Improving Soil Quality During and After Organic Transition

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

Introduction:

Organic agriculture continues to expand in the U.S. but 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. The ISU Neely-Kinyon Long-Term Agroecological Research (LTAR) farm (see Appendix) 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 to 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.

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 2007 Summary

Five randomly-located soil cores (0-15 cm) were removed from each plot in the fall after harvest but before plowing. The cores were mixed together to produce one composite sample from each plot. Soil quality was higher in the organic rotations relative to the conventionally managed corn-soybean rotation. 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. Macroaggregation was especially high in the soybean-winter wheat system, possibly as a result of the dense rooting system of winter wheat and relatively fewer passes with the moldboard plow. The 3-yr organic rotation had higher inorganic P and K concentrations 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, which are critical for maintenance of N fertility in organic systems, and for basic cation concentrations, which control nutrient availability through the relationship with CEC.

2007 Organic Farm Summary

Soil samples (0-15 cm) were removed from 3 fields at each of the organic farms. Crop rotations at all the farms included corn, soybean, small grains and forage legumes. Soil biological, chemical and physical properties for the Errett Farm (Table 1) indicated overall soil quality was highest for Field 8 compared with Field 7 and 9. This result is similar to data collected in May 2006. 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 at this field may be greater because alfalfa hay was cropped in this field during 2003 and 2004. 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 (Table 2) but this pattern was not as consistent as what we observed in 2006. 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 were less definitive than the other 2 farms (Table 3). 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.

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. 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. a total of 92 farmers and ag professionals participated in these sessions.

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 next year of the project, we

will seek to quantify these changes in behavior and knowledge, in addition to soil quality changes on participating organic farms.

Table 1. Neely-Kinyon LTARS 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 $\mu S\ cm^{-1}$	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 LTARS 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 $\mu S\ cm^{-1}$	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 LTARS 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 $\mu S\ cm^{-1}$	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. 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	14.9b	1.70b	3.3ab	0.23b (p=0.0637)	434a	46.5a	2.06c	3.78b	13.4b	222a	499a	3436a	184ab	7.07a	28.9a	1.35a
F8	21.9a	2.33a	3.9a	0.33a	429a	45.5a (p=0.0622)	7.03a	7.52a	13.9b	410a	422b	2637c	175b	6.78b	31.2a	1.34a
F9	16.1b	1.78b	2.8b	0.21b	311b	38.7b	5.88b (p=0.0823)	6.44a	21.9a	223a	481a	3154b	199a	5.98c	19.9b	1.41a
lsd	1.6	0.17	0.95	0.10	61	7.1	1.30	1.76	6.4	260	27	255	20	0.21	3.7	0.10

Table 5. 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	15.4b	1.74b	2.8b	0.20a (p=0.1000)	429b	49.9b (p=0.0539)	7.00b	8.16b	23.0b	213b	555a	3272b	231b	6.43b	36.1a	1.29b
F3	25.2a	2.32a	4.2a (p=0.0959)	0.19a	536a	63.9a	3.27c	3.85c	56.0a	687a	335b	3042c	139c	5.99c	34.0a	1.28b
F4	17.0b	1.69b	2.6b	0.11ab	316c	37.7c	9.72a	10.84a	10.5c	166b	564a	3973a	268a	6.85a	35.7a	1.57a
lsd	2.7	0.23	1.61	0.11	91	12.4	1.92	2.36	9.11	334	57	205	*	***	ns	0.18

Table 6. 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	19.7a	2.06a	2.64a	0.13b	424b	45.3a	23.97a	26.39a (p=0.0696)	37.63a	272a	462b	2825c	262b	6.40c	21.1a	1.54a
F9	13.3b	1.63b	2.94a	0.29a	484a	47.7a	20.41a	20.72b	8.97c	158b	734a	3673a	331a	7.36a	17.3b	1.52a
F16	19.2a	2.02a	2.70a	0.28a	481a	48.3a	11.10b	12.14c	22.58b	168b	469b	3145b	211c	6.80b	21.1a	1.51a
lsd	1.0	0.09	0.69	0.076	48	8.9	5.47	6.16	8.51	25	57	176	36	0.16	3.5	0.07

Table 7. 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 $\mu S\ cm^{-1}$	ph	Aggs %	bd gcm^{-3}
F7	17.1	1.77	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	2.45	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	1.66	2.8	0.16	356	48.8	5.69	8.19	25.3	186	529	3206	226	6.38	14.6	1.24

Table 8. 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 $\mu S\ cm^{-1}$	ph	Aggs %	bd gcm^{-3}
F2	17.5	1.87	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	2.27	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	1.82	3.0	0.21	375	49.1	5.11	5.11	11.7	192	594	3696	184	6.38	53.5	1.29

Table 9. 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 $\mu S\ cm^{-1}$	ph	Aggs %	bd gcm^{-3}
F6	19.3	1.98	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	1.89	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	1.90	2.8	0.10	485	55.6	2.64	12.26	25.0	187	502	3143	155	6.41	18.1	1.32