Comparing Energy Use in Conventional and Organic Cropping Systems

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Both conventional and organic agriculture depend on fossil fuel and solar energy. The amount of energy used on farms varies depending on the size and geographic location of the farm, as well as the types of products and processes used on the farm. It has been estimated that since 1992, direct energy expenses from fuel and electricity averaged around 7 percent of the average U.S. farm's total operating costs. Incorporating indirect expenses from such things as fertilizers and pesticides increases this average to 15 percent of total operating costs (1).

Horticulturist Eric Brennan records data on weed seedling growth between rows of a young cover crop at USDA's 17-acre certified organic research plot in Salinas, California. Photo by Scott Bauer, courtesy USDA ARS.

Energy use in agriculture

Energy consumption can vary significantly between conventional and organic production systems when accounting for direct energy inputs as well as indirect energy involved in manufacturing, shipping and applying pesticides and nitrogen-based fertilizers. Because organic agriculture reduces the amount of indirect energy inputs, it is often assumed that organic agriculture is less energy intensive than conventional agriculture. However, this is not always the case.

Practices such as irrigation, heavy machinery use and heated greenhouses consume large amounts of energy. These practices are utilized by both organic and conventional operations. Energy use associated with processing, packaging, storage and distribution must also be taken into account. Several studies have attempted to compare the yield differences, energy inputs and environmental effects associated with conventional and organic cropping systems. What follows is a summary of some of the results of these studies.

Comparison considerations

Several factors must be considered when comparing the energy intensiveness of conventional and organic systems. One significant challenge is representing a typical conventional or organic system. Farming practices vary widely depending on the location and size of the farm, the type of crop produced and individual farmer decisions. Conventional farming practices range from high-input intensive systems to near-organic systems. Similarly, organic systems, although adhering to a set of standards, differ in implementation. Some organic farms are highly sustainable ecological systems, but some are large-scale monocropping or mass livestock operations that operate like conventional farms, with the exception of not using synthetic pesticides, fertilizers and veterinary drugs (2).

Other factors that affect a reliable comparison of conventional and organic agricultural systems include:

- *Limited research in the United States*

  Many of the studies included in this publication are international in scope. This is due to a lack of comparison trials in the United States. Energy utilization comparisons are difficult among countries because differences in climatic conditions and crop rotations affect inputs and yields. International organic certification standards also may differ somewhat from U.S. Department of Agriculture standards.

- *Structure of comparison*

  One issue that affects reliable comparison is how to account for the potential yield differences between systems. Should energy consumption be measured per unit of land area, per unit of economic activity or per unit of produce?

- *Boundaries of comparison*

  Another issue is how to account for embedded and indirect energy consumption. How do comparisons incorporate pre- and post-production energy inputs?

Studies

Rodale Institute Farming Systems Trial

The widely referenced 27-year Rodale Institute Farming Systems Trial (FST) is the longest-running side-by-side comparison of organic and conventional corn and soybean production systems in the United States. The study compares a conventional farm that uses recommended fertilizer and pesticide applications with an organic animal-based farm where manure is applied and an organic legume-based farm that uses a three-year rotation of hairy vetch/corn and rye/soybeans and wheat. The two organic systems receive no chemical fertilizers or pesticides.

David Pimentel, a Cornell University professor of ecology and agriculture, was the lead author of this study and concluded that "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." (3) *www.organic-center.org/reportfiles/ENERGY_SSR.pdf*

Sustainable Agriculture Farming Systems Project: University of California, Davis

A team of researchers, farmers and farm advisors established the Sustainable Agriculture Farming Systems project (SAFS) at the University of California, Davis, in 1988 to study the transition from conventional farming systems to low-input organic systems. The project has compared four systems: organic, low-input, conventional four-year rotations and a conventional two-year rotation. Cash crops in the four-year rotations include processing tomatoes, safflower, dry beans, wheat and corn. The two-year rotation includes tomatoes and wheat.

The team found that the low-input system was most energy efficient and that crop yields were comparable among the different systems. Tomato and corn yields in the organic system were a little lower than in the low-input and conventional systems, mainly from nitrogen limitations. Differences in yields were much greater between years than between systems.

