Carbon Footprint: A New Farm Management Consideration in the Southern High Plains

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Abstract

      As concerns continue to mount regarding man induced impacts to the global climate, the SHPT region could be faced with a unique scenario in which the net carbon balance should be considered in the producer's enterprise selection and production systems. Currently, the SHPT produces nearly one third of the U.S. cotton crop. Under a potential cap and trade system the challenge for the agricultural industry in the SHPT may be how to sustain the region's economic base and production capabilities. Thus, the objective of this study was to measure the net carbon relationships between irrigated cotton and irrigated corn production systems on the SHPT using data from the Texas Alliance for Water Conservation (TAWC, 2009). Due to the unique management and production challenges in the SHPT, additional comparisons were made regarding economic viability and irrigation efficiency. Within the parameters of this study, it is apparent that irrigated corn has an advantage over cotton in both its ability to return carbon to the soil, maintain profitability, and use water resources efficiently. If the agricultural industry is included in CO_2 regulation, it would appear that irrigated agricultural producers in the SHPT who have the ability to move between irrigated cotton and corn should be aware of the advantages corn possesses. However, even under changing commodity prices and profitability scenarios, corn still presents a significant advantage over cotton in its ability to reduce atmospheric CO_2 by depositing larger amounts of biomass carbon into the soil.

Introduction

  Increased interest in climate change, CO2 emissions, and energy independence could impact production decisions in industries across the country. The energy intensive production agriculture industry is a likely candidate to be included in proposed "Cap and Trade" legislation which aims to reduce fossil fuel consumption and resulting atmospheric CO2 emissions. While implementation details are currently uncertain, CO2 emission regulation could become an additional management decision for agricultural producers. Fossil fuel based inputs represent much of the derived energy used in agricultural production throughout the Southern High Plains of Texas (SHPT).

  The amount of energy consumed and the resulting emissions released within the U.S. have been a legislative focus dating back to the mid 1970's when emission standards were first introduced on American vehicles and the first of several major "oil crisis" occurred. While emissions are not typically regulated on farm level inputs, with the exception of late model farm equipment, it is crucial to understand how the management of dryland and irrigated agriculture in the SHPT could conform to proposed regulations for energy independence, conservation, and CO2 emissions.

  Traditional irrigated and dryland farming operations in the SHPT rely on the intensive use of commercial fertilizers and pesticides, which utilize fossil fuels in their production process. Additionally, large energy demands come in the form of electricity and natural gas which power pumping plants to support irrigated agriculture throughout the region. In essence, field level inputs are directly or indirectly tied to fossil fuel consumption and the resulting release of atmospheric CO2. While there is some literature on how different agricultural systems consume energy and emit carbon, the specific needs of the producers in the SHPT must be addressed in

accordance with their dependence upon primary inputs such as irrigation, fertilizer, and pesticides.

The "carbon footprint" has become a focal point in the evaluation of environmental legislative actions throughout the last decade, giving a basis for how damaging or beneficial a certain industry or action is to the environment. While most industries produce tangible non-biological goods, the agricultural industry is unique in that it must consider CO_2 emission calculations for both emissions from inputs and a biological interface. As mentioned previously, inputs used in production agriculture are primarily derived from fossil fuels eventually releasing CO_2 into the atmosphere. However, through the biological and physiological process of crop production, CO_2 is absorbed by crops in the photosynthetic process to produce biomass. Thus, if crop specific calculations are considered on a per acre basis by estimating the amount of carbon released from input utilization along with the carbon biologically consumed by the crop, a net carbon footprint estimate can be derived.

As concerns continue to mount regarding man induced impacts to the global climate, the SHPT region could be faced with a unique scenario in which the net carbon balance should be considered in the producer's enterprise selection and production systems. Currently, the SHPT produces nearly one third of the U.S. cotton crop. Under a potential cap and trade system the challenge for the agricultural industry in the SHPT may be how to sustain the region's economic base and production capabilities. Thus, the objective of this study was to measure the net carbon relationships between irrigated cotton and irrigated corn production systems on the SHPT using data from the Texas Alliance for Water Conservation (TAWC, 2009). Due to the unique management and production challenges in the SHPT, additional comparisons were made regarding economic viability and irrigation efficiency.

Methods and Materials

The data for this study was provided through detailed production system information obtained from individual producer records from the Texas Alliance for Water Conservation (TAWC), which represents 29 farm sites in Floyd and Hale Counties in the central SHPT. Six sites were chosen for evaluation, four irrigated cotton and two irrigated corn sites, for the 2008 growing season. The irrigated cotton sites represent three different irrigation technologies including center-pivot irrigation, drip irrigation, and furrow irrigation. Both corn sites utilized center-pivot technology. Carbon emissions from inputs were estimated using previously documented values according to the quantity of input used. Under this process, field level inputs were broken down into several major categories such as fuel, fertilizer, chemicals, and electricity with each category having an average carbon equivalent derived from Lal (2004) as seen in Table 1. These generalized carbon equivalents, or pounds of carbon emitted per unit of input, were then applied to the gross quantity of each input used within the specific field budget. The resulting value represents the total carbon emitted from the use or consumption of an input category

Direct carbon emissions from irrigation were calculated assuming electricity as the primary fuel source and 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. The carbon coefficients, particularly those for nitrogen fertilizer, are primarily driven by the amount of natural gas required in the production process.

