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OVERVIEW

This publication uses a case-study approach to investigate the impacts of linking corn production, ethanol, and backgrounding calves on economics and soil sustainability. The purpose of the paper is to initiate a dialog and provide an example of how the three industries can be integrated to enhance profitability. Conclusions drawn from this case study should not be extrapolated beyond the scope of this publication.

Corn is an incredibly productive plant, and in 2008 the average yield in South Dakota, Iowa, Nebraska, and Minnesota was 162 bu/acre. Historically, corn was used to produce high-quality protein (beef, pork, chicken) for human consumption. Currently, approximately one-third of the grain produced is used to produce two co-products: ethanol and distillers grain. Distillers grain is a protein-rich feed that can be combined with corn stover (traditionally considered a waste product) to produce rations for stock cows and back-

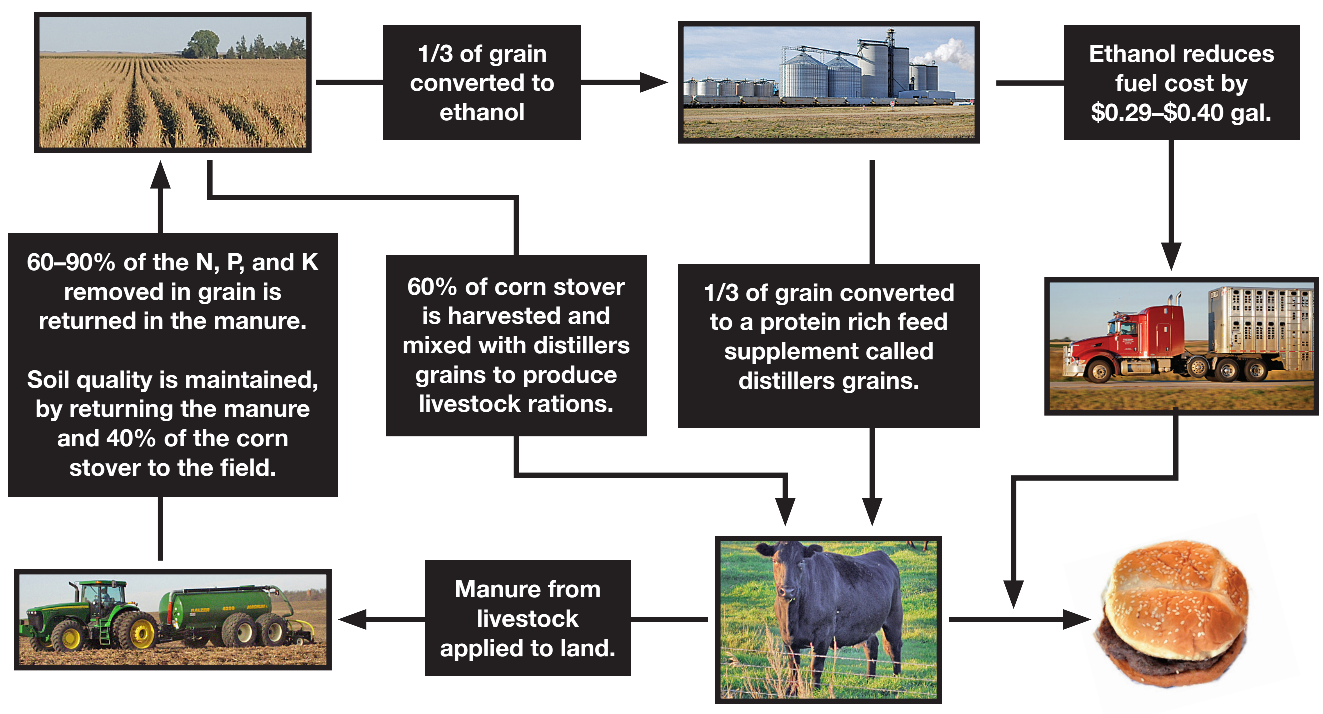

Figure 1. Carbon and energy flow chart of an ethanol production system*
* In the diagrammed system, distillers grains and corn stover are used for backgrounding steers and manure is applied to soil.

grounding calves (weight gain from 450 to 750 lbs).

Carbon mass balance and partial-budgeting approaches were used to explore the impact of harvesting the grain and stover on ethanol and backgrounding calves, soil-quality sustainability, and profitability. Research indicates that 1) adopting an integrated grain, ethanol, and livestock system increased profitability and the efficiencies of the land and fertilizer resources; and 2) profitability and productivity can be increased by integrating livestock, ethanol, and crop production industries. Economics related to competition between the ethanol and cattle-feeding industries for corn as a resource were not considered in these calculations.

