Improving Soil Quality During and After Organic Transition

Kathleen Delate and Cynthia Cambardella
Iowa State University and USDA-ARS National Soil Tilth Lab

Introduction:

The organic agriculture industry continues to expand in the U.S. at 17% annually despite the economic downturn. With additional economic and environmental benefits associated with transitioning to organic agriculture, greater interest in organic transition has occurred. Strategies to optimize biological turnover to enhance soil quality in transitional organic farming are not well understood. A long-term organic research site has been established to examine the short- and long-term physical, biological, and economic outcomes of certified organic and conventional cropping systems at the ISU Neely-Kinyon Long-Term Agroecological Research (LTAR) site to examine these effects. The LTAR site is a systems experiment where treatments consist of a suite of farmer-developed practices (soil amendments, tillage, crop selection/rotation) established as complete management strategies. In addition, three on-farm sites were selected to monitor changes during the transition and beyond certification.

Objectives:

In this research, we are testing the hypothesis that organic systems relying on locally derived soil fertility inputs are capable of providing stable yields, while maintaining soil quality and plant protection, compared to conventional systems with less diverse crop rotations and greater levels of external, fossil-fuel based inputs. This project was started in 2006, building on farmer-based experiences and our long-term research program experience to address the following research objectives:

Objective 1: Examine the effects of required organic farming practices, including crop rotations, cover cropping, compost application, and non-chemical weed control, on soil quality, crop yield and grain quality;

Objective 2: Examine how soil organic matter (SOM) quantity and quality influence the interrelationships among soil fertility, crop resistance to pests and diseases, and environmental conservation of nutrients and carbon; and

Objective 3: Determine which crop rotations and nutrient management practices will increase the crop's competitiveness with weeds, build soil fertility, and maximize biological control of insect pests and diseases.

LTAR 2005-2008 Soil Data Summary

Five randomly-located soil cores (0-15 cm) were removed from each plot every fall after harvest but before plowing from 2005 to 2008. The cores were mixed together to produce one composite sample from each plot. Soil quality was consistently higher in the organic rotations relative to the conventionally managed corn-soybean rotation during this four-year period. The organic soils had more soil organic carbon, total N, labile organic N, higher P, K, Mg and Ca concentrations and lower soil acidity than conventional soils

(Table 1,2,3,4). Soil organic C was lower for the organic soybean-winter wheat rotation that the other organic rotations, reflecting the lack of carbon-rich inputs from corn (Fig. 1). However, macroaggregate stability was higher in the soybean-winter wheat system in 3 out of 5 years, likely because of the dense, fibrous rooting system of the small grain (Fig. 2). The 3-yr organic rotation had more inorganic P (Fig. 3) and K than the 4-yr organic rotation reflecting the greater manure application intensity (2 of 3 yrs) in the 3-yr rotation. Soil quality enhancement was particularly evident for labile soil N pools (Fig. 4), which are critical for maintenance of N fertility in organic systems, and for basic cation concentrations (Fig. 5), which control nutrient availability through the relationship with cation exchange capacity (CEC).

2006-2008 Organic Farm Soil Data Summary

The organic farms are located in Shelby County, Iowa (Errett and Rosmann) within the Marshall soil association and Guthrie County (Hafner), Iowa, within the Shelby-Sharpsburg-Macksburg soil association. Crop rotations at all three farms included corn, soybean, small grains and forage legumes. Three fields, each in a different phase of the rotation, were sampled at each farm. Sampling locations for the 3 fields at each farm were chosen to fall within the same soil type to reduce variability. Soil sampling was conducted in May 2006 and 2007, and in the fall of 2008. Three sampling transects were delineated at each field. Four sampling sites were located at 20-m intervals along each transect. Three soil cores (depth 0-15 cm) were removed from each sampling site and all cores were composited from each transect for a total of 3 composite soil samples from each field. Soil samples were analyzed for a suite of soil quality indicator variables including soil organic (SOC), total N (TN), particulate organic matter C (POMC) and N (POMN), microbial biomass C (MBC), potentially mineralizable N (PMinN), inorganic N, Bray P, extractable K, Mg, Ca, electrical conductivity (EC), pH, macroaggregate stability (Aggs%), and bulk density (BD). For the samples collected in fall 2008, a sub-set of the suite of indicator variables was analyzed.

