Energy Efficiency in Conventional versus Alternative Farming Methods

Nancy Ghuman MES Candidate 2016

Faculty of Environmental Studies, York University

Abstract

Sustainable agriculture is "the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species" (Sustainable Agriculture Initiative Platform, 2010).

Agriculture is responsible for two types of greenhouse gasses (GHG): nitrous oxide, N_2O, and methane, (CH4). Ultimately there are two major classifications of agricultural methods practiced today: conventional and alternative. This research focuses on energy usage in conventional farming to alternative and organic farming methods.

Research Question

1) Which type of farming method is more energy efficient (Conventional vs Organic).

Background

Energy is defined as "the capacity of a physical system to do work" (Physics, 2013). In comparing the two types of agriculture, the energy expelled in the duration of each system will be examined: direct and indirect energy inputs.

Direct energy inputs refer to direct fossil fuels used in machinery and the utilization of electricity, and indirect energy inputs are those that require intensive energy inputs such as fertilizer, pesticides, chemically treated crop seeds, water and methane (Cormack, 2000; 4). The dominant share of direct energy input comes from fuels to run machinery for field operations (Beckman, et al., 2013; 10), both conventional and alternative farming methods use fuel operated machinery, however, due to the large size of conventional farms an increased amount of machinery is required. The average size of an organic farm in the US is just over 140 acres (Ikerd, 2001), while the average conventional farm has doubled between 1982 and 2007 from 589 acres to 1,105 (MacDonald, et al., 2013).

The impact of energy inputs, in agriculture, on the environment need careful analysis, because, "agriculture is about as inseparable from the environment as weather is from climate" (Vandermeer, et al., 2009; 20).

Agriculture covers "almost one-third of the earths surface, 4 billion hectares" (Bulgaria, 2009; 20), of this organic agriculture only accounts for 30 million ha (Chappell, 2009; 6), representing only 0.75% of agriculture land occupation. With conventional agriculture continuing to take up large masses of land, a loss in biodiversity and increases in GHG emissions will continue to be experienced. Agriculture contributes 10-20% of global anthropogenic (originating from human activity) GHG emissions, the greatest contribution comes from fertilizer use (38%), enteric fermentation (32%), biomass burning (12%), rice pady (11%) and manure handling (7%) (Vandermeer, et al., 2009; 21).

Organic

Organic farming is commonly criticized for its lack of yield potential to feed the rapidly growing global population, a feat that conventional farming currently promises. The problem with global food security is not one of supply, but rather the need for equitable global distribution and local accessibility of food (Chapell, Lavelle, 2009; 8), which alternative agriculture can deliver, and conventional has proven to not.

•Organic agriculture uses methods that examine low-input, sustainable, biological, agro-ecological and organic agricultural practices (Chappell, LaValle, 2009, 5).

•Organically grown crops require around 50% of the energy input per unit area compared to conventional crops (Cormack, 2000; 2).

(Figure 1)

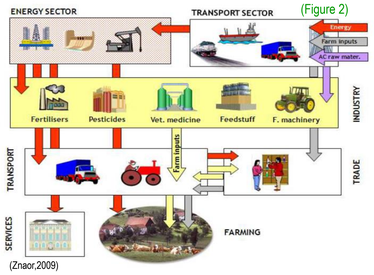
	Organic Farm	Conventional Farm
Indirect Energy MJ	116,240- 59%	322,408 - 72%
Direct Energy MJ	82,249 - 41%	122,990- 28%
Total Output MJ	489,747	489,747
Total Energy Input MJ	198,489	445,398
Per unit area (MJ/ha)	397	891
Overall Energy Ratio	2.47	1.10

(Cormack, 2000; 16)

Conventional

- As much as 50-80% of energy inputs in conventional farming come from manufacturing and the transport of pesticides (Cormack, 2000; 2).
- Conventional farming is energy intensive during the production and transportation of synthetic pesticides, as well in the application of unnatural farming methods that use synthetic, chemicals in managing weeds.

(Figure 2)



(Znaor,2009)

CO2

Indirect carbon dioxide emissions arising from the use of fertilizers and pesticides are estimated to be responsible for 88 % of CO2 in the atmosphere (Zanor,2009; 63). Organic agriculture has the potential to reduce total CO2 concentrations in the atmosphere by 3.5- 4.8 Gt of CO2 per year (Zanor, 2009; 63).