Table 1. Carbon values utilized to estimate emissions from the production process of inputs.
(Lal, 2004)

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

The biological component of carbon was estimated both through field level biomass
sampling and computer generated simulation models. Agricultural soils gain carbon during the
crop growing season through input from crop residues which include above and below ground
plant biomass.   The stover (leaves and stems), cotton burrs, and roots are the primary residue
materials which remain in the field after harvest. In the case of corn, stover is the primary source
of above ground biomass that is added to the soil (Wilhelm et al., 2007). Cotton stover is
primarily made of stalks and leaves with cotton burrs also contributed to the residue mass. As
this residue is incorporated into the soil through tillage and decay, the carbon balance is
increased. It must be noted that in both the case of irrigated corn for grain and cotton that the
portion of biomass removed from the field in the form of yield is not accounted for in this study.
Additionally, results for irrigated corn for grain cannot be compared with corn silage as there are
differences in the amount of stover left in the field upon harvest.

The method for estimating the amount of carbon returned through residue deposit utilizes
YieldTracker (Maas et al., 2004), which is a plant growth simulation model that simulates the
growth and development of plants during the growing season. This model uses remotely sensed
crop ground cover or leaf area index data to project within season simulation of plant growth.
The primary data input into YieldTracker is ground cover estimates derived from Landsat-5

satellite observations(Maas and Rajan, 2008). Other data inputs required to run YieldTracker include the planting date and daily weather data for the region (solar radiation, air temperature, and rainfall) which is retrieved from field level records within the TAWC. Using the previously listed data inputs, the model determines the phonological development of the crop based on growing degree-days.

Crop growth is determined by converting the daily photo-synthetically active radiation (PAR) absorbed by the plant canopy into the daily increase in plant biomass, accounting for water stress effects due to inadequate rainfall or irrigation. This daily increase in plant biomass is partitioned among the various plant organs, including leaves, stems, and roots according the phonological stage of growth. YieldTracker outputs leaf, stem, and root biomass accumulations for each day during the growing season. The carbon input into the soil from leaves, stems, and roots was determined by multiplying the corresponding amount of biomass by its percentage carbon content (Loomis and Lafitte, 1987; Pinter et al., 1994). In this calculation, 1 gram of dry biomass contains approximately 0.4 grams of carbon. Combining both carbon emissions from the field level production process and biological generated carbon, net estimates in pounds of carbon per acre were made for both irrigated corn and cotton observations.

Within the complex matrix of production decisions that SHPT's agricultural producers must make each growing season, economic considerations and irrigation efficiencies are crucial. Thus economic budgets, using partial budget analysis methods, were estimated for each field level production system observed. These economic estimates account for all detailed inputs used in the production process on a per acre basis. Mechanical operations, harvest, chemical applications, and yield were considered in the profitability estimates. Irrigation efficiencies were determined through electronic measurements of water output at the delivery system for each

observation through the use of NetIrrigate®. These water measurements were then compared against revenue to determine irrigation efficiency by crop.

Results

The results focused on three main factors: net carbon balance of crop production, economic profitability, and irrigation efficiency. The results are summarized in the Tables 2 and 3. The net carbon balance was estimated as the difference between the amount of direct carbon deposited into the soil as a result of residue materials left on the field after harvest and the amount of carbon emissions resulting from the use of agricultural inputs for each crop.   As expected, cotton deposits less carbon into the soil due to its lower production of biomass. As depicted in Table 2, carbon deposited into the soil on the irrigated cotton fields ranged from 3,406 to 5,642 lbs/acre. The highest carbon residue occurred on the drip irrigated field 27-1. This result is consistent with expectations since this field produced the highest crop yield thus producing the most biomass per acre. The average carbon returned to the soil for the irrigated cotton sites was 4,571 lbs per acre.

Table 2. Estimated biomass carbon, input carbon, and net carbon balance for irrigated cotton and corn in pounds per acre.

Field No	Crop	Irrigation Type	Biomass Carbon (lbs/acre)	Input Carbon (lbs/acre)	Net Carbon Balance (lbs/acre)
3-1	Cotton	Center-pivot	3406	347	3059
6-2	Cotton	Center-pivot	4950	433	4517
11-2	Cotton	Furrow	4287	222	4065
27-1	Cotton	Drip	5642	479	5163
6-3	Corn	Center-pivot	6860	557	6303
24-1	Corn	Center-pivot	9310	662	8648
Average	Cotton		4571	370	4201
Average	Corn		8085	610	7476

Table 3. Estimated net carbon balance, gross margin, and irrigation efficiency for irrigated cotton and corn.