Soil biological, chemical and physical properties for the Errett Farm (mid-length organic operation) indicated overall soil quality was highest for Field 8 compared with Field 7 and 9 in 2006 (Table 5) and 2007 (Table 6). Soil organic C, total N, particulate organic matter C and N, microbial biomass C, N mineralization potential, and macroaggregation were all significantly higher for Field 8. Soil quality for this field may be greater because alfalfa hay was cropped during 2003 and 2004. In 2006, we observed consistently higher values for soil properties related to soil quality for Field 3 compared to Field 2 and 4 at the Hafner Farm (shortest time in organic production) (Table 8). Soil organic C, total N, particulate organic matter C and N, microbial biomass C, and N mineralization potential were significantly greater for Field 3. All three fields at the Hafner Farm were planted to crop rotations that had 2-3 years of clover in the last 5 years so soil quality differences were likely not due to forage legume impacts. Soil quality at Field 3 may be related to manure applications since this field was planted to corn in 2002 and 2004 whereas Field 2 and 4 were cropped to corn only once since 2002. We also observed higher values for some of the soil properties related to soil quality for Field 3 compared to Field 2 and 4 at the Hafner Farm in 2007 and 2008 (Tables 9 and 10) but the pattern was not as consistent as what we observed in 2006 (Table 8). Soil organic C, total N, and N mineralization potential were significantly greater for Field 3 but particulate organic matter C and N, and microbial biomass C were not. Field 2 was planted to barley/clover in 2006 and field 4 was cropped to corn, which received manure. The forage legume and manure impacts on soil quality may account for the 2007 differences among the 3 fields relative to 2006 data. Patterns in soil properties related to soil quality at the Rosmann Farm (the longest time under organic management) were less definitive than the other two farms (Tables 11, 12 and 13). Nearly all of the soil properties we measured trended lower in Field 9, relative to Field 6 and 16, but the difference was significant only for soil organic C. No consistent pattern emerged for differences among the fields at the Rosmann Farm.

Estimates of whole-farm soil quality were made by averaging data for all fields within a farm across all three years (Table 14). The Hafner Farm had more SOC, labile organic N, inorganic P and extractable K, and greater aggregate stability than the Errett and Rosmann Farms. Since SOC and aggregate stability are higher at every field for all years at the Hafner Farm, these differences can be attributed to inherent differences in soils in the two Iowa counties. However, differences in P and K are most likely related to differences in manure/compost type, rates of application, and application timing. Overall, the three farms exhibit remarkably similar values for soil quality indicator variables despite differences in crops, soil types, and organic amendments.

Accomplishments/Milestones:

In the first year of the sampling, distinct differences were noted in soil quality, with longer years in organic production leading to higher soil quality, but after three years, all organic farms exhibited similar high levels of soil quality, suggesting that soil response to organic transitioning rapidly leads to greater soil quality. Accomplishments and milestones included establishing a collaborative environment with farmer-cooperators with significant participation from farmers. Two of the farmer participants, Ron Rosmann and Earl Hafner, presented information on project results and concepts of soil quality in organic farming at the Iowa Organic Conference on November 19, 2007, at Iowa State University, Ames, Iowa, with a total of 292 farmers and ag professionals participating in these sessions. In 2008, Ron Rosmann held a Field Day at his farm and discussed project results and soil quality in organic operations. Project results were also discussed by Kathleen Delate at the Iowa Organic Conference on November 24, 2008, for 236 people.

Impacts and Outcomes:

One of the most significant outcomes to date is the result that the organic soils had more soil organic carbon, total N, biologically active organic C and N, higher P, K, Mg and Ca concentrations and lower soil acidity than conventional soils. With organic farming often criticized for excessive tillage, and the potential for degradation of soil carbon pools, this research shows the opposite: organic farming can lead to increases in soil quality, including carbon pools. Farmers participating in this research also show more interest in lowering tillage operations and improving soil quality. In the final year of the project, we will quantify the economic benefits of transitioning to organic and the benefits beyond certification on participating organic farms.