(Figure 3)

Emissions Source	Annual Emissions gas emitted (million t CO2-eq)	Gas emitted
Soil Fertilization (organic and mineral)	2,100	Nitrous oxide
Enteric fermentation in rumen	1,880	Methane
Biomass burning	700	Methane, nitrous oxide
Rice production	600	Methane
Livestock Manure	400	Methane, nitrous oxide
Other (mechanization, irrigation, greenhouses)	900	Carbon dioxide, nitrous oxide
Deforestation and devegetation	8,500	Carbon dioxide
Total	**15,080**	

(Scherr,2008)

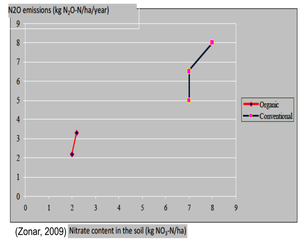
GHG

Alternative agricultural methods are 6-10 times more energy efficient than conventional agricultural methods, due to a decrease in energy dependency of "inputs and less petro fuel-dependent infrastructure, they also restore soils and nitrogen fixating bacteria, reducing emissions up to 15%" (Vandermeer, et al., 2009; 6).

Nitrous Oxide

- Nitrous Oxide is a greenhouse gas that is largely the outcome of modern agriculture activities; its potential to warm the planet is 298 times stronger than CO2 per unit weight (IPCC, 2007).
- Globally, agricultural accounts for 24% of annual N_2O emissions (IPCC, 1996). In the US this number is larger, with the agricultural sector being responsible for 75% of annual N_2O emissions. The use of synthetic fertilizer has increased by about 150% since 1970 (IPCC, 1996).

(Figure 4)



(Zonar, 2009) Nitrate content in the soil (kg NO_3-N/ha)

Water

- Organic soil retains 15-20% more water than conventional soil does.
- Conventional legumes show signs of greater water stress than organic, resulting in larger applications and requirements of water (Roadale Institue, 2011).

(Figure 5)

(Wood,2003)

(Figure 6)

	Units	Organic farm				Conventional farm			
		On-site	Indirect		Total	On-site	Indirect		Total
			1st Order	Higher-order			1st Order	Higher-order	
Energy intensity	MJ/A$	2.2	2.6	4.0	8.8	1.8	3.7	8.3	13.8
Greenhouse gas intensity	kg/A$	0.2	0.2	0.5	0.9	0.1	0.8	1.0	1.9
Water intensity	L/A$	22.4	1.9	22.5	46.8	149.2	14.0	57.7	220.9
Land use intensity	kha/A$m	3.9	0.0	0.0	4.0	4.1	0.2	0.1	4.5
NO_x intensity	g/A$	1.0	1.3	1.8	4.0	0.7	1.8	3.6	6.1
SO_2 intensity	g/A$	0.2	0.4	1.7	2.3	0.1	0.4	3.6	4.2
Employment intensity	emp-y/A$m	9.7	2.3	4.5	16.5	12.6	4.7	8.9	26.3

(Wood,2003)

Fertilizer

A high concentration of synthetic fertilizer is used in conventional farming methods, where as organic farming only uses less environmentally strenuous methods of producing fertile soil.

(Figure 7)

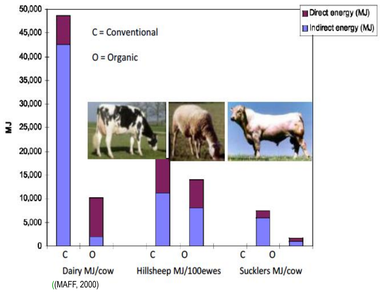
Group	Energy MJ/kg
Ammonium Nitrate	49.1
Phosphate Rock Fertilizer (P2O5)	7.02
Phosphorus Acid Fertilizer (P2O5)	17.7
K2O	10.5
Lime	2.39

(Patyk, Reinhardt, 1997)

Methane

Non-organic, "indoor" livestock farms tend to have concrete or slatted floors so they produce a massive quantity of liquid slurry, a by product that emits a large quantity of methane compared to solid manure (Stolze et al, 2000).

(Figure 8)

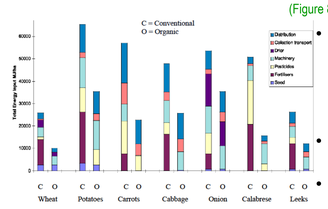


((MAFF, 2000)

- Approximately 10% of slurry is converted to methane while only 1% of solid manure is converted to methane (Gibbs, Woodbury, 1993).
- Organic farming practices grazing, where manure is "deposited on the land" (Foeried, Høgh-Jensen, 2004) producing a drier, denser manure product with lower methane emissions than slurry.

