PRACTICAL farmers of Iowa
working together, always learning

RESEARCH REPORT
Released 10.30.12 | pages 1 of 3

Farm Energy Production and Use Between Two Iowa Cropping Systems

Written by Sarah Carlson and Rich Schuler

Cooperators
Chris Goedhart, Dordt College

Project Timeline
2009-2011

Staff Contact
Sarah Carlson, 515-232-5661
sarah@practicalfarmers.org

Rich Schuler
rich@practicalfarmers.org

Web Link
http://bit.ly/pfi_fieldcrops
http://bit.ly/pfi_onfarmenergy

Funding
Sustainable Agriculture Research and Education - USDA

Abstract

Considerable capacity for biofuel production, both ethanol and biodiesel, exists in the state of Iowa. Many farmers sell their harvested corn and soybean grains to these markets. At the same time, energy is a large expense for farmers. However, energy use varies across cropping systems. Two cropping systems were compared for three years in northwest Iowa to examine differences in energy expended and biofuel produced. Analysis of fossil fuel flow reveals that a more diverse cropping system was significantly more energy efficient than continuous corn. Additionally, total biofuel produced per acre was similar in two of three years for both treatments. A three-year cropping system used significantly less energy to produce similar amount of energy than continuous corn in two of three years.

Background

Energy use in agriculture varies across cropping systems. This project explores the differences in energy use between two practical Midwest cropping systems; calculating energy needed to grow, harvest, and process crops into biofuels, and ultimately the net biofuel- and fossil-energy ratio. Diverse cropping systems, those with three or more crops, use a fraction of the energy inputs as compared to continuous corn. Klepper et al. (1977) compared 14 Midwest organic farms with similar farms not using organic practices and found that the organic farms produced corn for 36 percent the energy inputs used on the conventional farms. Nitrogen fertilizer is the greatest single energy input in corn production. In the Klepper et al. study, all farms whether organic or not, kept livestock and applied manure. Thirty years later, these two types of farming have diverged. Many conventional row crop operations do not have access to manure, and N fertilizer rates have increased.

The energy footprint of agriculture is an issue that SARE has always focused on through research and demonstration projects. Practical Farmers of Iowa (PFI) field days and workshops in 1992-1993 (LNC92-044) showed that farmer cooperators saved the energy equivalent to 12 gallons of diesel per acre by reducing nitrogen fertilizer by 50 lbs per acre. To follow up on those initial on-farm demonstrations PFI partnered with Dordt College in NW IA (pictured below) to compare these systems in a controlled, side-by-side experiment.

Methods

Dordt College established two farming system treatments in 2008: continuous corn (CC) versus a Gateway to Sustainability rotation (G2S) including corn, soybean, and oats with an underseeding of red clover. Treatments were replicated three times and randomized in blocks across the field. Dordt College documented all field operations for planting and harvesting, the inputs applied to each, and harvested yields (corrected for moisture content, see note).

PFI staff used the data to create a fossil fuel flow chart of the energy used to grow the different farming systems at Dordt College. Then PFI staff conducted a literature review and used published values to calculate the amount of energy needed to process the corn from both systems into ethanol and the soybeans from the G2S system into bio-diesel. The energy used to grow each crop was calculated from the diesel equivalents; organized into pre-harvest machinery, seed/inputs, and harvest machinery—estimated from Iowa State University Extension publication PM709. Published values were also used to estimate the amount of renewable energy produced and the heating equivalent, as if the products were burned.

Two separate equations, *Energy Efficiency* and *Land Efficiency* were used to summarize and report the final data results (**Box 1**).

Energy Efficiency is a ratio of the output energy to the input energy, while the *Land Efficiency* is the netted amount of energy per area of land. To understand how efficient the cropping systems were in their production of energy per acre we used both equations to ultimately determine which systems were more efficient.

Box 1

Equation 1

$$\text{Energy efficiency} = \frac{\text{Total biofuel energy output}}{\text{Total energy input}}$$

where:

Total Energy Input = Farm Energy Cost of Production + Biofuel Processing Energy

Equation 2

$$\text{Land use efficiency} = \text{Biofuel Energy Output} - \text{Farm Energy Cost of Production}$$

where:

Biofuel Energy Output = Total Biofuel Energy Output – Biofuel Processing Energy

Box 1. The Energy Efficiency value is a dimensionless ratio of the amount of energy returned as either ethanol or bio-diesel for each unit of energy put into the system, specifically in the processing, planting and harvesting of the crop. The Land Efficiency value is reported in mega-BTUs/Acre. This value is the NET energy produced per acre.

Note: Yields were adjusted to accommodate the difference in rotation length. Since the G2S system is a three-year rotation, the corn, soybeans and oat/red clover crops is each only a third of the total area each year. In contrast, the continuous corn system is 100% of the total area each year. Therefore, 100% of the continuous corn plot was assigned as the effective-area, while only 33.3% of each G2S component was assigned as the effective-area. No bio-fuel product was estimated for the oat/red clover part of the rotation; therefore 33.3% of the G2S rotation was assigned a zero for the calculation.

