A NOTE ON SOIL ORGANIC CARBON, SOIL ORGANIC NITROGEN, AND PARTICULATE ORGANIC MATTER ON THE WICST PLOTS

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INTRODUCTION

Soil organic matter is one of the most important attributes of a soil because it affects nutrient cycling, soil structure, and water availability. Maintaining, or better yet, increasing soil organic carbon (SOC) content is an important measure of the sustainability of a cropping system. In fact, the USDA has developed a Soil Conditioning Index (SCI) that is a tool that can predict the consequence of cropping systems and tillage practices on the trend of soil organic matter accumulation (USDA, 2002). A positive index is the first criteria used in the Conservation Security Program (CSP) for advancement from Tier I to Tier II stewardship payments (USDA, 2004). Overall, management practices that contribute to increasing SOC levels include those that add more organic carbon to the soil than the amount removed from the system (e.g. crop residues), increase the diversity of organic materials added (e.g. cover crops, manure), or decrease the rate of organic matter loss (e.g. reduced tillage, reduced erosion) (Magdoff, and Weil, 2004).

Soil organic carbon can be usefully envisioned as consisting of three pools: an active rapid-turnover pool (0-5 years); a moderate to slow turnover pool (6-25 years); and a recalcitrant pool that may have a half-life of several hundred years (Paustian et al., 1992). According to Wander (2004), the active fraction of organic matter (usually considered as organic material of recent origin) is most closely associated with soil biological activity, materials of intermediate age contribute to soil physical structure and the carbon with the longest residence time in the soil has its greatest influence on the physicochemical reactivity of the soil. The labile, or active fraction of soil organic matter can be assessed by characterizing the Particulate Organic Matter (POM), which is composed primarily of plant-derived remains and includes fungal spores, hyphae and in some cases, charcoal. (Wander, 2004). POM's primary value is as an indicator of early trends of changes in soil organic matter characteristics.

Soil organic matter and POM were measured on the Wisconsin Integrated Cropping Systems Trial (WICST) plots at the Arlington Research Station (ARS) and the Lakeland Agricultural Complex (LAC). These plots were established in 1990 to compare alternative cropping systems and their impact on productivity, profitability and the environment. Three of the rotations are cash grain based [CS1-continous corn (CC); CS2-no-till corn-soybeans (NT CSb); CS3- Organic Grain (OG) corn-soybeans-wheat/red clover] and three forage based systems [CS4- Conventional Forage (CF) alfalfa-alfalfa-alfalfa-corn with manure; CS5- Organic Forage (OF) oats/peas/alfalfa -alfalfa-corn with manure; and, CS6-rotational grazing (RG)]. (**see Figure 1**)

These systems are common to Upper Midwestern farms and vary in the intensity of tillage, amount and type of biomass amendments, and crop diversity.

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Our initial hypotheses were:
H1: The dairy rotations, due to the inclusion of manure and leguminous forage crops would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than in the grain based systems (CS4 + CS5 + CS6 > CS1 + CS2 + CS3);

H2: Since tillage and cultivation promote organic matter oxidation, it was hypothesized that the systems with these interventions would result in lower levels of SOC, lower levels of readily oxidizable organic matter and POM would represent a lower percentage of SOC than in the no-till systems (CS1 + CS3 + CS4 + CS5 < CS2 + CS6).

H3: The systems with higher biological diversity would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than the lower crop diversity systems (CS3 + CS6 > CS1 + CS4);

In addition, we anticipated that within the grain-based systems and the forage-based systems, the more diverse rotations would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than the less diverse rotations (CS3>CS1; CS6>CS4).

METHODS

Soils were sampled from the Arlington site (ARS) on April 11, 2003 and from the Lakeland site (LAC) on April 12, 2003. This was 13 years after the plots had been established. Only the initial 6 plots/replicate that were established in 1990 (T1, T3, T5, T7, T11 and T14) were sampled at Arlington. In addition, the newly established (1999) prairie plots (high diversity) and the companion continuous corn plots were sampled. At Lakeland, the initial plots established in 1990 were also sampled, however, due to the change in cropping pattern in Cropping System 5, there were only 5 plots/replicate (T1, T3, T5, T7, T14). At each site there were four replicates (**see Figure 2a and b**). Three sub samples, from the north, center and south ends of each plot, each constituted by bulking six cores that were in near proximity to each other (3/4" dia. probe), were collected. Soil was sampled to 3 depths: 0 to 5 cm, 5 to 10 cm, and 10 to 20 cm.

Soil samples were air dried on the lab bench and then sieved through a 2-mm screen to remove rocks and plant debris. 50g of soil were ground to pass a 10-µm sieve for Total C and Total N. To determine the particulate organic matter or POM fraction of whole soil, a 20-g sub sample was place in a 250 ml Nalgene bottle with 100 ml of dionized water and 10 6-mm glass beads, and shaken for 16 hours at 180 cycles per min (Cambardella and Elliot, 1992; Chantigny et al., 1999). Then the soil was passed through a 53-µm sieve. The material retained in the sieve was oven dried at 50° C and ground to pass a 10 -µm sieve. Total soil C and N were determined by dry combustion (LECO CNS-2000, Leco Corp., St. Joseph, MI).

