Impacts of Organic Farming on the Efficiency of Energy Use in Agriculture

An Organic Center
State of Science Review

By
David Pimentel
Cornell University
Ithaca NY

August 2006

I. FOCUS STATEMENT

Each year, the food system utilizes about 19 percent of the total fossil energy burned in the United States (Pimentel et al., 2006) (Figure 1). Of this 19 percent, about 7 percent is expended for agricultural production, 7 percent for processing and packaging, and 5 percent for distribution and food preparation by consumers (Pimentel et al., 2006). If forestry production and utilization are included, the total for the food, fiber, and forestry sectors of the economy rises another 5 percent, to 24 percent of national fossil energy use. This amount of energy (24 percent) is similar to that consumed by automobiles each year in America (USCB, 2004-2005).

The total fossil energy used in U.S. conventional crop production is approximately 1,000 liters per hectare (107 gallons per acre) (Pimentel et al., 2002). Of this, about one-third is for fertilizers, another third is for mechanization to reduce labor, and about a third covers all other activities and inputs, including pesticides. Past studies on energy use in alternative and sustainable corn and soybean production systems have pointed to nitrogen fertilizer and pesticides as the inputs leading to the biggest differences in energy use and efficiency, compared to conventional production systems (Pimentel et al., 2005; Pimentel and Pimentel, 1996).

The high degree of reliance of conventional farming systems on cheap energy became a pressing concern in the wake of rapidly growing oil demand by the U.S., China, and India, and damage to Gulf Coast energy infrastructure in the summer and fall of 2005. In addition, Congress passed a major energy bill in 2005, extending costly subsidies for ethanol production, and dramatically increasing goals for energy production from ethanol and other biofuels, mostly derived from corn. The more than $3-a-gallon gasoline, the war in Iraq, continued instability in the Middle East, and declining global energy reserves in the face of strongly growing worldwide demand, have further elevated the prominence of energy use and efficiency on both the agriculture and energy policy agendas.

Rising energy costs have doubled the cost of many farm inputs and routine farming operations compared to just a year ago, and both fuel and natural gas prices are projected to increase another 30 percent to 50 percent in 2006 (USCB, 2004-2005). Across the country, farmers are deeply worried over energy-driven increases in their production costs. This State of Science Review (SSR) analyzes the extent to which:

- Conversion to organic farming systems will reduce the dependence of farmers on energy; and
- Organic farming can increase the efficiency of energy use per unit of production.

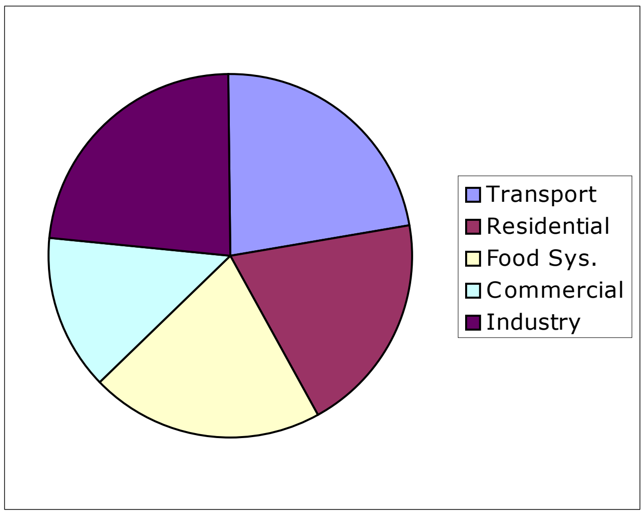

Figure 1. The relative percentages of the approximately 100 quads of fossil energy that is utilized in the United States each year. Note that about 19% is consumed in the food system.

Both organic and conventional farming systems are dependent on fossil and solar energy. In several respects and in carrying out many routine tasks, energy use actually does not differ significantly on conventional and organic farms. The energy cost of trucking grain to market is the same per mile. The same amount of energy is needed to manufacture and run a tractor (these lifecycle costs have been included in the 19 percent above). The energy cost of pumping irrigation water is the same per acre-foot on a conventional and organic farm. The energy tied up in seed, or livestock-breeding stock differs little between conventional and organic farms.