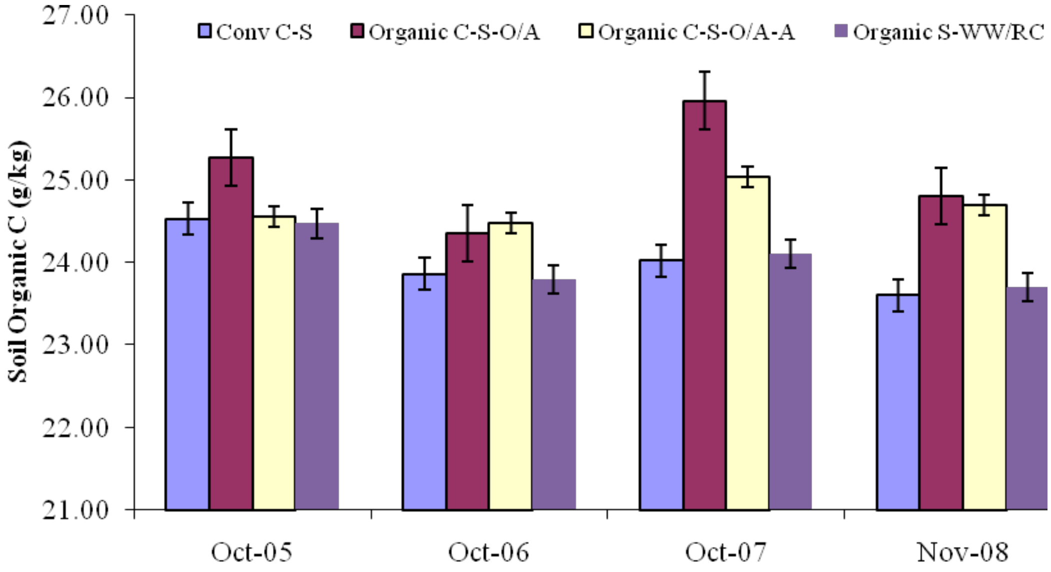

Figure 1. Soil organic C concentrations at the ISU Neely-Kinyon LTAR site.

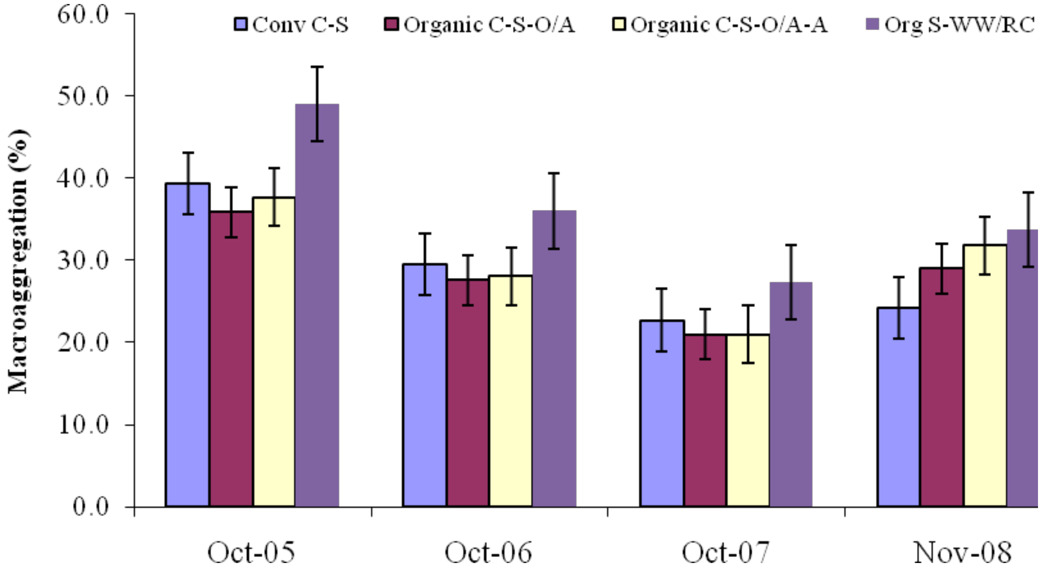

Figure 2. Aggregate Stability at the ISU Neely-Kinyon LTAR site.