We are reporting the coarse POM fraction including loose and occluded fractions. The occluded fraction refers to aggregated and protected soil organic matter and the loose fraction refers to non-aggregated soil organic matter (Wander, 2004).

Bulk density samples (2 per plot) were taken concurrently from 0-10-cm depth.

RESULTS & DISCUSSION

Combined Analysis

Soil Organic Carbon and Total Nitrogen

Initially the data was analyzed across both sites for the five common production systems. The probability of significant differences is summarized in **Table 1**. Total SOC was highly significantly different between sites at all three depths (e.g.; 0-5 cm, LAC=36.47 g C/kg of soil; ARS=30.12 g C/kg of soil). And by the same token, Total N was also highly significantly different at all three depths (e.g. 0-5, LAC= 3.23 g N/kg of soil; ARS= 2.58 g N/kg of soil). This is primarily due to the more poorly drained status of the soils at the Lakeland Agricultural Complex (Griswold and Pella series). Cropping systems SOC and total N were also significantly different at 0-5 and 5-10 cm, but not at 10-20 cm depth. At both sites, the pasture plots were the highest in SOC and total N (see **Table 2**). For SOC and total N, there was no interaction between site and cropping systems (**Table 1).**

POM-Carbon, POM-Nitrogen and % POM-C and % POM-N

POM-C and POM-N were significantly different between sites at all three depths (LAC > ARS) but not the % POM-C or % POM-N. This suggests that like total organic matter, the g POM/kg of soil was also higher at the more poorly drained Lakeland site, but the "quality" or % POM was not different- on average between sites. Not surprisingly, cropping systems POM-C and POM-N were significantly different, as were their proportion in the organic matter (% POM-C, % POM-N) at all three depths. The range in % POM-C by systems across sites (0-5 cm) was 22.4 % for the rotational grazing to 15.2% in the no-till system and 18 % to 11.8 % for total N. This indicates that quality of the organic matter, assuming that more POM indicates a more biologically active organic matter component did change with cropping system.

An interesting anomaly in the data is the interaction at 0-5 and 5-10 cm depth between cropping systems and site for POM-C, POM-N and their percent of the total SOC content. Most of the interaction at 0-5 cm is due to the organic grain system (CS3) that actually was lower in POM-C at Lakeland than it was at Arlington (**Figure 3a)**. The other four systems produced higher POM-C at Lakeland, although the increase was very modest in CS1 (continuous corn) and CS2 (no-till corn/soybean). At 5-10 cm depth (**Figure 3b**), POM-C in CS3 was again lower at Lakeland and CS1 was nearly constant. It is surprising that although there was no interaction at 10-20 cm depth—all five systems had higher POM-C at Lakeland and the arithmetically highest was CS3 (data not shown). The same pattern was found for POM-N (**Figure 4a & b**).

Site Analysis

Total SOC, POM-C, and %POM-C were generally highest in the rotationally grazed plots (CS6) at both locations (see **Table 3 & 4**). The same was the case for total N, POM-N and % POM-N. Surprisingly, the system with the lowest levels of SOC, POM-C and %POM-C at Arlington was the no-till corn and soybean system (CS2). The trend was the same for total N, POM-N and % POM-N. At Lakeland, it was more difficult to distinguish a trend other than that the three grain systems (CS1, CS2, CS3) were generally lower in both the carbon and nitrogen variables than the forage systems (CS4 and CS6).

Prairie vs. Continuous corn
The prairie and continuous corn plots were initiated at Arlington in 1999, so this analysis was conducted after only four years. SOC and total N were not yet different between the two systems but the amount of POM-C in the surface horizon (0-5 cm) was significantly higher in the prairie plots (**see Table 3**).

Hypothesis testing

Linear contrasts were used to test the hypotheses set out in the introduction

H1: The dairy systems with manure and forage legumes would have increased levels of soil organic matter (SOC), levels of POM, and that POM would represent a larger percentage of total carbon. Table 5a summarizes the results from the contrasts between the dairy (CS6, CS5, CS4) systems and the grain (CS3, CS2, CS1) systems. Not surprisingly, the combined analyses, as well as the individual site contrasts showed that the dairy systems tended to have higher SOC levels and higher POM-C levels as well as a greater percentage of their total carbon in the active POM fraction.