Differences between this and previous studies resulted from changing the perspective from producing ethanol to producing food. These findings were the result of the following:

- Nutrients are concentrated into the distillers grain during the grain-ethanol production process. The relatively inexpensive, protein-rich distillers grain is a good supplement for blending with low-quality feeds such as corn stover that previously were left in the field.
- Manure contains a significant amount of organic carbon, which helps maintain soil quality and reduce erosion.

ENERGY SUSTAINABILITY OF CORN PRODUCTION

Many people conclude that if corn is used to produce ethanol, then food production must be reduced. To explore this question, a basic understanding of crop, ethanol, and livestock production is needed. Agriculture is one of the largest producers and consumers of energy in the world. Products from these energy investments are delivered to people in many forms, including biofuels, clothing, and food.

In agriculture, energy from a variety of sources is used to produce food, fiber, and energy products. Most of the energy used in agriculture was ultimately derived from the sun. For example, essential nutrient nitrogen (N) is converted from atmospheric N2 to fertilizer in a process that uses energy from the sun that has been stored in fossil fuels, while the conversion of CO2 to sugar and other organic compounds, which is done by most higher plants, uses energy from the sun through a process called photosynthesis. N fertilizer increases the efficiency of the sun harvesting process.

The amount of energy stored by photosynthesis is dependent on crop type, weather, yield-limiting factors, and management. Achieving energy independence requires that agricultural production stores more energy than is consumed. Studies published 20 years ago suggest that corn ethanol production at that time had a negative energy balance (Pimentel et al. 1991). Analysis using current technology indicates opposite results (Shapouri et al. 2002). For example, Mamani-Pati et al. (2010) used Biofuel Energy System Simulator software (Liska et al. 2008) to estimate energy efficiency of corn grown near Brookings, S.D. They reported that corn managed for high yields (208 bu/acre) had an energy gain of 25 GJ (acre · year)-1. For comparative purposes, 25 GJ is equivalent to the energy stored in 189 gallons of gasoline. Further gains in energy efficiency may be possible by fully integrating crop, ethanol, and livestock operations.

CORN PRODUCTION

In the Great Plains, corn yields per acre have been increasing. These increases are the result of many factors, including the adoption of improved management practices and the wide-scale use of genetically enhanced plants. In corn grown in South Dakota, the net impact of these practices has been an annual 2 bu (acre•year)-1 yield increase (fig. 2). In 2008 in South Dakota, Minnesota, North Dakota, and Nebraska the average grain yield and total aboveground biomass produced were approximately 162 bu/acre and 9 tons/acre, respectively. Corn grain yields generally out-yielded wheat or soybean by 200 to 300% (Singer et al. 2004), and total aboveground yields out-yielded switchgrass, a native plant, by 200 to 300% (Schmer et al. 2008).

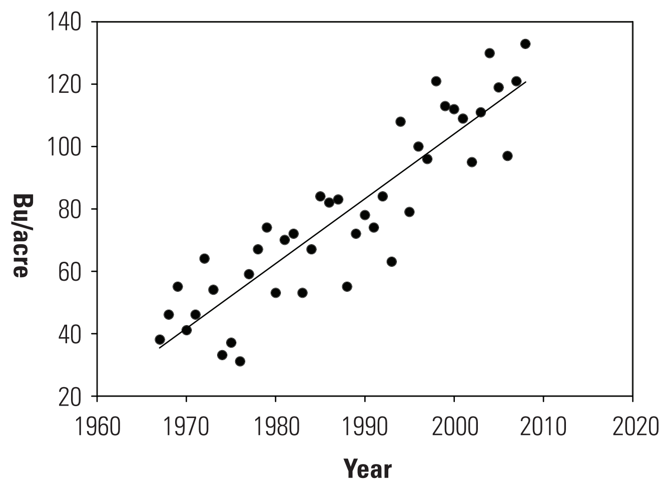

Figure 2. South Dakota statewide average corn grain yields from 1967 to 2008

Prior to ethanol, gradual corn grain yield increases resulted in extremely low prices paid for corn. Since ethanol, corn prices have increased to a point where they are almost equal to the cost of production. For example, in Iowa the estimated 2010 cost of corn production (corn-on-corn rotation) ranged from \$3.78/bu (\$699.60/acre for 185 bu/acre crop) to \$4.02/bu (\$582.74/acre for a 145 bu/acre crop) (Duffy and Smith 2008). South Dakota production costs are estimated at \$459.20 (140 bu/acre), or \$3.28/bu.

Corn prices in the region have ranged from \$3 to \$6 per bushel. In the four-state region of S.D., Minn., Neb., and Iowa, approximately 2.2 billion bushels of corn were used to produce ethanol in 2008. In spite of the large amount of ethanol produced in the region, the amount of grain not used in ethanol production is almost identical (4.8 and 4.9 billion bushels in 1990 and 2008, respectively) to the amount of non-ethanol grain produced in 1990 (Baker and Zahniser 2006; USDA-NASS 2009).

