Org. Agr. (2017) 7:53–61
DOI 10.1007/s13165-015-0145-z

Studies on long-term performance of organic and conventional cropping systems in Pennsylvania

Rita Seidel · Jeff Moyer · Kris Nichols · Vijay Bhosekar

Received: 6 November 2015 / Accepted: 8 December 2015 / Published online: 14 December 2015

Abstract Since 1981, organic and conventional cropping systems have been compared in a field trial at the Rodale Institute in Kutztown, Pennsylvania. Cropping system differences were evaluated for yields, soil quality, economic, and energy performance. Results showed that overall organic systems produced yields equal to conventional plots while at the same time improving soil quality. Organic systems also led to greater profitability while requiring less energy and emitting fewer greenhouse gases to produce the same amount of crops as the conventional systems.

Keywords Organic · Cropping systems · Conventional · Energy systems · Corn and soil quality

Introduction

When the Farming Systems Trial (FST) was started in 1981, the National Organic Program was 20 years from being formulated and organic price premiums were basically unheard of. The trial was originally set up to determine how best to transition from a conventional, chemically based system to an organic system. Since those early years, acreage in organic production has increased from less than 1 million acres in 1990 (when Congress passed the Organic Foods Production Act) to more than 4.8 million acres in 2008 (USDA-ERS (U.S. Department of Agriculture's Economic Research Service) 2011) and US sales of organic food and beverages have grown from $1 billion in 1990 to $26.7 billion in 2010 (Trade Association) 2011).

Over the course of the 30-year trial, the specific rotation for each system has changed several times; however, the distinct characteristics of the original three systems stayed the same: organic systems with and without manure inputs compared to a conventional system. The purpose of this paper is to present and support broad conclusions that can be made from this long-term study relative to agronomic, environmental, economic, and energetic comparisons.

Materials and methods

Site

The FST is located at the Rodale Institute in Kutztown, Pennsylvania. Field investigations on this 6-ha site began in 1981. Prior to establishment of the experiment, the site was farmed conventionally with continuous corn for at least 25 years. The soil type is a moderately well-drained silt loam. The growing climate is subhumid temperate (average temperature is 12.4° C, and average rainfall is 1105 mm per year).

Three main cropping systems were initiated in 1981: (1) manure-based organic, (2) legume-based organic, and (3) conventional. The experimental design was a split-plot randomized block with eight replications for the three systems. Main plots were 18 × 92 m, split into

R. Seidel · J. Moyer · K. Nichols · V. Bhosekar (✉)
Rodale Institute, Kutztown, PA, USA
e-mail: vijaybhosekar@gmail.com

three 6 × 92 m subplots, which allowed for comparison of three crops in any given year. The main plots were separated by 1.5-m grass buffer strips. Farm-scale equipment was used for operations and harvesting. Additional field site and experiment details can be found in reference (Liebhardt et al. 1989; Lotter et al. 2003; Ryan et al. 2009), and (Teasdale et al. 2007).

In 2008, each of the original three systems was divided into a “tilled” and “no-till” portion yielding four replicate plots of the subsequent six farming systems (Table 1). The organic no-till treatments in the FST are not continuous no-till systems. Small grains and cover crops are still established with tillage, while the large-seeded crops (corn and soybean) are planted without tillage. In our system, winter annual cover crops (hairy vetch and rye) are converted into mulches for corn and soybeans using a roller crimper. The roller is mounted to the front of the tractor, while a planter attached to the tractor’s rear allows the farmer to roll/kill the cover crop and plant the main crop into the rolled cover crop in one field pass without any further seed bed preparation. The rolled cover crop has several functions: weed suppression, soil moisture conservation, and N input (in the case of vetch).

In addition to including no-till in the trial, that year also saw the inclusion of genetically modified (GM) corn and soybeans in both the tilled and no-till conventional systems to keep this system up to date with current agricultural practices. These changes introduced several new sets of variables and made direct comparisons between crops and systems more difficult, e.g., organic cultivars versus conventional (including GM) cultivars, long-season versus short-season cultivars for the tilled and no-till sections, and the necessary early and late planting dates for corn and soybeans.