H2: The systems with tillage would have lower levels of soil organic carbon (SOC), lower levels of POM, and that POM would represent a lower percentage of total SOC than the systems without tillage. The results of the contrasts between the systems with tillage (CS1, CS3, CS4, CS5) and the systems without tillage (CS2, CS6) are presented in **Table 5b**. In the combined and individual site analyses, the systems with tillage had lower SOC levels, lower POM-C levels, as well as a lower percentage of their total carbon in the active POM fraction. This contrast is not consistent at Arlington, where the no-till pasture was much higher, in SOC than the other systems, while the no-till corn and soybean system was actually the lowest of the six. Nonetheless, on average, SOC and POM were significantly higher in non-tilled systems than the other four systems with tillage. In contrast, at Lakeland, both no-till systems were among the highest in SOC.

H3: The systems with higher biological diversity would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than the lower crop diversity systems. These contrasts are summarized on **Table 5c**. This is the hypothesis that is least supported by the data. Generally the contrasts were non-significant at the 5-10 cm depth for most of the analyses, nor were they significant at Lakeland. At Arlington, there was a clear tendency to find higher SOC, higher POM-C and a higher percentage of SOC that was POM when comparing the more diverse organic grain (CS3) and pasture systems (CS6) versus the less diverse conventional forage (CS4) and continuous corn (CS1) plots.

When we looked within the dairy systems (**Table 5d**), for SOC, POM-C, and % POM-C, the more diverse grazing system (CS6) generally had higher values than the less diverse conventional forage system (CS4) at both sites. Within the grain systems (Table 5d), the picture was less clear due to anomalous behavior of CS3. We noted earlier that although for the carbon and nitrogen variables, all the systems showed higher values at LAC than ARS, the organic grain system (CS3) was an exception. As a result, at Arlington the more diverse CS3 had significantly

higher SOC, POM-C and % POM-C than continuous corn (CS1), but this was not the case at Lakeland.

CONCLUSION

Cropping systems, after a relatively modest time after establishment (13 years), do alter soil carbon and nitrogen characteristics. This is particularly the case in the surface soil depths: 0 to 5 and 5 to 10 cm. Below 10 cm depth, few significant differences were observed. In this case the research was conducted on prairie derived silt loam soils at two locations, a somewhat poorly drained site (Lakeland Agricultural Complex) and at a well drained site (Arlington Research Station).

As might be expected, soil organic carbon, particulate organic matter, and the percentage of organic matter as POM were higher in the dairy-based systems than the grain-based systems. Intensity of tillage also modified organic matter characteristics, and systems without tillage had higher levels of SOC than those with tillage. It is more difficult to argue that the more diverse systems promoted higher levels of SOC, POM or % POM-C.

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Fig. 1. Schematic drawing of cropping systems in the Wisconsin Integrated Cropping Systems Trial. Numbers within circles represent year of rotation.

Cash Grain Cropping Systems:

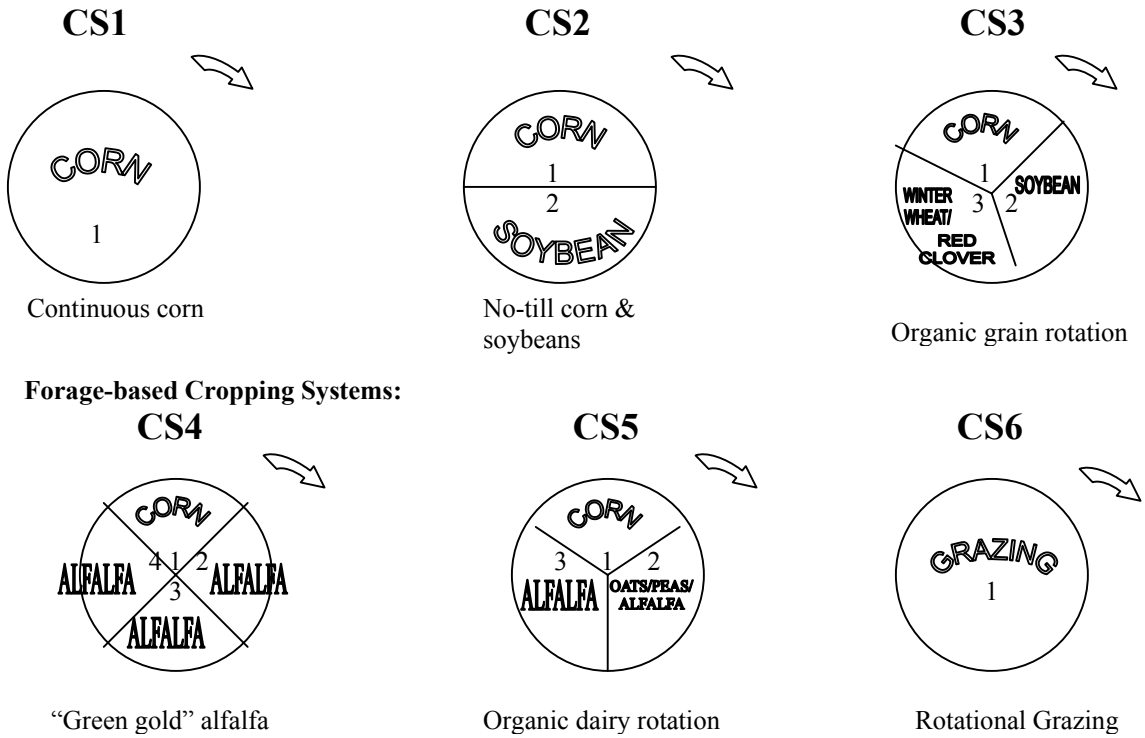

Figure 2a. Arlington Research Station (ARS) Site Map. Location of initial plots (1990)