The SAFS team concluded that "the organic system is less efficient than the low-input system because of the great distance that many organic fertilizers (such as dried seaweed) are shipped before arriving at the field, and because of energy requirements for mechanical weed control." (4) *http://wsare.usu.edu/pro/pr2001/SW99-008.pdf*

Related ATTRA Publications

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Federal Resources for Sustainable Farming and Ranching

Federal Conservation Resources

Food Miles: Background and Marketing

University of Manitoba Glenlea Study of long-term rotations

The Glenlea Study began in 1992 with the objective of creating a long-term comparison of the biological, environmental and economic impacts associated with conventional, low-input and organic cropping systems.

Reseachers analyzed energy use between 1992 and 2003. The experiment included two four-year crop rotations of either wheat-pea-wheat-flax (WPWF) or wheat-alfalfa-alfalfa-flax (WAAF); and two crop input combinations of either a fertilizer- and herbicide-added (F+H+) conventional system or a no-inputs organic system (F-H-). See *Table 1* for more information.

This study found that eliminating fertilizer and pesticide inputs in the organic system resulted in energy-use reductions. Also notable is the potential of perennial forage legume crops, in this case alfalfa, in reducing energy use.

For a full discussion of results, along with cropping system yield information, weed dynamics, soil nutrient status and economic analysis, see the Glenlea Study Web site at *www.umanitoba.ca/faculties/afs/plant_science/glenlea/glenlearesresults.html*.

Washington State University: Sustainability of three apple production systems

In this study, researchers at Washington State University investigated the sustainability of organic, conventional and integrated apple production systems in Washington State from 1994 to 1999. In terms of environmental and economic sustainability, this study rated the organic system first, the integrated system second and the conventional system last.

Researchers measured several indicators of sustainability, including energy efficiency. Energy accounting was divided into inputs such as labor, fuel, fertilizers and so on; output, or yield; and output-to-input ratios, or a measure of energy efficiency. Cumulative energy inputs and outputs for the six-year study period were lower for the organic system than for the conventional and integrated systems. The output-to-input ratio for the organic system during the six-year study period, however, was 7 percent greater than that for the conventional system and 5 percent greater than that for the integrated system, making the organic system the most energy efficient (5).

Learn more about the study online at *www.nature.com/nature/journal/v410/n6831/full/410926a0.html*.

Switzerland Research Institute of Organic Agriculture: Soil Fertility and Biodiversity in Organic Farming

The DOK (bio-Dynamic, bio-Organic, and Konventional) long-term field experiment was developed in 1978 in Therwil, Switzerland. The experiment investigated differences in crop yield, soil biology, environmental health and product quality among organic, biodynamic and conventional agriculture methods.

Table 1. Total rotational energy consumption (MJ/ha)* in the Glenlea long-term cropping systems study, 1992-2003

Rotation	Inputs	Total energy consumption	Seed energy	Fuel and lube energy	Machinery energy	Pesticide energy	Fertilizer energy
WPWF	F+H+	68,498	7,902	16,133	2,367	7,116	34,980
WPWF	F-H-	24,233	7,902	14,229	2,102	0	0
WAAF	F+H+	49,255	3,657	18,184	2,515	3,499	21,400
WAAF	F-H-	22,181	3,657	16,213	2,311	0	0

WPWF = wheat-pea-wheat-flax; WAAF = wheat-alfalfa-alfalfa-flax *MJ/ha=megajoules/hectare

Between 1978 and 1998, this Swiss experiment evaluated energy use for potatoes, winter wheat, beetroots, barley and grass-clover under four different cropping systems:

1) BIODYN, or biodynamic;

2) BIOORG, or bioorganic;

3) CONFYM, or conventional using mineral fertilizer plus farmyard manure; and

4) CONMIN, or conventional using mineral fertilizer exclusively.

This study found that the organic farming systems used from 20 to 56 percent less energy to produce a crop unit, measured in metric tons. Per land area this difference was from 36 to 53 percent. See *Table 2* for additional information (6).

For more information on this experiment, visit *http://orgprints.org/7682/01/Fliessbach_et_al_DOK-trial.doc* and *www.mindfully.org/Farm/Organic-Farming-Fertility-Biodiversity31may02.htm.*

Agricultural University of Norway: Energy Utilization in Crop and Dairy Production in Organic and Conventional Livestock Production Systems

This study used data recorded between 1990 and 1992 from 14 organic and 17 conventional farms affiliated with the Norwegian Institute of Agriculture Science. All of the farms studied had dairy production combined with grain production, except two of the organic farms that had beef cattle as the main endeavor.

Energy use was analyzed for small grains, grass clover and fodder beets in three soil types. Energy price was determined by the total number of energy inputs in megajoules divided by the total yield output in kilograms.