On the other hand, energy use on conventional and organic farms differs substantially in several ways. The largest and most readily measured differences are associated with the energy required to manufacture, ship, and apply pesticides and nitrogen-based fertilizers. Other often-significant differences are harder to quantify and include the impact of organic and conventional farming systems on soil quality and health, and on the conservation of water.

This SSR focuses on the production of corn and soybeans under organic and conventional systems. Data are also presented on the energy inputs in the production of several other major crops grown under conventional systems. The energy inputs in U.S. livestock production systems are also discussed.

Energy Dependence Has Steadily Grown

Yields of most U.S. crops have increased approximately four-fold since the 1940s (USDA, 1940, 2004). Steady yield gains have been the result of technological changes rooted in the breeding of higher-yielding plant varieties, increases in the number of seeds planted per acre, more intensive use of fertilizers and pesticides, and more extensive irrigation of cropland. All of these new production technologies depend on the use of significant amounts of fossil energy.

The availability of ample quantities of fossil energy and new farm technologies has reduced the human labor required to grow and harvest a hectare (2.47 acres) of row crops like corn and soybeans from approximately 1,200 hours per hectare prior to the introduction of farm machinery, to about 11 hours now (Pimentel and Pimentel, 1996; Pimentel and Patzek, 2005).

Comparing labor and energy use across time periods and agricultural systems is tricky. Often, the energy required at a production facility to manufacture a ton of fertilizer is reported as the total energy cost of that fertilizer, ignoring the energy required to ship the fertilizer to the farmer, and the cost of energy embedded in the tanks and equipment needed to handle and apply the fertilizer. In calculating the total energy expended in major crop production on the farm, the additional energy expended by workers who mined and refined the oil, plus that of the workers who made the tractors and other farm equipment, are typically not included.

The energy data for most of the workers who play a role in bringing energy-intensive inputs to the farm remain extremely difficult to obtain. If all human labor that supports conventional farm production is included, an estimated 30 hours of human labor are expended in order to produce a hectare of corn. Even so, the estimated 30 hours of labor are significantly less than the average 1,200 hours expended when corn is raised by hand (Pimentel and Pimentel, 1996).

Peak oil and natural gas supplies are projected for the year 2007, and the resulting decline in energy supplies will change lifestyles and impose economic stresses on all sectors of the economy, including agriculture over several decades

(Youngquist and Duncan, 2003; Campbell, 2005). The decline in fossil energy resources will surely result in increasing prices for fuel, fertilizer, and other essential farming inputs for both organic and conventional farmers.

Both oil and natural gas prices are projected to increase from 30 percent to 50 percent during the year 2006. Economic pressures on farmers triggered by rising energy processes will intensify interest in the identification of farming system alternatives that will consistently increase energy efficiency, and hence reduce the amount of energy needed to produce a given quantity of a particular crop. This SSR highlights the contributions that organic farming practices can make in this quest for more energy-efficient farming systems.

V. CONCLUSIONS

Organic farming systems significantly reduce the fossil energy inputs in production and also improve several aspects of agriculture's environmental performance compared with conventional farming systems.

This SSR reports several key findings:

- Fossil energy inputs in organic corn production were 31 percent lower than conventional corn production, and the energy inputs for organic soybean production were 17 percent lower than conventional soybean production.

- No commercial nitrogen was used in the organic corn and soybean production systems.

- No synthetic pesticides were used in the organic corn and soybean production systems.

- Soil erosion was significantly reduced in the organic production systems compared with the conventional production systems, thus conserving nitrogen, phosphorus, and potassium.

- Water resources were conserved in the organic production systems compared with the conventional production systems.

- Corn and soybean organic farming system-yields during drought years were 30 percent and 50 percent higher than the conventional corn and soybean-yields, respectively.

- Soil organic matter in the organic farming systems was 54 percent higher than in the conventional farming systems.

- The organic corn farming system collected 180 percent more solar energy than the conventional corn farming system.

- The organic beef grass-fed system required 50 percent less fossil energy than the conventional grain-fed beef system.