414	CS4	**T8**	DS Alfalfa		408	CS2	T2	NR Soybeans
413	CS5	**T11**	Est. Alfalfa I		407	CS3	T6	WR Soybeans
412	CS1	**T1**	Continuous Corn		406	CS4	T9	Corn
411	CS3	**T5**	Wheat/red clover		405	CS6	T14	Pasture
410	CS5	**T12**	Oat/pea/alfalfa		404	CS4	T10	Est. Alfalfa II
409	CS4	**T7**	Est. Alfalfa I		403	CS5	T13	Corn
Restored prairie					402	CS3	T4	Corn
					401	CS2	T3	No-till Corn
					309	CS4	T10	Est. Alfalfa II
					308	CS4	T9	Corn
314	CS5	T12	Oat/pea/alfalfa		307	CS3	T5	Wheat/red clover
313	CS3	T6	WR Soybeans		306	CS1	T1	Continuous Corn
Restored prairie					305	CS4	T7	Est. Alfalfa I
					304	CS5	**T11**	Est. Alfalfa I
312	CS5	T13	Corn		303	CS2	T3	No-till Corn
311	CS4	T8	DS Alfalfa		302	CS6	T14	Pasture
310	CS2	T2	NR Soybean		301	CS3	T4	Corn
114	CS5	T13	Corn		214	CS2	T3	No-till Corn
113	CS4	T8	DS Alfalfa		213	CS5	T12	Oat/pea/alfalfa
112	CS6	T14	Pasture		212	CS3	T6	WR Soybeans
111	CS4	T7	Est. Alfalfa I		211	CS5	T13	Corn
110	CS5	T11	Est. Alfalfa I		210	CS4	T8	DS Alfalfa
109	CS1	T1	Continuous Corn		209	CS4	T7	Est. Alfalfa I
108	CS2	T2	NR Soybean		208	CS5	T11	Est. Alfalfa I
107	CS4	T10	Est. Alfalfa II		207	CS6	T14	Pasture
106	CS3	T5	Wheat/red clover		206	CS2	T2	NR Soybeans
105	CS4	T9	Corn		205	CS4	T10	Est. Alfalfa II
104	CS3	T4	Corn		204	CS1	T1	Continuous Corn
103	CS5	T12	Oat/pea/alfalfa		203	CS4	T9	Corn
102	CS3	T6	WR Soybeans		202	CS3	T5	Wheat/red clover
101	CS2	T3	No-till Corn		201	CS3	T4	Corn
A	CS3	50#N	Wheat/Red Clover		D	CS3	50#N	Corn w/starter
B	CS3		WR Soybeans		E	CS3	50#N	Wheat/Red Clover
C	CS3	50#N	Corn w/starter		F	CS3		WR Soybeans

Figure 2b. Lakeland Agricultural Complex (LAC) Site Map. Location of initial plots (1990)

101 CS1 T1	201 CS5 T23	301 CS4 T20	401 CS1 T1
102 CS15 18	202 CS4 T7	302 CS14 T19	402 CS15 T18
103 CS4 T7	203 CS2 T2	303 CS1 T1	403 CS4 T20
104 CS6 T14	204 CS3 T4	304 CS2 T2	404 CS3 T4
105 CS15 T22	205 CS3 T5	305 CS15 T18	405 CS5 T23
106 CS15 T21	206 CS2 T3	306 CS3 T6	406 CS3 T5
107 CS3 T5	207 CS15 T22	307 CS3 T5	407 CS3 T6
108 CS2 T2	208 CS3 T6	308 CS3 T4	408 CS6 T14
109 CS3 T4	209 CS15 T18	309 CS15 T22	409 CS2 T2
110 CS14 T19	210 CS1 T1	310 CS4 T7	410 CS2 T3
111 CS3 T6	211 CS15 T21	311 CS2 T3	411 CS4 T7
112 CS4 T20	212 CS14 T19	312 CS15 T21	412 CS15 T22
113 CS2 T3	213 CS6 T14	313 CS5 T23	413 CS15 T21
114 CS5 T23	214 CS4 T20	314 CS6 T14	414 CS14 T19

Table 1. Combined Soil Organic Matter Analysis of WICST Cropping Systems (4/2003). Probability that the F-test is significant