ETHANOL PRODUCTION

Ethanol is produced from grain by converting sugar and starch into ethanol. One bushel of corn yields between 2.7 and 2.84 gallons of ethanol (Baker and Zahniser 2006; Lauer 2009). With advances in technology, efficiency is gradually increasing. Based on a 2.7 gal bu-1 conversion rate, a corn crop (162 bu of grain acre-1) can produce 437 gallons of ethanol acre-1 and 2,920 lbs of dried distillers grain with solubles (DDGS) (18 lbs bu-1). During ethanol production, the nutrients and proteins contained in grain are concentrated into a byproduct called distillers grains (table 1), which can be used to produce feed for fish, poultry, cattle, and swine.

Table 1. Average grain corn (S.D., Minn., Iowa, and Neb.), expected dried distillers grains with solubles (DDGS) from the grain, corn stover if 60% of the stover is harvested, and average soybean yields related to crude protein and total digestible nutrients per acre (Preston, 2009; NRC, 2000)

Product	Yield/ acre	Dry mater g/g	Crude g/g	Protein lbs/ acre	Total digestible g/g	Nutrients lbs/acre
Corn grain	162 bu/ acre	0.88	0.09	719	0.88	7,025
DDGS	2,916 lbs/acre	0.91	0.30	796	0.99	2,627
60% corn stover harvested	5,443 lbs/acre	0.80	0.05	218	0.56	2,439
Soybean	42 bu/ acre	0.88	0.40	887	0.93	2,062

To produce high-quality feed rations, distillers grains can be blended with a variety of products, including grass hay, corn stover, and wheat straw (Wortmann et al., 2008; NRC, 2000). For example, during backgrounding, calves (550 lbs) can be fed a diet consisting of wet distillers grain (30%), hay (22%), shelled corn (15%), and corn stover (33%). In South Dakota this diet has an estimated efficiency of 8.15 lb feed (lb live weight gain)-1 (NRC, 2000).

Distillers grains can be effectively included in finishing diets; however, fat and sulfur concentrations in the distillers grains limit inclusion rates. It should be noted that including distillers grains in diets in at rates higher than 30% can reduce marbling and gains (Reinhardt et al. 2009).

INTEGRATED CROP, ETHANOL, AND LIVESTOCK ENTERPRISES

Using a system that integrates crop, ethanol, and livestock operations can be very profitable (table 2). Mass balance calculations shows that backgrounding calves with corn stover (33%), hay (22%), shelled corn (15%), distillers grain (30%), and inserting an ionophone can produce an estimated crop + livestock profit of $278 acre-1. When the grain was sold separately, the profit was much lower at $139/acre. Details about the calculations are shown in appendix 1.

IMPACTS OF HARVESTING CORN STOVER ON SOIL SUSTAINABILITY

Integrating the livestock into the system had the added benefit of reducing the amount of N and P that was removed from the farm. Exporting the grain off the farm resulted in loss of approximately 146 and 62 lb N and P_2O_5 from the farm. If both grain and 60% of the stover were harvested, it was estimated that 192 and 78 lbs acre-1 of N and P_2O_5 would be exported off the farm annually. Integrating livestock into the operation reduced the N and P_2O_5 losses to 57.5 and 24 lb N and P2O5/acre, respectively.

These calculations assume that harvesting corn stover

Table 2. Calculated products produced and nutrients returned for two corn management scenarios. Partial profits do not include production costs for land, pesticides, seeds, equipment, insurance, and labor (see appendix 1 for calculation details)

Farm enterprise	On-farm products		Estimated profit ($/acre)	Soil sustainability		
	Corn grain ethanol (gal/acre)	Beef (lbs/acre)		Carbon returned (lbs/acre)	N removed (lbs/acre)	P removed (lbs P_2O_5/acre)
Non-integrated farm; corn sold to ethanol plant; no livestock; stover returned to the field	437	0	139	6,920	146	62
Integrated crop, ethanol, livestock system; 60% stover harvested; backgrounded calves fed DDGS and corn stover; manure applied to the field	383	760	278	5,629	57.5	24

from a continuous corn production system will maintain the soil's long-term productivity. Agricultural sustainability can be enhanced by returning more crop residues than is required to maintain the current soil organic carbon level. Maintaining this level is critical to insure long-term productivity. The amount of soil organic carbon contained in the soil is directly related to many factors, including texture, temperature, and the amount of non-harvested carbon returned to soil. Decreasing the soil organic carbon can lead to increased soil erosion.

