



Dordt College Continuous-Corn and Three-Year Rotation farming systems

Bioenergy and diversity from sustainable systems

by Rich Schuler and Sarah Carlson

Which cropping system is best for producing biofuels: corn-on-corn, or a three-year rotation? It is well documented that a three-year or longer rotation takes fewer external or “off-farm” inputs compared to a corn-on-corn system. But, what is the result if we compare these two systems, not only by how much energy is used on the farm, but also by how much energy is produced in the form of biofuels?

The production of biofuels requires significant energy to process the harvested farm products into ethanol or biodiesel. If farmers are planning to sell crops that will be made into biofuels or to make biofuels on-farm, the overall energy use (from the first tilling pass to the delivery of the first gallon of biofuel) could be substantially different. An understanding of all the energy costs associated with varying cropping systems will allow farmers to be better decision-makers in the biofuel marketplace.

The recent volatility in energy costs and the varying claims of biofuel production efficiencies prompted Dordt College and Practical Farmers of Iowa to cooperate in a three-year bioenergy and crop diversity study beginning in 2008. This ongoing project compares two Midwest cropping systems by evaluating the difference between the energy used to grow, harvest and process crops into biofuels and the energy embodied in the final biofuel products. The two cropping systems are defined as: Continuous Corn (corn-on-corn) and Three-Year Rotation (corn, soybean and oats with an under

seeding of red clover). Dordt College and PFI chose to analyze these two farming systems to determine which is most practical for producing biofuels.

Dordt College in Sioux Center established the two farming system treatments in a controlled, side-by-side experiment. The Continuous-Corn and the Three-Year Rotation treatments have all parts of the rotation present in every year (See photo, top of the page). Each plot is 0.4 acres in size and each treatment is replicated three times. Dordt College representatives took extensive field notes on all field operations for planting and harvesting, all inputs applied to each cropping system, and the yield and moisture content of the crops. The red clover in the Three-Year Rotation was clipped and returned to the farming system as green manure. Only oat grain and straw were harvested from that part of the rotation. Using data from published literature, PFI staff calculated the energy required to process the corn from the Continuous-Corn and Three-Year Rotation systems into ethanol, and the soybeans from the Three-Year Rotation system into biodiesel. In addition, PFI staff computed the energy in the final biofuel products (ethanol and biodiesel).

Table 1 (below) includes the results of this study to date and clearly reveals two distinct categories of efficiency: Energy Efficiency and Land Efficiency. Energy Efficiency is the ratio of the output energy to the input energy, while the Land Efficiency is the net energy derived per acre of land.

In 2009 and 2010, the Three-Year Rotation and Continuous-Corn treatments yielded an average of 1.74 and 1.30 M-BTUs respectively for each fossil fuel M-BTU input used to plant, harvest and process the crops into biofuels. These values are statistically different; therefore, the Energy Efficiency, or amount of energy produced compared to the amount

needed in the Three-Year Rotation was 29 percent greater than the Continuous-Corn system. This was attributed to the greatly reduced amounts of nitrogen fertilizer needed to grow, maintain and harvest the crops in the Three-Year Rotation.

With respect to the energy per acre derived in 2009 and 2010, the Continuous-Corn and Three-Year Rotation systems yielded an average net energy of 8.66 and 6.66 M-BTU/acre respectively. These values are also statistically different; consequently, the Land Efficiency, or the amount of energy produced per acre of land, in the Continuous-Corn system is 26 percent higher than the Three-Year Rotation system. This result is attributed to the oat/red clover part of the Three-Year Rotation not providing any “biofuel” to the total biofuel produced per acre.

Since neither the Continuous-Corn nor the Three-Year Rotation system has a higher efficiency in both the energy and land categories, a definitive conclusion cannot be drawn on the basis of energy alone. On one hand, if the main goal is to maximize the biofuel energy output with respect to the fossil fuel energy input, the Three-Year Rotation system is superior. On the other hand, the Continuous-Corn system is the preferred choice if the highest biofuel energy output per acre is the primary objective.

To draw an appropriate conclusion on the overall superiority of either system, the analysis must be expanded to include additional parameters. Consequently, the economics and the CO₂ emissions produced by the two different cropping systems will be evaluated. This “expanded analysis” will be conducted following the 2012 harvest.

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Table 1. Summary of the Energy and Land Efficiencies computed for 2009 and 2010.

Year	ENERGY EFFICIENCY (M-BTU/M-BTU)		LAND EFFICIENCY (M-BTUs/A)	
	Continuous Corn	Three Year Rotation	Continuous Corn	Three Year Rotation
2009	1.29	1.76	7.86	6.01
2010	1.32	1.72	9.45	7.32

$$\text{Energy Efficiency} = \frac{\text{Total Biofuel Energy Output}}{\text{Total Energy Input}}$$

$$\text{Land Efficiency} = \frac{\text{Total Biofuel Energy Output} - \text{Total Energy Input}}{\text{Acre}} = \frac{\text{Net Energy}}{\text{Acre}}$$