Bioenergy and Diversity from Sustainable Systems and Crops

Sarah Carlson, Rich Schuler, Practical Farmers of Iowa
Chris Goedhart, Dordt College

Background

Energy is expensive and the cost has been unpredictable. This project compares two practical Midwest cropping systems to explore the difference between energy use to grow and harvest crops, energy used to process those crops into biofuels and the resulting net biofuel energy and fossil energy ratio. Cropping systems with three or more crops use a fraction of the energy inputs as compared to continuous corn and provide a diversity of farm enterprises. Klepper *et al.* (1977) paired 14 Midwest organic farms with comparable farms not using organic practices, finding that the organic farms produced corn for roughly 36 percent the energy inputs per bushel used on the conventional farms. As noted, nitrogen fertilizer is the greatest single energy input in corn production. In the Klepper study, all farms whether organic or conventional 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 risen. The energy footprint of agriculture is an issue that SARE has always kept alive through research and demonstration projects. Practical Farmers of Iowa field days and workshops in 1992-1993 (LNC92-044) showed that farmer cooperators saved the energy equivalent of 12 gallons of diesel per acre by reducing nitrogen fertilizer an average of 50 lbs per acre.

Methods

To compare these systems in a controlled, side-by-side experiment Dordt College in northwestern, IA established two farming system treatments in 2008. The treatments included: a continuous corn (CC) system versus a gateway to sustainability (G2S) corn→ soybean → oats with red clover rotation. Dordt College documented all field operations for planting and harvesting and the inputs applied to the different treatments. Once the crop was harvested, yields (corrected for moisture content) were reported. PFI staff used the documented field operations, input information and harvested yield data to create a fossil fuel flow chart of the energy that Dordt used to grow the different farming systems. Then PFI staff used published literature to calculate the amount of energy needed to convert or process the corn in both systems into corn ethanol and the soybeans from the G2S system into bio-diesel. PFI staff also estimated (based on published literature) the amount of renewable energy from the ethanol and the bio-diesel products. Since the G2S system is a three-year rotation the corn, soybeans and oat/red clover crops are each only a third of the total area (calculated to an acre) each year. In contrast, the continuous corn system is 100% of the total area each year. This difference was accommodated by assigning 100% of the continuous corn plot as the effective-area, and designating 33.3% of each G2S component as the effective-area. Using this method PFI adjusted the resulting yields of the crops from the rotation.

Discussion

The energetic differences between the two farming systems were calculated. The diesel equivalents for each crop year's field operations organized into preharvest machinery, seed/inputs and harvest machinery were estimated from Iowa State University Extension publication PM709. The energy usage to produce the crops was calculated from the diesel equivalents in the preharvest machinery, seed/inputs and harvest machinery. The energy used to process the crop into ethanol or bio-diesel was also calculated and the energy produced from the resulting ethanol or bio-diesel biofuel. Two separate equations were used to summarize the data.

Equation 1) Energy Efficiency = Total Bio-fuel Energy Output / Total Energy Input: where Total Energy Input = Total Bio-fuel Energy Output / Farm Energy Cost of Production reported as a dimensionless number. This value is a 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.

Equation 2) Land Efficiency = Total Bio-fuel Energy Output – Total Energy Input: where Total Energy Input = Total Bio-fuel Energy Output - Farm Energy Cost of Production reported in mega-BTUs/Acre. This result provides us with the NET or how much total energy is produced per acre.

	ENERGY EFFICIENCY (M-BTU/M-BTU)		**LAND EFFICIENCY (**M-BTUs/A)	
	Continuous Corn	*Gateway to Sustainability*	*Continuous Corn*	*Gateway to Sustainability*
2009	1.27	1.72	6.94	5.86
2010	1.29	1.69	8.41	7.07

Table 1. References used to calculate table (Berge 1974, Cruse et al., 2010, Hanna 2001, Lammers 2009, Sawyer et al., 2010, Uhrig et al., 1992)

Conclusions

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. In 2009 and 2010, the G2S treatment yielded 33% or a 1/3 more energy for every fossil fuel BTU expended to plant, harvest and process the crop as compared to the CC system. The G2S system in 2009 and 2010 were more efficient in terms of energy yielded from energy expended. However it is important to consider the total amount of energy that the different farming systems are producing. In 2009 and 2010 the CC yielded more bio-fuel/A than the G2S. On average between the two years the CC averaged 7.68 M-BTUs while the G2S treatment averaged 6.47 M-BTUs. When both the energy and land efficiency results are considered, the conclusion is that although less total energy /acre was extracted from the G2S system, it required less energy input (i.e., BTUs per acre) to convert energy from a crop to a biofuel. 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” will be forthcoming.

References

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.