Farming systems

Manure organic

This system represents an organic dairy or beef operation. It features a long rotation including both annual feed grain crops and perennial forage crops (Table 1). The system’s fertility is provided by leguminous cover crops and periodic applications of manure or composted manure. The system does not use herbicides, relying instead on tillage and cultivation for weed control.

Legume organic

This system represents an organic cash grain system without livestock. It features a mid-length rotation consisting of annual grain crops and cover crops (Table 1). The system’s sole sources of fertility are leguminous cover crops. Like the organic manure system, it does not use herbicides, relying instead on tillage and cultivation.

Conventional

This system represents a conventional grain operation. It relies on synthetic nitrogen (N) for fertility and herbicides for weed control (Table 1). Fertilizer and pesticide applications follow Pennsylvania State University Cooperative Extension recommendations.

Data collection

Data were collected on crop yields; cover crop, weed, and crop biomass; soil carbon (C) and soil N; biologically active soil organic matter (SOM) pools; and mycorrhizal spore populations (Douds et al. 1993; Liebhardt et al. 1989; Lotter et al. 2003; Pimentel et al. 2005; Ryan et al. 2009; Wander et al. 1994). All field operations and inputs were logged for contribution to overall economic and energy analyses. The economic analysis was conducted using the Mississippi State Budget Generator (MSBG Mississippi State Budget Generator & Mississippi State University 2001). The energy analysis was performed using the Farm Energy Analysis Tool (FEAT) (Camargo et al. 2011).

Results

Direct crop yield comparisons can only be made between corn, soybeans, and wheat because they are the only crops that are present in all systems.

In the first 4 years of the trial, corn yields were significantly lower in the two organic systems compared to the conventional system, mostly due to N deficiency and weed competition (Liebhardt et al. 1989). During that same time period, soybean yields were equal between legume and conventional and

Table 1 Overview of cropping system management of the Rodale Institute Farming Systems Trial, 2008–2010

Cropping systems	Crop rotation	Primary tillage	Weed control	Fertility
Manure tilled	hv/C-r/O-r/SB-W-H-Csil-W	MB	Tillage, RH/TW, RC	AM, GM, K
Manure no-till	hv/C-r/O-r/SB-W-H-Csil-W	MB and none	Tillage, RH/TW, RC, CC	AM, GM, K
Legume tilled	hv/C-r/O-B/SB-W	MB	Tillage, RH/TW, RC	GM, K
Legume no-till	hv/C-r/O-r/SB-W	MB and none	Tillage, RH/TW, RC, CC	GM, K
Conventional tilled	C-SB	Ch	Tillage, herbicides	N, P, K
Conventional no-till	hv/C-r/SB-W	None	Herbicides	N, P, K

C corn, *SB* soybean, *H* hay (either red clover, red clover + alfalfa, or orchard grass + alfalfa), *W* winter wheat, *Csil* corn silage, *B* winter barley, *hv* hairy vetch cover crop, *r* rye cover crop, *MB* moldboard plow, *Ch* chisel plow, *RH* rotary hoe, *TW* tine weed, *RC* row cultivation, *CC* rolled cover crop mat, *N* urea ammonium nitrate, *P* monoammonium phosphate, *K* potassium sulfate in organic and potassium chloride in conventional systems, *GM* green manures, *AM* animal manures (raw manure (1981–2002) or composted manure (2004–2010))

significantly higher in the manure system. Yields may not decrease during the transition from conventional to organic production as a similar trial in Iowa showed: Here, corn and soybean yields were the same in organic and conventionally managed rotations for the first 3 years and higher in the organic plots in the fourth year (Delate & Cambardella 2004).

Over the 30 years of the FST, however, organic corn and soybean yields were equivalent to conventional yields in the tilled systems (Table 2). An analysis of crop yields and weed data by Ryan et al. (Ryan et al. 2009) showed that yields were the same despite the two organic systems having significantly greater weed biomass. These results suggest that corn and soybean crops in the organic systems may be able to tolerate much higher levels of weed competition than their conventional counterparts.