Table 2. Energy input per unit land area (GJ ha–1) in the second crop rotation (n = 3)

Crop	BIODYN	BIOORG	CONFYM	CONMIN
Potatoes	26.39	28.42	39.85	40.69
Winter wheat 1	12.52	11.56	18.88	19.74
Beetroots	16.31	15.14	28.53	31.56
Winter wheat 2	10.31	9.79	20.49	21.81
Barley	8.82	9.62	16.29	15.78
Grass-clover sowing year	6.43	7.63	6.78	6.75
Grass-clover 1st year	3.91	4.27	5.22	11.75
Grass-clover 2nd year	4.86	6.48	9.98	20.47
Sum	89.55	92.91	146.02	168.55
Mean (energy input per year, sum/7)	12.79	13.27	20.86	24.08
Mean% (CONFYM = 100%)	61	64	100	115
	biodynamic	bioorganic	with manure	without manure

This study found that "conventional crop yields were higher but they also used more indirect energy with input factors, especially fertilizers. The conventional yields were not sufficiently higher to compensate for the extra use of energy compared with the organic crops." (7)

Learn more about this study at *http://orgprints.org/6189/01/6189.pdf.*

Department for Environment, Food and Rural Affairs: Energy use in organic farming systems

The United Kingdom Department for Environment, Food and Rural Affairs (DEFRA) has conducted a number of studies related to the sustainability of organic agriculture systems. The objective of this March 2000 report was to develop a model of energy inputs in organic farming systems. The model was used to compare energy use in organic and conventional systems of similar capacities. The model incorporated average yield data from previous studies including vegetables, dairy, beef and sheep. This report also took into account energy use associated with transportation.

Among the results found in this study, the following points were established:

- Mechanical weeding of organic crops involved less energy than herbicides did in conventional production.
- Flame weeding may involve as much or more energy than herbicides.
- Transport energy inputs for organic vegetable crops are greater because of smaller production levels, smaller delivered loads and longer average distances to certificated organic packing facilities.
- Organically grown crops have a lower energy input per unit area than conventional crops, largely because of lower fertilizer and pesticide inputs. See *Figure 1* for a graph of energy input by category on an area basis.
- Organic crops still show a lower energy per unit when energy input is analyzed per yield, but the difference is reduced due to the lower organic output. Organic carrots are more energy intensive due to flame weeding and higher distribution costs than conventional carrots. See *Figure 2* for a graph of energy input by category on a unit output basis.

For livestock enterprises, energy input is lower in organic systems, particularly dairy. See *Figure 3* (next page) for a graph of direct and indirect energy inputs into livestock enterprises (8).

Figure 1. Energy input by category on an area basis (MJ/ha)

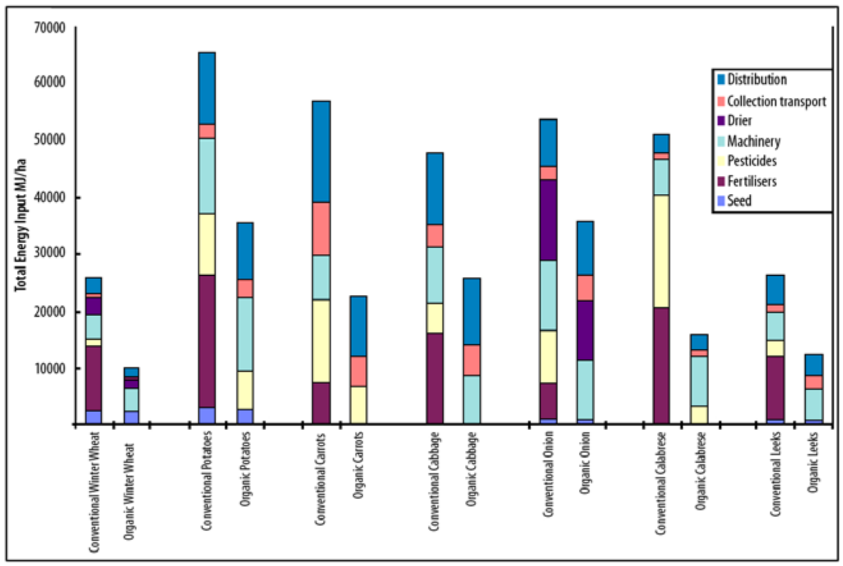


Figure 2. Energy input by category on a unit output basis (MJ/t yield)

