67	316.19
2008	18.97	109.80	6.56	12.04	0.18	126.67	274.22
2009	12.36	129.79	4.79	15.03	0.36	148.01	310.34
2010	27.66	153.92	7.96	13.13	1.21	86.49	290.36
Average	20.75	127.46	5.41	20.10	1.14	130.97	305.83

Table 3.Goodness-of-fit tests for lognormal distribution.

Test	Statistic		p Value	
Kolmogorov-Smirnov	**D**	0.06149205	**Pr > D**	0.187
Cramer-von Mises	**W-Sq**	0.09260494	**Pr > W-Sq**	0.072
Anderson-Darling	**A-Sq**	0.68912708	**Pr > A-Sq**	0.025

Table 4. 95% Confidence interval quantiles for distribution

95% Confidence Limit quantiles	
Lower bound	Upper bound
166.56	533.52

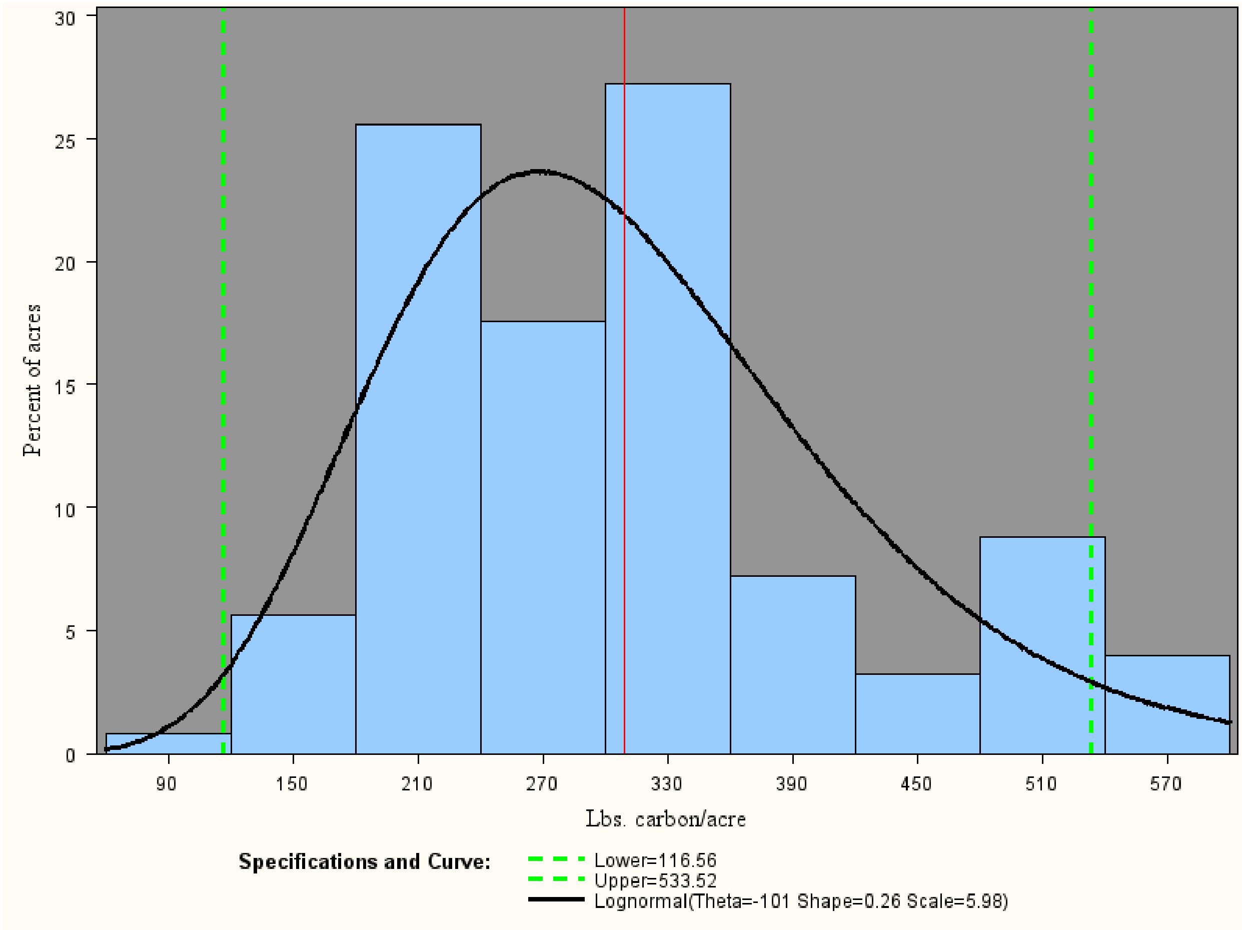

Figure 1.Probability density function for carbon emissions in irrigated cotton