In four out of five drought years, organic corn yields were significantly higher in the two organic systems: 6938 and 7235 kg ha^{-1} in the manure and legume systems, respectively, compared with 5333 kg ha^{-1} in the conventional system. These higher corn yields in drought years were attributed to higher water holding capacity of organic soils (Lotter et al. 2003).

Wheat yields were not different between organic and conventional systems (Table 2).

In the last 3 years, both corn and soybean yields were lower in the organic than the conventional systems. As mentioned above, recent changes made to the trial introduced several new sets of variables. Since this trial is not designed as a factorial trial but rather as a systems trial, these new variables make it more difficult to explain differences between treatments. The latest yield differences may be attributed to

- Cultivar differences (varieties used to be the same in organic and conventional plots but are now different);
- Varied planting dates (resulting in dry spell periods at different developmental stages for each system) and/or
- Crop-weed competition.

Soil

The long-term soil focus was on total C and N although shorter term studies with other concentrations have also been conducted in FST.

In 1981, soil C and N were not significantly different between the systems. By 1994 (the first intensive sampling since the start of the trial), both C and N had increased significantly in the organic systems, despite intensive tillage, but not in the conventional plots. This trend has remained the same since then (Table 3). Soil C increases were greatest in the first 14 years of the trial. Carbon continued to build in both organic systems after 1994 but at a slower rate. All systems seem to have leveled off or shown a decrease in soil C in more recent years although this decrease is not statistically significant. In a trial in Maryland, soil C and N in an organic rotation with tillage were also higher than in conventional no-till systems (Teasdale et al. 2007). The authors concluded that organic systems provide greater long-term soil benefits, pointing out, however, that these

Table 2 Corn and soybean yields in kg ha^{-1} in the Rodale Institute Farming Systems Trial 1981–2010

	Corn yield 1981–2010	Soybean yield 1981–2010	Wheat yield[b] 1981–2010
Manure tilled	6083ab	2447ab	2883a
Manure no-till[a]	5392a	1900a	2752a
Legume tilled	6011ab	2227ab	2712a
Legume no-till[a]	5338a	1910a	2650a
Conv. tilled	6572ab	2630ab	3392a
Conv. no-till[a]	7664b	3009b	2913a

Values within the same crop and time period followed by the same letter are not significantly different at $P < 0.05$

Conv conventional

[a] Yields for no-till systems represent means for only 3 years (2008–2010)

[b] Wheat yields for conventional systems are for the years 2004–2010

benefits may not be realized in terms of crop yields if weeds cannot be adequately controlled.

Wander et al. (Wander et al. 1994) tested the impact of organic and conventional management on soil fertility in FST after 10 years. The legume system had accumulated the most SOM, more particulate SOM, and higher total soil C and N than the manure and conventional systems. The soil in the conventional system had the lowest biological activity, measured as N supply and soil respiration rates, and SOM did not increase in that system in the first 10 years of the trial (Wander et al. 1994). In a different study, spore counts of soil from organically farmed plots had greater populations of arbuscular mycorrhizal fungi than that farmed conventionally (Douds et al. 1993).

Table 3 Soil carbon and nitrogen changes in the Rodale Institute Farming Systems Trial, 1981–2010

	Manure	Legume	Conventional
Soil C (%)			
1981	1.92a	2.06a	1.87a
1994	2.32b	2.31b	2.01a
2010	2.38b	2.25b	1.87a
Soil N (%)			
1981	0.31a	0.31a	0.31a
1994	0.31b	0.29b	0.27a
2010	0.34c	0.31b	0.28a

Values within the same year followed by the same letter are not significantly different at $P < 0.05$

Economic analysis

Annual returns

An economic analysis of the first 15 years (Hanson et al. 1997) showed that after a short period of investment in "soil capital," net returns for the legume system were competitive and sometimes greater than those of the conventional system, assuming that all farm products received the same market price. (This analysis did not include the manure system—only cash grain systems were compared.)

Seed inputs, labor, and equipment costs were higher in the legume system whereas fertilizers and pesticides costs were higher in the conventional system.