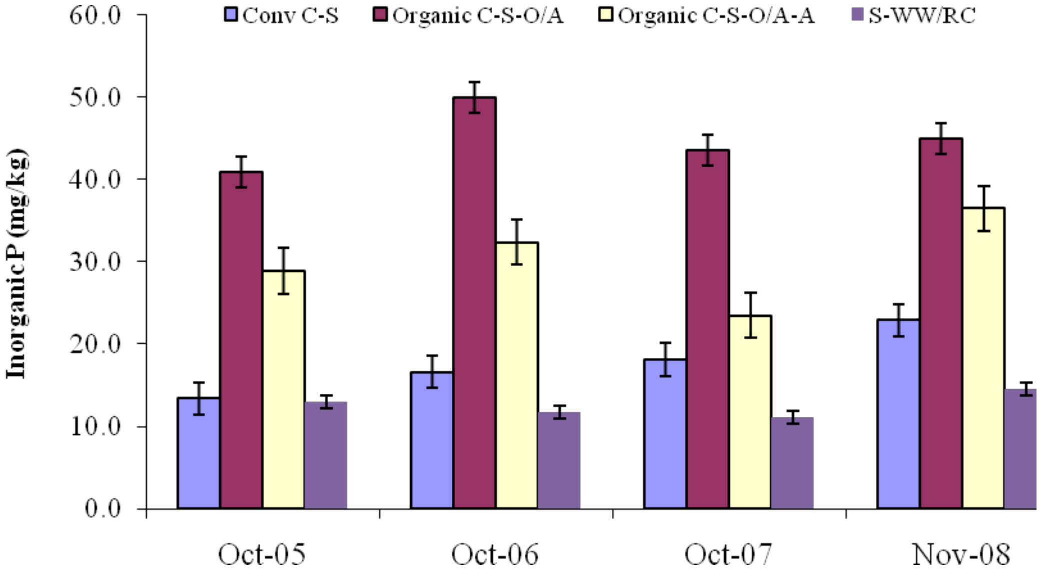

Figure 3. Inorganic P concentrations at the ISU Neely-Kinyon LTAR site.

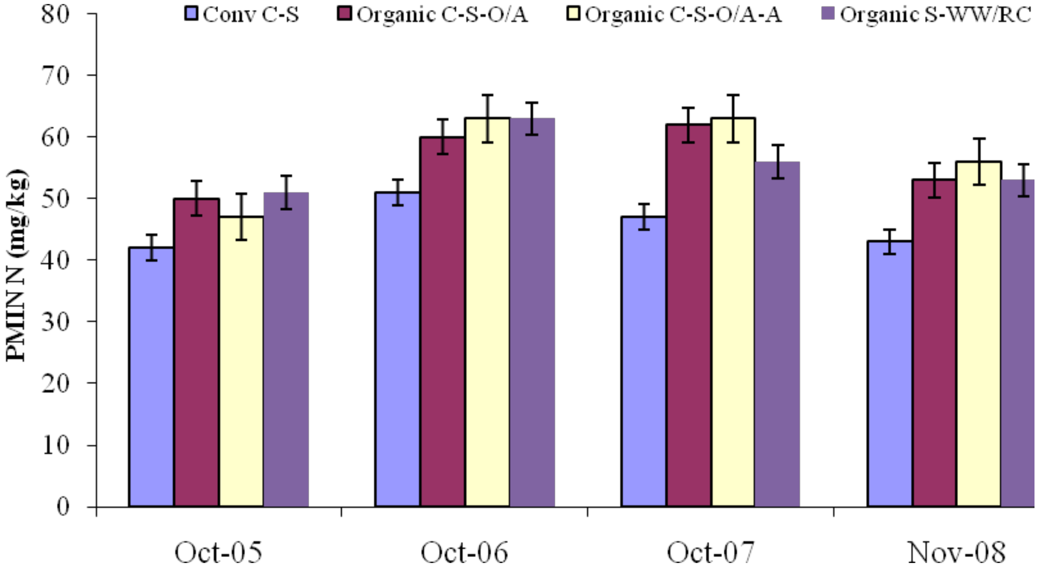

Figure 4. Mineralizable organic N concentrations at the ISU Neely-Kinyon LTAR site.