A. Main effect of Site (Arlington & Lakeland)

depth	Total SOC	Total N	POM C	POM N	% POM C	% POM N
0-5 cm	0.0210	0.0077	0.0017	0.0012	0.8966	0.6674
5-10 cm	0.0165	0.0044	0.0025	0.0001	0.4155	0.1458
10-20 cm	0.0021	0.0037	0.0216	0.0007	0.8548	0.4227

B. Main effect of Cropping System (Systems 1-4 & 6)

depth	Total SOC	Total N	POM C	POM N	% POM C	% POM N
0-5 cm	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
5-10 cm	0.0633	0.0194	0.0001	0.0001	0.0001	0.0001
10-20 cm	0.5294	0.4229	0.0135	0.0038	0.0051	0.0007

C. Interaction of Site x System

depth	Total SOC	Total N	POM C	POM N	% POM C	% POM N
0-5 cm	0.2197	0.0743	0.0001	0.0001	0.0001	0.0001
5-10 cm	0.4610	0.1201	0.0043	0.0160	0.0070	0.0001
10-20 cm	0.8884	0.5256	0.9291	0.8145	0.9656	0.0766

Figure 3a. POM-C Site x System interaction (0-5 cm)

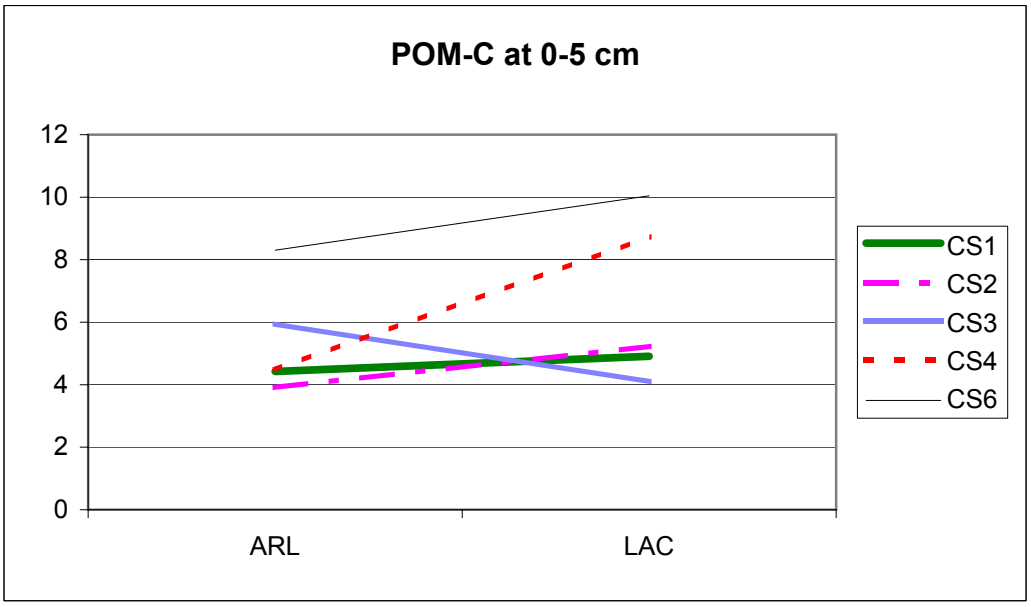

Figure 3b. POM-C Site x System interaction (5-10 cm)