Analysis of historic carbon studies indicates that maintenance requirement for many soils are approximately 5,000 lbs C/acre (Larson et al. 1972; Barber 1979; Huggins et al. 1998; Clay et al. 2010). The calculated amount of carbon returned exceeded this value for the scenarios tested in table 2. Biomass removal and amount of nutrients not returned were related to management. In the integrated system, the application of manure improved the sustainability of the system by returning carbon as well as reducing nutrient losses and fertilizer requirements. These results suggest that the sustainability and agriculture energy efficiency of agriculture can be improved by integrating livestock, ethanol, and crop production systems. By using corn stover to replace carbon converted to ethanol, the impact of ethanol on the beef backgrounding enterprise was reduced.

SECONDARY BENEFITS OF ETHANOL PRODUCTION

Ethanol production has many secondary benefits for rural and urban communities. For urban communities, ethanol has reduced the cost of gasoline. Du and Hayes (2008) estimated that even though less than 2% of gasoline sales are replaced with ethanol, the growth of the ethanol market has reduced retail gasoline prices \$0.29 to \$0.40 per gallon. This price reduction comes at the expense of the oil refinery industry. In rural communities, ethanol has created jobs and revenues for local governments. Sneller and Durantee (2006) reported that at Plainview, Neb., the development of a 25-million-gallon ethanol plant resulted in the creation of 33 new jobs, \$30 million being paid to local farmers, and \$128,772 paid in property taxes. These revenues are critical for reversing trends in declining rural populations (Johansen 1993; Coffman and Anthan 2005, Cantrell 2005). Similar advantages were observed in Groton, S.D. (Sneller and Durantee 2006).

Results of this analysis indicate that a synergy between certain crop, ethanol, and livestock enterprises exists. By encouraging integrated systems, profitability can be improved and fertilizer requirements can be reduced.

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Appendix 1. Budget calculations for values reported in table 2

Integrated ethanol, calves, and corn	lbs/acre		Purchase price	Selling price	Total cost ($/acre)	Income ($/acre)
N fertilizer	57.5		$0.42/lbN		$24.15	
P_2O_5	23.5		$0.259/lb P_2O_5		$6.09	
Other costs					$350.00	
	bu/acre					
corn ($/bushel)	142.4			$3.5/bu		$498.26
Backgrounded calves						
		# animals/				
	lbs/animal	acre	$/lb			
Calves	550	4.22	$1.10		$2,553.00	
Feeders ($/lbs)	730	4.22		$1.00/lb		$3080.60
		lbs/acre	$/ton			
DDGS		1,858	$110.00		$102.19	
Stover harvested		4,600	$15.00		$34.50	
			$/animal			
Other beef costs		4.22	$54.78		$231.17	
Corn + livestock est. profit/ acre						$278.03
Corn sold as feed or ethanol	**lbs/acre**		**Purchase price**	**Selling price**	**Cost**	**Income**
N fertilizer	146		0.42		$61.32	
P_2O_5	61.56		0.259		$15.94	
Other costs					$350.00	
	bu/acre					
corn	162			3.5		$567.00
Estimated profit						**$139.74**

Calculation details:
- 60% of corn stover can be sustainably harvested from a continuous corn rotation when livestock manure is applied.
- The corn root-to-shoot ratio was 0.55.
- Stover contains 43% carbon.
- Ethanol (CH_3CH_2OH) does not contain N, P, and K.
- For backgrounded calves, the feed efficiency was 8.15 lbs of feed per lb of live weight gain (NRC 2000).
- Each backgrounded calf was estimated to produce 6 lbs of dry manure/day containing 30% carbon (Fry 1973) and 70% of the nutrients contained in the grain and stover (James et al. 2006; North Dakota Extension Service 2009)
- The distillers grains and stover mixture used for backgrounding calves was 30% stover, 30% DDGS, 22% hay, and 15% chelled corn. Steers were implanted with an ionosphere. Based on the crude protein content of the stover (4.8%) and hay (9%), the stover was converted into hay. The 4.22 calves per acre were based on available feed. Estimated profits were calculated based on corn selling price of $3.5/bu, DDGS delivered purchase price of $115/ton, N selling price of 0.42/lb, P_2O_5 selling price of 0.259/lb, corn production costs of $350/acre, the purchase and selling price of a 730 lb yearly was $100/100 lbs, and the purchase price of a 550lb calf was $110/100lbs (Dierson, 2008). For backgrounding, non-feed costs were estimated at $54.79/each (labor $10.5; vet $3.00; machinery $2.70; marketing $7.20; interest $13.36; fixed costs for housing and machinery $8.40; 1% death at $3.62; Ionophone $6.00) (calculations based on 60% of the 5-month budgets reported by Ellis et al. (2009).

EXEX8165 Access at http://agbiopubs.sdstate.edu/articles/ExEx8165.pdf.