The most recent economic analysis was conducted for the time period 2008 to 2010 for a comparison of the current six systems. Preliminary results show that the two conventional systems had the lowest annual returns of all six systems: \$421 and \$518 ha^{-1} for the conventional no-till and tilled system, respectively. With annual profits between \$1213 and \$1613 ha^{-1}, returns for the four organic systems were 2.9 to 3.8 times higher than the two conventional systems (Table 4). The highest returns were achieved by the tilled legume system followed by the tilled manure system. This large difference in profits of organic and conventional systems was mainly the result of a much higher income in the organic systems due to organic price premiums. If organic price premiums are taken out of the equation, the net returns for the organic systems decrease to \$317–446 ha^{-1} $year^{-1}$, with the no-till legume system at the low end. The other three organic systems still have higher returns than the no-till conventional system and remain competitive with the tilled conventional system with 14–18 % lower returns (data not shown). Other long-term trials in Maryland, Wisconsin, and Iowa had very similar results for returns of organic and conventional systems (Cavigelli et al. 2009; Chavas et al. 2009; Delate et al. 2003).

Across all three major systems (organic manure, organic legume, and conventional), the tilled systems had higher net returns compared to the matching no-till systems (6 % higher in the manure, 23 % higher in the conventional, and 33 % higher in the legume system). This was due primarily to higher income as a result of higher yields in the tilled manure and legume systems and higher seed and herbicide expenses in the no-till conventional system.

Table 4 Income, expenses, and returns per crop in the Rodale Institute Farming Systems Trial, 2008–2010 (all data on annual basis, except for hay which is based on 2 years)

	\$ ha^{-1} year^{-1}	Manure tilled	Manure no-till	Legume tilled	Legume no-till	Conv tilled	Conv no-till
Corn	Income	2375	2106	2333	2044	1271	1394
	Expenses	803	613	802	612	1052	1327
	Returns	1571	1493	1531	1433	219	67
Oats	Income	1174	1025	1131	935		
	Expenses	828	823	592	590		
	Returns	345	203	539	346		
Soybeans	Income	1901	1484	1762	1530	1162	1289
	Expenses	616	428	412	429	346	540
	Returns	1285	1055	1350	1101	816	749
Wheat 1	Income	2700	2625	2458	2478	0	1010
	Expenses	512	499	493	504	0	564
	Returns	2188	2126	1965	1974	0	446
Hay	Income	3157	3157				
	Expenses	1769	1769				
	Returns	1387	1387				
Corn silage	Income	3328	3328				
	Expenses	1268	1270				
	Returns	2060	2058				
Wheat 2	Income	2700	2625				
	Expenses	512	499				
	Returns	2188	2126				
Barley	Income			1471			
	Expenses			402			
	Returns			1069			
Years in rotation		8	8	4	4	2	3
Total income		2167	2044	2289	1747	1217	1231
Total expenses		789	738	675	534	699	810
Total returns		1378	1306	1613	1213	518	421

Conv conventional

The most profitable grain crop in all organic systems (with price premiums) was wheat (\$1974–\$2188 ha^{-1} year^{-1}), while soybeans were most profitable in both conventional systems (\$749–\$816 ha^{-1} year^{-1}). No-till conventional corn was the least profitable crop at \$67 ha^{-1} year^{-1} (Table 4).

Expenses

Overall, the no-till conventional system incurred the highest expenses (\$810 ha^{-1} year^{-1}) followed by the tilled manure system (\$788 ha^{-1} year^{-1}). The no-till legume system had the lowest expenses (\$534 ha^{-1} year^{-1}) (Table 5). Across all six cropping systems, the single greatest expense was for seeds, which made up between 33 and 49 % of the total expenses. In the four organic systems, the second and third highest direct expense was for custom hauling (22 % in the manure systems, 11 % in the legume systems) and fuel (11–16 % of total expenses), while costs for herbicides (22 %) and fertilizers (17–21 %) were the second and third highest direct expense in the two conventional systems. Labor expenses made up 8–11 % in the organic systems whereas they were only 4–5 % in the two conventional systems. Due to higher equipment needs in the organic systems, fixed expenses comprised 12–16 % in the four organic systems, about double the proportion as in the two conventional systems (Table 5).