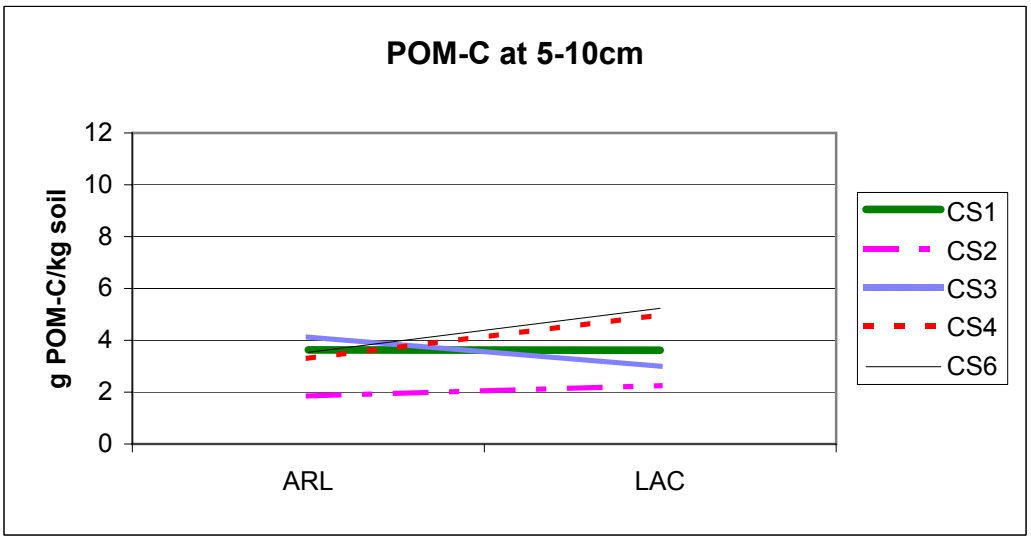

Table 2. Combined site analysis of systems 1-4 and 6
Means across sites *

System	Total g SOC/kg soil					g POM-C /kg soil					% POM C				
	0-5cm		5-10cm		10-20cm ns	0-5cm		5-10cm		10-20cm	0-5cm		5-10cm		10-20cm	
1.Cont. corn	29.54	c	27.98	b	24.93	4.67	c	3.63	ab	2.02	a	0.159	c	0.131	a	0.079	a
2. No-till Csb	30.05	bc	26.24	b	24.33	4.57	c	2.05	c	1.38	b	0.152	c	0.079	b	0.058	b
3. C-sb/w-w/rcl	30.48	bc	28.88	ab	26.39	5.02	c	3.56	b	2.33	a	0.165	c	0.125	a	0.088	a
4. A-A-A-C	34.70	b	31.17	ab	26.33	6.61	b	4.14	ab	1.95	a	0.187	b	0.134	a	0.075	a
6. Rot. graze	41.69	a	33.33	a	28.47	9.17	a	4.39	a	2.33	a	0.224	a	0.134	a	0.086	a

System	Total g N/kg/soil					g POM-N/kg of soil					% POM N				
	0-5cm		5-10cm		10-20cm ns	0-5cm		5-10cm		10-20cm	0-5cm		5-10cm		10-20cm	
1. Cont. corn	2.59	c	2.49	bc	2.25	0.301	c	0.234	b	0.136	a	0.118	c	0.095	b	0.061	b
2. No-till Csb	2.57	c	2.31	c	2.13	0.304	c	0.148	c	0.098	b	0.118	c	0.064	c	0.047	c
3. C-sb/w-w/rcl	2.64	c	2.55	bc	2.33	0.304	c	0.242	b	0.165	a	0.119	c	0.099	ab	0.072	a
4. A-A-A-C	3.06	b	2.79	ab	2.36	0.486	b	0.311	a	0.150	a	0.156	b	0.111	a	0.063	ab
6. Rot graze	3.68	a	2.97	a	2.50	0.640	a	0.317	a	0.168	a	0.180	a	0.109	a	0.071	ab

*** multiple range test (p=0.05)**

Figure 4a POM-N Site by System Interaction (0-5 cm)

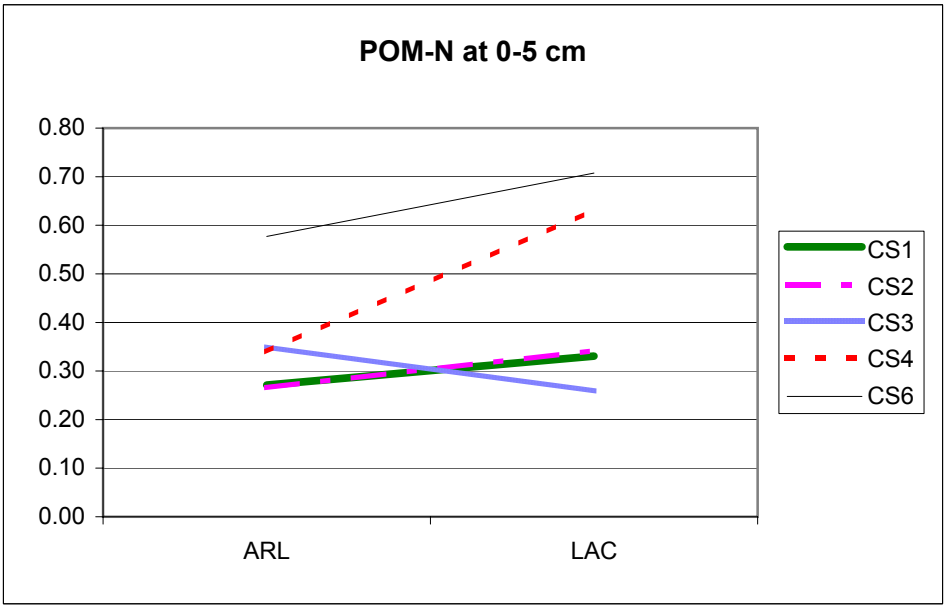

Figure 4b POM-N site by system Interaction (5-10 cm)