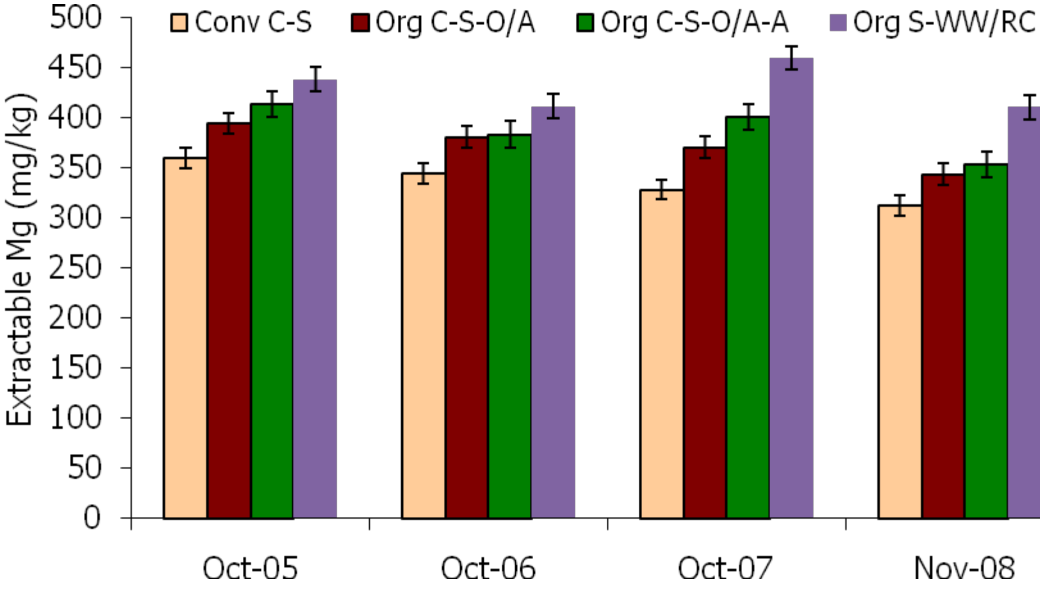

Figure 5. Extractable Mg concentrations at the ISU Neely-Kinyon LTAR site.

Table 1. Neely-Kinyon LTAR Soil Quality (Conc)–Fall 2005 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**aggs** %	**bd** gcm^{-3}
I	24.53	2.26	3.76	0.27	258	42	9.91	12.14	13.4	236	359	3711	206	6.38	39.4	1.15
II	25.27	2.35	4.56	0.36	275	50	9.61	12.49	40.9	378	394	3995	230	6.84	35.9	1.12
III	24.55	2.29	3.82	0.26	277	47	7.18	7.74	28.9	260	413	3968	224	6.69	37.7	1.19
IV	24.47	2.28	4.15	0.26	333	51	5.95	6.62	13.0	187	438	4049	225	6.57	49.0	1.12

Table 2. Neely-Kinyon LTAR Soil Quality (Conc)–Fall 2006 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**aggs** %	**bd** gcm^{-3}
I	23.86	2.27	3.16	0.22	429	51	7.42	8.62	16.6	260	344	3334	210	6.61	29.5	1.24
II	24.35	2.35	3.12	0.24	463	60	6.03	7.02	46.9	323	380	3621	243	6.98	27.6	1.22
III	24.48	2.40	3.43	0.28	467	63	8.00	9.20	32.4	296	383	3593	265	6.92	28.1	1.25
IV	23.79	2.33	3.46	0.23	552	63	8.47	9.49	11.7	198	411	3451	244	6.64	36.0	1.08

Table 3. Neely-Kinyon LTAR Soil Quality (Conc)–Fall 2007 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**aggs** %	**bd** gcm^{-3}
I	24.0	2.29	3.88	0.38	339	47	3.58	4.85	18.1	290	328	3199	177	6.40	22.7	1.17
II	26.0	2.31	3.88	0.28	386	62	3.81	5.81	43.6	396	370	3723	217	6.70	21.0	1.12
III	25.0	2.38	4.17	0.33	395	63	3.38	4.26	23.5	281	400	3592	238	6.66	21.0	1.23
IV	24.1	2.30	2.76	0.25	468	56	2.77	4.02	11.1	272	459	3875	219	6.62	27.3	1.13