Table 5 Average production costs for six systems in the Rodale Institute Farming Systems Trial, 2008–2010

\$ ha^{-1} year^{-1}	Manure tilled	Manure no-till	Legume tilled	Legume no-till	Conv tilled	Conv no-till
Total income	2167	2044	2289	1747	1217	1231
Direct expenses						
Fertilizer	66	66	0	0	146	138
Herbicide	0	0	0	0	153	176
Seeds	197	197	265	263	180	264
Custom haul	171	166	75	53	42	57
Labor	72	59	75	46	33	32
Fuel	124	110	95	59	49	42
Repair and maintenance	41	37	38	26	18	20
Interest on op. cap.	17	16	17	13	18	23
Total direct expenses	687	649	565	459	640	752
Total fixed expenses	102	89	110	74	59	59
Total specified expenses	789	738	675	534	699	810
Returns above total specified expenses	1378	1306	1613	1213	518	421

Conv conventional, *op. cap* operating capital

Energy analysis

Energy inputs

An energy analysis conducted for the time period 2008 to 2010 showed that total energy inputs ranged from 7474 to 11,955 MJ ha^{-1} year^{-1}, with no-till manure having the lowest followed by no-till legume < tilled manure < tilled legume < tilled conventional < no-till conventional (Table 6). Across all organic cropping systems, the single greatest energy use component was diesel fuel, which ranged from 66 L ha^{-1} year^{-1} (39 % of total energy) in the no-till legume system to 98 L ha^{-1} year^{-1} (48 % of total energy) in the tilled legume system. The single greatest energy component across the two conventional cropping systems was N fertilizer, representing 43 and 39 % of the total energy for the tilled and no-till conventional systems, respectively.

Energy inputs were lower for organic cropping systems mainly because of the use of alternatives to N fertilizer. Energy inputs from seeds were lower in the

Table 6 Energy inputs for six systems in the Rodale Institute Farming Systems Trial, 2008–2010

Farming system Input (MJ ha^{-1} year^{-1})	Manure tilled	Manure no-till	Legume tilled	Legume no-till	Conv tilled	Conv no-till
N	0	0	0	0	4938	4605
P_2O5	0	0	0	0	195	130
K_2O	102	102	102	102	118	118
Compost transport	14	14	0	0	0	0
Compost production	229	229	0	0	0	0
Lim	203	203	203	203	243	243
Seed	1865	1865	2639	2839	1357	2547
Herbicide	0	0	0	0	732	1050
Transportation of inputs	322	322	384	396	384	491
Equipment	849	866	748	725	635	594
Diesel fuel	3890	3312	4380	2941	2418	1853
Labor	693	563	614	329	456	324
Total	8166	7474	9070	7534	11,473	11,955

Conv conventional

Table 7 Ratio between energy input and crop output for six systems in the Rodale Institute Farming Systems Trial, 2008–2010

Cropping systems	Input (MJ ha^{-1} $year^{-1}$)	Output (kg DM ha^{-1} $year^{-1}$)	Ratio (MJ kg^{-1} DM)	Percent[a]
Manure tilled	8166	4788	1.71	62 %
Manure no-till	7474	4588	1.63	60 %
Legume tilled	9070	4162	2.18	80 %
Legume no-till	7534	2880	2.62	96 %
Conv. tilled	11,473	4641	2.47	91 %
Conv. no-till	11,955	4377	2.73	100 %

DM dry matter, *Conv* conventional

[a]Calculated as percent of conventional no-till

two manure systems compared to the two legume systems due to the perennial hay crop in that rotation. Fuel use and labor were lower in the no-till manure than in the tilled manure system because of the reduced field operations for corn and soybeans. On the other hand, both conventional systems had about the same total energy consumption. As mentioned above, N fertilizer was responsible for the biggest portion in energy use in both tilled and no-till conventional. Seed energy and diesel fuel were the next biggest contributors in energy use in both conventional systems. However, the tilled conventional system had low seed energy and high diesel fuel inputs, while those two parameters were reversed in contribution to energy use in the no-till conventional system (Table 6).