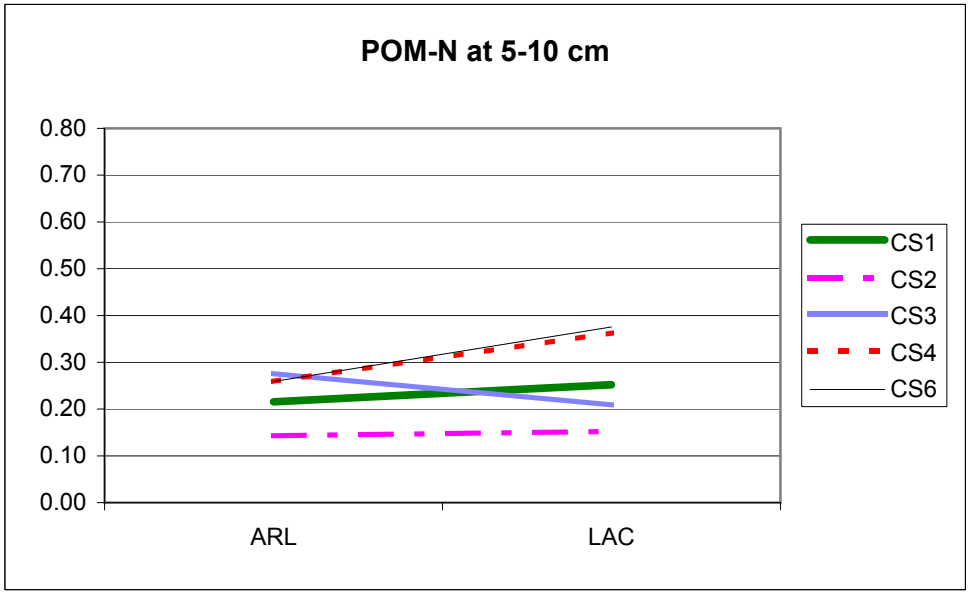

Table 3. SOC, POM and Total N analysis at Arlington (ARS)*

System	Total g SOC/kg soil					g POM-C/kg soil					% POM-C				
	0 to 5 cm		5 to 10 cm		10 to 20 cm	0 to 5 cm		5 to 10 cm		10 to 20 cm	0 to 5 cm		5 to 10 cm		10 to 20 cm
1. Cont. corn	28.37	bc	26.95	ab	23.03	4.42	d	3.63	ab	1.88	0.158	c	0.139	a	0.079
2. No-till Csb.	25.76	c	22.25	b	20.29	3.91	d	1.85	c	1.19	0.152	c	0.080	b	0.059
3. C-sb/w-w/rcl	29.85	bc	27.77	b	23.9	5.94	b	4.13	a	2.01	0.198	b	0.150	a	0.085
4. A-A-A-C	28.92	bc	26.91	ab	22.75	4.47	d	3.30	b	1.63	0.156	c	0.125	a	0.073
5. C-o/p/a-A	31.71	b	30.13	a	25.31	5.21	c	3.89	ab	1.94	0.168	c	0.134	a	0.079
6. Rot. Graze	37.67	a	29.25	a	26.35	8.30	a	3.53	ab	2.18	0.226	a	0.126	a	0.087
p-value	*0.0010*		*0.0511*		*0.2375*	*0.0001*		*0.0001*		*0.1915*	*0.0001*		*0.0079*		*0.2797*
grand mean	30.38		27.21		23.61	5.38		3.39		1.81	0.176		0.126		0.077
HD prairie	30.02		24.30		20.95	5.92	a	3.13		1.58	a	0.197		0.135		0.080
prairie corn	25.01		23.31		18.65	4.60	b	2.94		1.46	b	0.184		0.121		0.076
p-value	*0.1138*		*0.5856*		*0.2874*	*0.0499*		*0.4890*		*0.0218*		*0.1603*		*0.2381*		*0.6142*

System	Total g N/kg soil					g POM-N/kg soil						% POM-N					
	0 to 5 cm		5 to 10 cm		10 to 20 cm	0 to 5 cm		5 to 10 cm		10 to 20 cm		0 to 5 cm		5 to 10 cm		10 to 20 cm	
1. Cont. corn	2.23	b	2.17	b	1.87	0.271	c	0.215	b	0.119	ab	0.124	c	0.102	b	0.064	ab
2. No-till Csb	2.39	b	2.12	b	1.91	0.266	c	0.143	c	0.091	b	0.111	c	0.068	c	0.048	b
3. C-sb/w-w/rcl	2.37	b	2.22	b	1.93	0.349	b	0.276	a	0.149	a	0.147	b	0.126	a	0.078	a
4. A-A-A-C	2.91	a	2.69	a	2.24	0.349	b	0.259	a	0.123	ab	0.117	c	0.097	b	0.055	b
5. O/p/a-A-C	2.82	a	2.66	a	2.21	0.351	b	0.263	a	0.134	a	0.126	c	0.100	b	0.061	b
6. Rot. Graze	3.02	a	2.35	ab	2.11	0.577	a	0.259	a	0.159	a	0.196	a	0.114	ab	0.078	a
p-value	*0.0006*		*0.0086*		*0.1621*	*0.0001*		*0.0001*		*0.0354*		*0.0001*		*0.0002*		*0.0063*	
grand mean	2.62		2.37		2.05	0.359		0.236		0.129		0.137		0.101		0.064	
HD prairie	2.63		2.14		1.85	0.381		0.205		0.106		0.145		0.100		0.059	
prairie corn	2.18		2.06		1.66	0.285		0.195		0.097		0.130		0.090		0.058	
p-value	*0.0713*		*0.5290*		*0.2636*	*0.0891*		*0.6595*		*0.2570*		*0.1754*		*0.3196*		0.8029	