Conclusion

(Figure 8)



((MAFF, 2000)

- Organic agriculture uses anywhere between 30-50 percent less energy in production in comparison conventional agriculture.
- Energy inputs & outputs need revision on per individual case.
- Sufficient data missing for Ontario, opportunity for research.
- Energy efficient methods must be adopted for economic and ecological strategies.

References

1. Beckman, Jayson. Borchers, Allison. Jones, A. Carol. (2013). Agriculture's Supply and Demand for Energy and Energy Products. *United States Depart of Agriculture.* Retrieved from http://www.ers.usda.gov/media/1104145/eib112.pdf
2. Bulgaria, Sofia. (2009). "Climate Change Organics". Proceedings of the International Conference on Organic Agriculture and Climate Change.
3. Chappell, Jahi, Michael. LaValle, A. Lillana. (2011). Food Security and biodiversity: can we have both? An Agroecological Analysis. *Agriculture Human Values 28: 3-26.*
4. Cormack, Dr. William (2000). Energy Use in Organic Farming Systems. *Ministry of Agriculture, Fisheries and Food.* Retrieved from http://orgprints.org/8169/1/OF0182_181_FRP.pdf
5. Foereid, B. & Høgh-Jensen, H., (2004), Carbon Sequestration Potential of Organic Agriculture in Northern Europe – a modelling approach, *Nutrient Cycling in Agroecosystems 68: 13–24*
6. Gibbs, MJ. Woodbury JW, (1993). Methane emissions from livestock manure. In: Van Amstel A.R.ed.: Methane and Nitrous Oxide. RIVM Report No 481507003. *National Institute of Public Health and Environmental Protection.* Bilthoven. The Netherlands. pp. 81- 91
7. Ikerd, John. (2001). The Architecture of Organic Production. *Inaugural National Organics Conference.* 27-28.
8. IPCC. (1996). Direct Emissions from Agricultural Soils. Good Practice Guidance Management in National Greenhouse Gas Inventories. 361-380. Retrieved from http://www.ipcc-nggip.iges.or.jp/public/gp/gpg-bgp.html
9. IPCC. (2007). Changes in Atmospheric Constituents and in Radiative Forcing. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf
10. McDonald, James, Korb, Penni & Hoppe, Robert. (2013). Farm Size and the Organization of U.S. Crop Farming. *United States Department of Agriculture, Economic Research Service. 152.*
11. MAFF (Ministry of Agriculture, Fisheries and Food), (2000). Energy use in organic farming systems.
12. Patyk A. & Reinhardt G. (1997), "Energy and Material Flow Analysis of Fertiliser Production and Supply 2, *4th Symposium for Case Studies in Life Cycle Analysis, 73-86.*
13. Physics. (2013). Energy. Retrieved from http://physics.about.com/od/glossary/g/energy.htm
14. Rodale Institute. (2011)."The Farming System Trial". Retrieved from http://rodaleinstitute.org/assets/FSTbooklet.pdf
15. Scherr SJ and Sthapit S, (2009). Mitigating Climate Change Through Food and Land Use, *Worldwatch report 179.*
16. Stolze M, Piorr A, Häring A, and Dabbert S, (2000) The Environmental Impacts of Organic Farming in Europe. Organic farming in Europe: *Economics and Policy. Volume 6.* Universität Hohenheim, Stuttgart.
17. Sustainable Agriculture Initiative Platform. (2010). Issues Related to the Principles of Sustainable Agriculture. Retrieved from *http://www.saiplatform.org/sustainable-agriculture/definition*
18. Vandermeer, John. Gerald Smith, Ivette Perfecto, Eileen Quintero, Rachel Bezner-Kerr, Daniel Griffith, Stuart Ketcham, Steve Latta, Brenda Lin, Phil MacMichaels, Krista McGuire, Ron Nigh, Diana Rocheleau ,and John Soluri . (2009). Effects of Industrial Agriculture on Global Warming and The Potential of Small-Scale Agroecological Techniques to Reverse Those Effects. *A Report to Via Campesina.*
19. Wood, R. Lenzen, Manfre. Dey, Christopher. Lundie. Sven. (2003). A Comparative Study of some Environmental Impacts of Conventional and Organic Farming in Australia. *Agricultural Systems.* 89. 324-348.
20. Znaor Darko. (2009). Impact of Large-Scale Conversion to Organic Farming on Greenhouse Gas Emissions. *Proceedings of the International Conference on Organic Agriculture and Climate Change*, Avalon Foundation, Wommels, pp. 58-68.