Table 4. Neely-Kinyon LTAR Soil Quality (Conc)–Fall 2008 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**aggs** %	**bd** gcm^{-3}
I	23.6	2.19	2.89	0.21	346	43	4.19	5.06	22.9	245	312	3319	160	6.45	24.2	1.23
II	24.8	2.31	3.26	0.26	356	53	4.46	5.10	45.0	311	343	3594	193	6.64	29.0	1.26
III	24.7	2.34	3.16	0.25	393	56	3.92	5.40	36.5	285	353	3653	198	6.70	31.8	1.26
IV	23.7	2.29	3.09	0.27	396	53	3.27	3.65	14.6	211	410	3713	181	6.50	33.7	1.24

Table 5. Errett Farm Soil Quality–May 2006 (depth 0-15 cm).

	SOC gkg^{-1}	TN gkg^{-1}	pomC gkg^{-1}	pomN gkg^{-1}	mbc mgkg^{-1}	pminN mgkg^{-1}	no3-N mgkg^{-1}	inorgN mgkg^{-1}	P mgkg^{-1}	K mgkg^{-1}	Mg mgkg^{-1}	Ca mgkg^{-1}	Ec µS cm^{-1}	ph	Aggs %	bd gcm^{-3}
F7	14.9	1.7	3.3	0.23	434	46.5	2.06	3.78	13.4	222	499	3436	184	7.07	28.9	1.35
F8	21.9	2.3	3.9	0.33	429	45.5	7.03	7.52	13.9	410	422	2637	175	6.78	31.2	1.34
F9	16.1	1.8	2.8	0.21	311	38.7	5.88	6.44	21.9	223	481	3154	199	5.98	19.9	1.41
Avg	17.6	1.9	3.3	0.26	391	43.6	4.99	5.91	16.4	285	467	3076	186	6.61	26.7	1.37

Table 6. Errett Farm Soil Quality–May 2007 (depth 0-15 cm).

	SOC gkg^{-1}	TN gkg^{-1}	pomC gkg^{-1}	pomN gkg^{-1}	mbc mgkg^{-1}	pminN mgkg^{-1}	no3-N mgkg^{-1}	inorgN mgkg^{-1}	P mgkg^{-1}	K mgkg^{-1}	Mg mgkg^{-1}	Ca mgkg^{-1}	Ec µS cm^{-1}	ph	Aggs %	bd gcm^{-3}
F7	17.1	1.8	2.8	0.20	339	47.2	8.25	13.11	12.9	193	481	3097	248	6.39	15.4	1.14
F8	25.3	2.5	4.8	0.34	443	68.9	4.02	5.31	16.8	286	408	2717	139	5.72	21.0	1.14
F9	15.3	1.7	2.8	0.16	356	48.8	5.69	8.19	25.3	186	529	3206	226	6.38	14.6	1.24
Avg	19.2	2.0	3.5	0.23	379	55.0	5.99	8.86	18.3	222	473	3007	204	6.16	17.0	1.17

Table 7. Errett Farm Soil Quality–Fall 2008 (depth 0-15 cm).

	SOC gkg^{-1}	TN gkg^{-1}	no3-N mgkg^{-1}	inorgN mgkg^{-1}	P mgkg^{-1}	K mgkg^{-1}	Mg mgkg^{-1}	Ca mgkg^{-1}	ph
F1	14.3	1.9	3.60	8.36	32.2	194	445	2749	6.92
F2	26.7	3.1	6.00	9.98	22.6	278	338	2200	5.80
F3	16.1	2.0	3.30	7.10	13.4	188	395	2801	6.82
Avg	19.0	2.3	4.30	8.48	22.7	220	393	2583	6.51

Table 8. Hafner Farm Soil Quality–May 2006 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**Aggs** %	**bd** gcm^{-3}
F2	15.4	1.7	2.8	0.20	429	49.9	7.00	8.16	23.0	213	555	3272	231	6.43	36.1	1.29
F3	25.2	2.3	4.2	0.19	536	63.9	3.27	3.85	56.0	687	335	3042	139	5.99	34.0	1.28
F4	17.0	1.7	2.6	0.11	316	37.7	9.72	10.84	10.5	166	564	3973	268	6.85	35.7	1.57
Avg.	19.2	1.9	3.2	0.17	427	50.5	6.66	7.62	29.8	355	485	3429	213	6.42	35.3	1.38