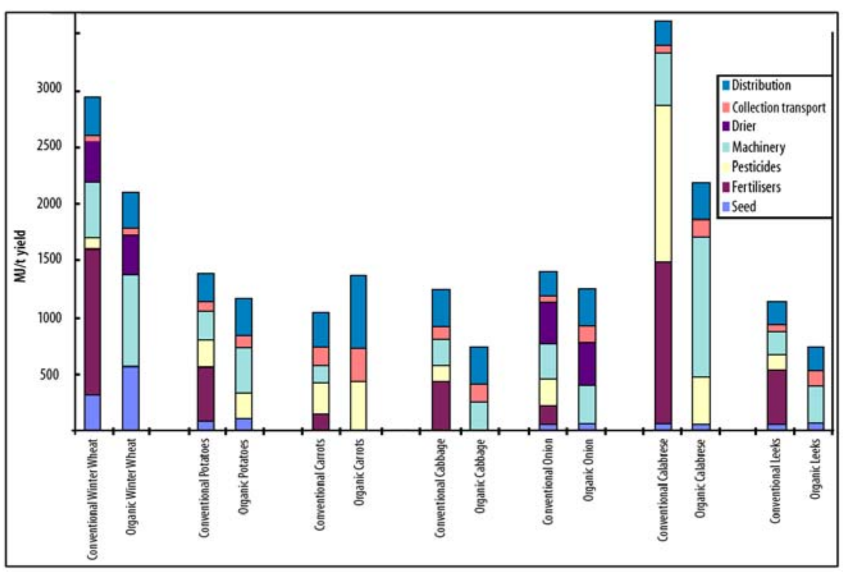
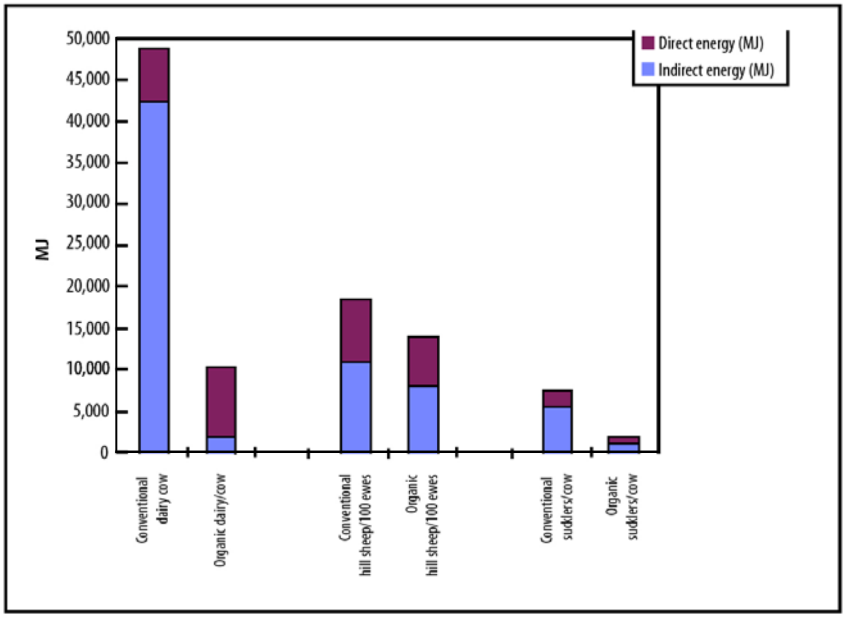


Figure 3. Direct and indirect energy inputs into livestock enterprises



For more information on this study, visit *http://randd.defra.gov.uk/Document.aspx?Document=OF0182_181_FRP.pdf.*

Department for Environment, Food and Rural Affairs: Environmental Impacts of Food Production and Consumption

This 200-page report was released by DEFRA in December 2006 with the objective of informing government policy about reducing the environmental impacts of food consumed in the United Kingdom. Included in this study was an analysis of the environmental impacts of organic versus conventional food systems in the United Kingdom. The report states producing many foods organically affects the environment less than producing the foods conventionally. However, that is not true for all foods and is rarely true for all classes of environmental effects. The report said that not enough evidence is available to state that organic agriculture will have fewer harmful effects on the environment than conventional systems.