Field No	Crop	Irrigation Type	Net Carbon Balance (lbs/acre)	Gross Margin ($/acre)	Irrigation Efficiency ($GM/acre inch)
3-1	Cotton	Center-pivot	3059	226	17
6-2	Cotton	Center-pivot	4517	335	19
11-2	Cotton	Furrow	4065	246	27
27-1	Cotton	Drip	5163	219	14
6-3	Corn	Center-pivot	6303	758	69
24-1	Corn	Center-pivot	8648	647	48
Average	Cotton		4201	257	19
Average	Corn		7476	703	59

However, we must consider the amount of carbon emitted during the production process to produce the crop. In the case of cotton, the amount of indirect/emitted carbon that was required for production inputs ranged from a low of 222 lbs/acre on the furrow irrigated site to a high of 479 lbs/acre on the drip irrigated site, averaging 370 lbs/acre across the cotton observations. It should be noted that these values are similar in quantity to previously estimated carbon equivalents from Nalley 2009 and West 2002. These numbers are consistent in that the production inputs required for drip and center pivot irrigated cotton are higher than those required for the furrow irrigated scenario. Increased water application rates, fertilizer, seed, and chemicals are all needed to produce the higher yields observed on the drip and center pivot irrigation systems, while furrow irrigated cotton is typically a low input production process. This consistency is further verified through the carbon input values as well as the economic budgeting process. In combining both the biomass carbon and input carbon values we can estimate the net carbon balance for the crop production process. For irrigated cotton these numbers averaged 4,201 lbs/acre with a range of 3,059 to 5,163 lbs/acre. These values represent a net carbon

balance for the period of the growing season, excluding the interaction of the carbon cycle after the crop was terminated and into the next growing season.

As expected, the irrigated corn fields produced higher levels of biomass which resulted in greater amounts of biomass carbon being deposited into the soil. The large volumes of corn stover left in the field after grain harvest allows for substantially more carbon to be deposited into the soil. As seen in Table 2, the net carbon balance for corn averaged nearly twice that of cotton at 8,085 lbs/acre. The difference in per acre net carbon balance of 36% between the two corn sites can be attributed to the large difference in observed yield of 50 bushels per acre. Corn has higher input carbon values due to more intensive input usage. On average the observed corn sites used 65% more input carbon with an average of 610 lbs/acre. This difference is mainly attributed to the increased quantity of irrigation water required for corn production and the corresponding increase in fertilizer utilization. Even with this increase in input intensity, the corn sites on average had a 78% higher carbon balance compared to cotton, with an average of 7,476 lbs/acre.

As previously discussed, as concerns over CO2 emissions increase, agricultural producers may need to incorporate cap and trade criteria into their management decisions. However, as in any business, they must be able to do this in a profitable manner while managing their available resources. Table 3 presents the net carbon balance in addition to the economic components of gross margin and irrigation efficiency. With an average gross margin (gross revenue less variable expenses) of $703/acre, corn profitability is 175% higher than cotton at $257/acre. These profit levels should not be considered a long run average since corn price in 2008 was at higher levels than the average marketing year. With limited water resource challenges facing irrigated producers on the SHPT, irrigation efficiency is of high importance in the decision

making process. As indicted in Table 3, the dollars of gross margin generated for an inch of

irrigation water was highest for the corn sites at $59 of gross margin per inch of water. While

corn traditionally uses more irrigation water than cotton, corn presents a 53% advantage for

returns on irrigation compared to cotton which averaged $19 per acre inch.

Conclusions

The results from this study provide producers and policy makers information on the

carbon balance for two important crops in the SHPT. By combining the potential decision and

management factors related to carbon balance with economic profit and irrigation efficiency,

irrigated agricultural producers in the SHPT will have a better understanding of how these

crucial decision measures are interrelated. Within the parameters of this study, it is apparent that

irrigated corn has an advantage over cotton in both its ability to return carbon to the soil,

maintain profitability, and use water resources efficiently.   If the agricultural industry is

included in CO2 regulation, it would appear that irrigated agricultural producers in the SHPT

who have the ability to move between irrigated cotton and corn should be aware of the

advantages corn possesses.   However, even under changing commodity prices and profitability

scenarios, corn still presents a significant advantage over cotton in its ability to reduce

atmospheric CO2 by depositing larger amounts of biomass carbon into the soil.

The life cycle of carbon sequestration evolves from one growing season to the next;

therefore, the amount of carbon held in the soil will change due to the affects of exogenous

variables such as rainfall, weather, tillage practices, and soil microbe activity.   A large portion of

the plant biomass materials deposited post-harvest will be lost from the soil through microbial

decomposition, and through time small amounts of the biomass carbon will be sequestrated into

the soil as stable soil carbon compounds. It should be noted that this study did not estimate the

relationships of carbon interactions of the harvested product. The corn harvested for grain

entered the carbon cycle through animal feeds and the cotton lint produced entered a carbon

cycle as a durable good.

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