Data Analysis

Data were analyzed using JMP Pro 10 (SAS Institute Inc., Cary, NC) and yield comparisons employ least squares means for accuracy. Comparisons of means were analyzed using the Tukey Honestly Significant Difference. Statistical significance is determined at α =0.05 level.

Results and Discussion

Biofuels

Based on the Energy Efficiency equation the G2S system in 2009 and 2011 were significantly more efficient than the G2S in 2010 (**Table 1**). The GS2 system was more energy efficient than CC in all years. The G2S system yielded more energy across years, 36%, 30% and 38% respectively, for every fossil fuel BTU expended to plant, harvest and process the crops as compared to the CC system. However it is important to consider the total amount of energy that the different farming systems produced per acre. On the other hand, based on the Land Efficiency equation the CC treatment yielded significantly more energy per acre (9.49 M-BTUs/A) in 2010 than any other treatment in any other year. However, in two years out of three the CC and G2S farming systems produced similar amounts of total energy/acre. The G2S treatment in 2009 yielded the least amount of total energy per acre at 6.02 MBTUs/A. The CC treatment in 2009 and the G2S in 2010 were statistically similar. Both farming system treatments were similar in 2011. The G2S farming system is not only more efficient in the amount of energy it takes to produce the resulting energy commodity but also total production of energy/A was similar to the CC farming system two out of three years.

Table 1	Energy Efficiency (M-BTU/M-BTU)		Land Efficiency (M-BTUs/A)	
	Continuous Corn	Gateway to Sustainability	Continuous Corn	Gateway to Sustainability
2009	1.29 CD	1.77 A	7.92 B	6.02 C
2010	1.32 C	1.72 B	9.49 A	7.32 B
2011	1.28 D	1.76 A	7.07 BC	7.10 BC

Table 1. Biofuel Energy Produced Per BTU and Per Acre References used to calculate table: Berge 1974, Cruse et al., 2010, Hanna 2001, Lammers 2009, Sawyer et al., 2010, Uhrig et al., 1992. Numbers that share the same letter are not statistically different

Table 2	Energy Efficiency (M-BTU/M-BTU)		Land Efficiency (M-BTUs/A)	
	Continuous Corn	Gateway to Sustainability	Continuous Corn	Gateway to Sustainability
2009	14.9 D	68.0 C	56.8 B	32.0 D
2010	16.8 D	96.5 A	64.9 A	45.7 C
2011	13.8 D	89.6 B	52.6 B	41.5 C

Table 2. Heat Energy Produced Per BTU and Per Acre References used to calculate table: Berge 1974, Cruse et al., 2010, Hanna 2001, Lammers 2009, Sawyer et al., 2010, Uhrig et al., 1992. Numbers that share the same letter are not statistically different

Heat Energy

The heat energy equivalent was also calculated to demonstrate the amount of energy produced if the corn and soybean grains harvested from the cropground were burned instead of processed into biofuel. The magnitude of energy produced is much greater than when turning the crops into a liquid biofuel. Based on the Energy Efficiency equation in 2010 the G2S yielded the greatest amount of heat energy for every M-BTU used in the system (**Table 2**). The G2S system in 2011 and 2009 were statistically different and less than in 2010 — but significantly greater than all years in the CC system. All years of the CC system were statistically similar and averaged 15.2 M-BTU/M-BTU. Comparing the yearly averages of the two systems, the G2S yielded 5.5 times more heat energy for every M-BTU expended to plant and harvest the crops as the CC system. However based on the Land Efficiency equation the CC system in 2010 yielded significantly more than the CC in 2009 and 2011. The G2S system in 2010 and 2011 yielded statistically more heat energy than in 2009. The annual average of the CC system yielded 1.3 times more heat energy per acre than the G2S.

Conclusions

When considering both the Energy and Land Efficiency calculations together, the G2S requires less energy input (i.e., BTUs per acre) to convert energy from a crop to a biofuel. The G2S system is more efficient and for biofuel production can achieve similar yields per acre as the CC system. Additionally even though the CC system produces more heat energy per acre it requires 5.5 times more energy to create heat energy. In order to draw an appropriate conclusion, the analysis must include the economics and the CO2 emissions produced by the two different cropping systems. This "expanded analysis" would be an excellent opportunity for future funding.

Literature Cited

Berge, O. 1974. Harvesting and Drying Soybeans A2665 Fact Sheet. Cooperative Extension Program University of Wisconsin.

Cruse, M., et al. 2010. Fossil Energy Use in Conventional & Low-External-Input Cropping Systems. Agronomy Journal Vol 102, Issue 3.

Hanna, M. 2001. Fuel Required for Field Operations: PM709. ISU Extension.

Klepper, R., et al., 1977. Performance and Energy Intensiveness on Organic and Conventional Farms in the Corn Belt: A Preliminary Comparison. Journal of Agricultural Economics V59 N1 P1-12.

Lammers, P. 2009. PhD Dissertation.

Sawyer, J., et al., 2010. Energy Conservation in Corn Nitrogen Fertilization: PM2089i. ISU Extension.

Uhrig, J. and D. Maier. 1992. Costs of Drying High-Moisture Corn. Cooperative Extension Service Purdue University.