Table 9. Hafner Farm Soil Quality–May 2007 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**Aggs** %	**bd** gcm^{-3}
F2	17.5	1.9	2.9	0.26	488	55.4	6.54	9.70	21.2	244	565	3726	237	6.73	49.4	1.16
F3	25.1	2.3	2.8	0.21	409	59.4	8.04	13.81	41.5	420	317	3046	167	6.04	33.0	1.23
F4	18.4	1.8	3.0	0.21	375	49.1	5.11	5.11	11.7	192	594	3696	184	6.38	53.5	1.29
Avg.	20.3	2.0	2.9	0.23	424	54.6	6.56	9.54	24.8	285	492	3489	196	6.38	45.3	1.23

Table 10. Hafner Farm Soil Quality–Fall 2008 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**no3N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**ph**
F2	19.5	2.3	2.73	7.91	29.5	285	560	3305	6.78
F3	25.0	2.3	4.64	7.14	37.6	290	289	2489	6.13
F4	18.7	2.6	2.05	6.80	42.3	271	494	3082	7.01
Avg.	21.1	2.4	3.14	7.28	36.5	282	448	2959	6.64

Table 11. Rosmann Farm Soil Quality–May 2006 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**Aggs** %	**bd** gcm^{-3}
F6	19.7	2.1	2.6	0.13	424	45.3	23.97	26.39	37.6	272	462	2825	262	6.40	21.1	1.54
F9	13.3	1.6	2.9	0.29	484	47.7	20.41	20.72	9.0	158	734	3673	331	7.36	17.3	1.52
F16	19.2	2.0	2.7	0.28	481	48.3	11.10	12.14	22.6	168	469	3145	211	6.80	21.1	1.51
Avg.	17.4	1.9	2.7	0.23	463	47.1	18.49	19.75	23.1	199	555	3214	268	6.85	19.8	1.52

Table 12. Rosmann Farm Soil Quality–May 2007 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**Aggs** %	**bd** gcm^{-3}
F6	19.3	2.0	2.6	0.17	394	51.2	3.38	5.17	50.4	252	460	3023	151	6.18	13.7	1.31
F9	17.1	1.9	2.6	0.28	365	50.5	4.53	6.70	12.3	184	523	2947	149	6.01	16.0	1.36
F16	19.8	1.9	2.8	0.10	485	55.6	2.64	12.26	25.0	187	502	3143	155	6.41	18.1	1.32
Avg.	18.7	1.9	2.7	0.18	415	52.4	3.52	8.04	29.2	208	495	3038	152	6.20	15.9	1.33

Table 13. Rosmann Farm Soil Quality–Fall 2008 (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**ph**
F1	18.6	2.2	1.81	7.17	17.0	185	412	2868	6.82
F2	19.5	1.8	3.80	8.24	4.1	157	317	4103	8.21
F3	19.1	2.3	2.11	5.60	21.6	185	347	3381	7.51
Avg.	19.1	2.1	2.57	7.00	14.2	176	359	3444	7.51

Table 14. Mean of all fields and all years for the organic farms soil quality (depth 0-15 cm).

	SOC gkg^{-1}	**TN** gkg^{-1}	**pomC** gkg^{-1}	**pomN** gkg^{-1}	**mbc** mgkg^{-1}	**pminN** mgkg^{-1}	**no3-N** mgkg^{-1}	**inorgN** mgkg^{-1}	**P** mgkg^{-1}	**K** mgkg^{-1}	**Mg** mgkg^{-1}	**Ca** mgkg^{-1}	**Ec** µS cm^{-1}	**ph**	**Aggs** %	**bd** gcm^{-3}
Errett	18.6	2.1	3.4	0.25	385	49.3	5.09	7.75	19.1	242	444	2889	195	6.43	21.9	1.27
Hafner	20.2	2.1	3.1	0.20	426	52.6	5.45	8.15	30.4	307	475	3292	205	6.48	40.3	1.31
Rosmann	18.4	2.0	2.7	0.21	439	49.8	8.19	11.60	22.2	194	470	3232	210	6.85	17.9	1.43