In addition, a ratio between energy input and crop yield output was used to compare the cropping system efficiency. The energy input/crop output ratio ranged from 1.63 to 2.73 MJ kg^{-1} dry matter (DM), with no-till manure exhibiting the best ratio and no-till conventional exhibiting the worst (Table 7).

Greenhouse gas emissions

Greenhouse gas (GHG) emissions from cropping system inputs ranged from 905 to 1635 kg CO_2e ha^{-1} $year^{-1}$, with no-till legume having the lowest followed by tilled legume < no-till manure < tilled manure < tilled conventional < no-till conventional (Table 8). Across all cropping systems, the major GHG contributor was nitrous oxide (N_2O) emissions, due to soil processes associated with N in mineral fertilizer, crop residues, and compost. N_2O emissions ranged from 303 kg CO_2e ha^{-1} $year^{-1}$ (33 % of total equivalents of CO_2 released) in the tilled legume system to 807 kg CO_2e ha^{-1} $year^{-1}$ (49 % of the total) in the no-till conventional system (Table 8). CO_2 emissions associated with N fertilizer production (where synthetic N

Table 8 Greenhouse gas emissions from inputs for six systems in the Rodale Institute Farming Systems Trial, 2008–2010

Input (kg CO_2 ha^{-1} $year^{-1}$)	Manure tilled	Manure no-till	Legume tilled	Legume no-till	Conv tilled	Conv no-till
N	0	0	0	0	323	302
P_2O_5	0	0	0	0	17	11
K_2O	8	8	8	8	9	9
Compost transport	1	1	0	0	0	0
Compost production	17	17	0	0	0	0
Lime	75	75	75	75	90	90
Seed	100	100	137	142	90	133
Herbicide	0	0	0	0	54	77
Transportation of inputs	17	17	20	21	20	26
Equipment	55	56	49	47	41	39
Diesel fuel	295	252	333	223	184	141
N_2O	552	586	303	389	738	807
Total	1121	1112	925	905	1566	1635

Conv conventional

Table 9 Ratio between greenhouse gas emissions from inputs and crop output for six systems in the Rodale Institute Farming Systems Trial, 2008–2010

Cropping systems	Input (kg CO_2e ha^{-1} year^{-1})	Output (kg DM ha^{-1} year^{-1})	Ratio (kg CO_2e kg^{-1} DM)	Percent[a]
Manure tilled	1121	4788	0.23	63 %
Manure no-till	1112	4588	0.24	65 %
Legume tilled	925	4162	0.22	59 %
Legume no-till	905	2880	0.31	84 %
Conv. tilled	1566	4641	0.34	90 %
Conv. no-till	1635	4377	0.37	100 %

DM dry matter, *Conv* conventional

[a] Calculated as percent of value for conventional no-till

fertilizer was used) and on-farm fuel use were the second and third highest categories of GHG in terms of overall impact.

The ratio between GHG emissions from inputs and crop yield output ranged from 0.22 to 0.37 kg CO_2e kg^{-1} DM, with tilled legume exhibiting the best ratio and no-till conventional exhibiting the worst (Table 9).

Conclusions

Successful organic systems require good management skills to develop the right crop rotation, fertility regime, and weed control. Corn (or any crop with a high N demand) is generally a poor crop choice for the transition period from conventional to organic systems due to N deficiency and weed competition. Planting soybeans, small grains, or a legume hay crop in the first years and avoiding corn until the third or fourth year are therefore recommended (Liebhardt et al. 1989). In general, organic systems are more successful the longer the rotation is: Higher N availability and a decrease in weeds result in higher yields and lower economic risk (Cavigelli et al. 2008; Cavigelli et al. 2009).

Except for the initial start-up period, organic systems in FST produced yields equal to conventional plots while at the same time improving soil quality.

FST results also showed that organic systems do not necessarily require manure inputs although the manure-based system seemed to provide better yield consistency for crops that did not receive direct N inputs (for example, wheat or oats).