More specifically, the DEFRA report proposed the following:

- Organic potato production has similar energy requirements to conventional potato production because cooling and storage account for 40 percent of the energy use in potato production for both organic and nonorganic crops.
- Organic milk production appears to require less energy but much more land than conventional production. It also creates more emissions of greenhouse gases, acid gases and eutrophying substances per unit of milk produced.
- Organic production of beef, sheep and pig meat is associated with lower energy demands, but organic poultry requires higher energy inputs. See *Table 3* (next page) for more information.

The DEFRA report concludes that more research needs to be done in order to more accurately determine the environmental impacts of organic and conventional foods (9).

This article received much press with titles such as "Why going organic could cost the earth," "UK research casts doubt on environmental claims" and "How green is organic?"

In response, the Soil Association released a statement to assure consumers of the benefits of organic food. See the following summary for details: *http://randd.defra.gov.uk/Document.aspx?Document=EV02007_4601_FRP.pdf*

Soil Association responds to the Manchester Business School report: Environmental Impacts of Food Production and Consumption

The Soil Association argued that organic farming is about 30 percent more energy efficient for producing the same quantity of food as conventional agriculture. In their argument, the association included the following list of food products and how much energy an organic system required to produce the food in comparison to a conventional system. See *Table 3* (next page) for more information.

The Soil Association also promoted the other environmental benefits of organic agriculture,

Table 3. Energy used to produce food products in organic agriculture systems compared to conventional systems

Leeks 58% less	Onions 16% less
Milk 38% less	Pig meat 13% less
Beef 35% less	Potatoes 2% more
Wheat 29% less	Eggs 14% more
Carrots 25% less	Tomatoes *(long season)* 30% more
Lamb 20% less	Chicken 32% more

including improved soil quality, supporting local food markets, increased biodiversity and reduced pesticide pollution, water usage and packaging waste. For more information, visit *www.soilassociationorg/web/sa/saweb.nsf/89d058cc4dbeb16d80256a73005a2866/80ca2af0ab639f5a8025728800608e08!Open Document.*

University College Dublin: Greenhouse Gas Emissions from Conventional, Agri-Environmental Scheme and Organic Irish Suckler-Beef Units

In this study, 15 suckler-beef units in southern Ireland were assessed in terms of greenhouse gas emissions. The units included five conventional, five organic and five Rural Environmental Protection Scheme (REPS) systems. REPS was implemented in Ireland as a system for rewarding farmers that adhere to strict guidelines regarding nutrient management and habitat conservation.

Emissions factors considered included diesel fuel used, fertilizer applied, manure management and electricity, among others. Results of this study indicated that applying REPS systems would result in less greenhouse gas emissions in comparison to conventional suckler-beef production. Emissions could be reduced even more by applying organic systems, but would result in a substantial drop in production (10). For additional information on this project, visit *http://jeq.scijournals.org/cgi/content/full/35/1/231.*

United Nations Food and Agriculture Organization: Energy Use in Organic Food Systems

This report, released in August of 2007 by the Food and Agriculture Organization of the United Nations, used existing research to examine the potential of organic and nonorganic agricultural systems to reduce energy consumption and mitigate climate change. The study revealed the following points:

- In most cases, organic agriculture uses from 30 to 50 percent less energy in production than comparable conventional agriculture.
- Organic agriculture typically uses energy more efficiently than nonorganic agriculture.
- Organic agriculture often requires about one third additional human labor hours as a trade-off for energy-intensive inputs used in conventional agriculture.

The report indicated that further research is needed to determine whether reductions in energy consumption on the production side of organic systems are maintained through post-production processing, packaging and transport.

According to the Food and Agriculture Organization, "Organic agriculture holds a great potential for pioneering energy-reducing practices through the framework of organic standards. Organic principles, which emphasize environmental stewardship, farm-level self-sufficiency and incorporation of externalities, can be leveraged to develop strategies for limiting use of fossil fuel-based energy in organic agriculture. Especially in the areas of post-production handling, innovations in the organic supply chain to decrease energy consumption can influence parallel conventional sectors." (2)

Visit *www.fao.org/docs/eims/upload/233069/energy-use-oa.pdf* for additional information on this research.

Conclusion

As is apparent in a review of existing studies, there are many complexities involved in comparing energy consumption in conventional and organic cropping systems. Some research indicates that organic agriculture is more energy efficient than conventional agriculture, but not in all cases. In some cases, organic agriculture may be more energy intensive depending on the specific farming operation, the crop produced and the post-production handling. It is important to assess the energy intensiveness of food systems in a holistic manner that incorporates energy consumption for the entire life cycle of the food product.

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Further resources

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