Further research is needed to monitor and improve the relatively new organic no-till systems and to close the yield gap between cultivars in the organic and conventional systems and between long- and short-season varieties.

Overall however, the organic systems in FST (both tilled and no-till) led to greater profitability while requiring less energy and emitting fewer GHG to produce the same amount of crops as both conventional systems.

This long-term study has inspired many other projects with similar goals and objectives across the USA. When compared over decades, data from this and other trials confirm that organic production strategies can match or outperform conventional systems in agronomic, environmental, economic, and energetic areas. Together, these trials are moving the industry in a positive direction by supporting farmers with applied research and documenting important scientific findings.

Acknowledgments We want to thank everybody who has contributed to this trial over the last 30 years. This study would not have been possible without the dedication of countless research and project managers, farm operations crews, collaborating scientists, technicians, and interns. We especially thank Gail Gillis and Dr. Romy Das who offered invaluable help in developing the economic summary presented in this paper. Since its initiation, this project was supported by the Rodale Institute and numerous grants. The work conducted to summarize the economic and energy data presented here was supported by a NE-SARE grant, entitled "Increasing Cropping System Sustainability through the Adoption of Cover Crop and Rotational No-Till Strategies" (project number LNE08-268).

References

Camargo GG, d. T, Ryan M, Richard T (2011) Energy usage and greenhouse gases from commodity and bioenergy crops using the farm energy analysis tool (FEAT) *In preparation*

Cavigelli M, Teasdale J, Conklin A (2008) Long-term agronomic performance of organic and conventional field crops in the mid-Atlantic region. Agron J 100:785–794

Cavigelli M, Hima B, Hanson J, Teasdale J, Conklin A, Lu Y (2009) Long-term economic performance of organic and conventional field crops in the mid-Atlantic region. Renewable Agric Food Syst 24(2):102–119

Chavas J-P, Posner J, Hedtcke J (2009) Organic and conventional production systems in the wisconsin integrated cropping systems trial: II. Economic and risk analysis 1993–2006. Agron J 101:288–295

Delate K, Cambardella C (2004) Agroecosystem performance during transition to certified organic grain production. Agron J 96:1288–1298

Delate K, Duffy M, Chase C, Holste A, Friedrich H, Wantat N (2003) An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa. Am J Altern Agric 18(2):59–69

Douds D, Janke R, Peters S (1993) VAM fungus spore populations and colonization of roots of maize and soybean under conventional and low-input sustainable agriculture. Agric Ecosyst Environ 43:325–335

Hanson J, Lichtenberg E, Peters S (1997) Organic versus conventional grain production in the mid-Atlantic: an economic overview and farming system overview. Am J Altern Agric 12(1):2–9

Liebhardt W, Andrews R, Culik M, Harwood R, Janke R, Radke J, Rieger-Schwartz S (1989) Crop production during conversion from conventional to low-input methods. Agron J 81(2):150–159

Lotter D, Seidel R, Liebhardt W (2003) The performance of organic and conventional cropping systems in an extreme climate year. Am J Altern Agric 18(3):146–154

MSBG Mississippi State Budget Generator, Department of Agricultural Economics at Mississippi State University, (2001) http://www.agecon.msstate.edu/what/farm/generator/

Pimentel D, Hepperly P, Hanson J, Douds D, Seidel R (2005) Environmental, energetic, and economic comparisons of organic and conventional farming systems. Bioscience 55(7): 573–582

Ryan M, Smith R, Mortensen D, Teasdale J, Curran W, Seidel R, Shumway D (2009) Weed-crop competition relationships differ between organic and conventional cropping systems. Weed Res 49:572–580

Teasdale J, Coffman C, Mangum R (2007) Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agron J 99: 1297–1305

OTA (Organic Trade Association) (2011) Organic industry survey. http://www.ota.com/organic/mt/business.html

USDA-ERS (U.S. Department of Agriculture's Economic Research Service) (2011) www.ers.usda.gov/data/organic

Wander M, Traina S, Stinner B, Peters S (1994) Organic and conventional management effects on biologically active soil organic matter pools. Soil Sci Soc Am J 58: 1130–1139