*** mulitple range test at (p=0.05)**

Table 4. SOC, POM and Total N analysis at Lakeland (LAC)*

	Total g SOC/kg soil					g POM-C/kg soil					% POM-C				
System	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	
1. Cont. corn	30.70	c	29.00		26.83	4.91	b	3.62	bc	2.15	0.161	b	0.123	a	0.078	a
2. No-till Csb	34.33	bc	30.23		28.38	5.23	b	2.26	c	1.58	0.153	bc	0.075	c	0.058	b
3. C-sb/w-w/rcl	31.10	bc	30.00		28.90	4.09	b	2.99	c	2.64	0.132	c	0.100	b	0.092	a
4. A-A-A-C	40.48	ab	35.43		29.90	8.74	a	4.98	ab	2.27	0.218	a	0.143	a	0.078	a
6. Rot. Graze	45.71	a	37.40		30.59	10.04	a	5.24	a	2.47	0.223	a	0.141	a	0.085	a
p-value	*0.0240*		*0.2768*		*0.9243*	*0.0001*		*0.0031*		*0.1153*	*0.0001*		*0.0001*		*0.0113*	
grand mean	36.47		32.41		28.91	6.60		3.81		2.22	0.177		0.116		0.078	

	Total g N/kg soil					g POM-N/kg soil					% POM-N				
System	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	
1. Cont. corn	2.94	b	2.81	b	2.63	0.331	b	0.252	bc	0.152	0.113	cd	0.088	bc	0.057	ab
2. No-till Csb	2.76	b	2.50	b	2.34	0.342	b	0.152	c	0.106	0.124	c	0.061	d	0.046	b
3. C-sb/w-w/rcl	2.90	b	2.88	ab	2.72	0.259	b	0.209	c	0.181	0.090	d	0.073	cd	0.067	a
4. A-A-A-C	3.22	b	2.90	ab	2.49	0.632	a	0.363	ab	0.176	0.195	a	0.126	a	0.071	a
6. Rot. Graze	4.34	a	3.60	a	2.89	0.708	a	0.375	a	0.176	0.164	b	0.104	b	0.063	a
p-value	*0.0027*		*0.0933*		*0.5929*	*0.0001*		*0.0040*		*0.1173*	*0.0001*		*0.0002*		*0.0313*	
grand mean	3.23		2.94		2.61	0.454		0.270		0.158	0.137		0.090		0.061	

*** multiple range test (p=0.05)**

Table 5a. Linear contrasts comparing dairy-based vs grain based system effects on soil organic matter characteristics

	Total g SOC/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS 4, CS 5* CS6	38.2	0.0001	32.8	0.0001	43.1	0.0001
CS1, CS2, CS3	30		28		32	
5-10 cm depth						
CS4, CS5*, CS6	32.3	0.0010	29.8	0.0025	36.4	0.0001
CS1, CS2, CS3	27.7		25.7		29.7	

	g POM-C/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS 4, CS 5* CS6	7.9	0.0001	6.0	0.0001	9.4	0.0001
CS1, CS2, CS3	4.8		4.8		4.7	
5-10 cm depth						
CS4, CS5*, CS6	4.2	0.0001	3.6	0.0090	5.1	0.0001
CS1, CS2, CS3	3.1		3.2		3.2	

	% POM-C					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS 4, CS 5* CS6	20.6	0.0001	18.3	0.0160	22.1	0.0001
CS1, CS2, CS3	15.9		16.9		14.9	
5-10 cm depth						
CS4, CS5*, CS6	13.4	0.0001	12.8	0.4800	14.2	0.0001
CS1, CS2, CS3	11.2		12.3		9.9	

*** CS5 was present at ARS, but not LAC so is only included in contrasts at ARS**

Table 5b. Linear contrasts comparing the effect of tillage vs no-tillage on soil organic matter characteristics

	Total g SOC/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS1, 3, 4, 5*	31.6	0.0001	29	0.0500	34.1	0.0001
CS2, CS6	35.9		31.7		40	
5-10 cm						
CS1, 3, 4, 5*	29.3	0.6000	27.2	0.0390	31.5	0.1000
CS2, CS6	29.8		25.8		33.8	

	g POM-C/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS1, 3, 4, 5*	5.4	0.0001	5	0.0001	5.9	0.0010
CS2, CS6	6.9		6.1		7.6	
5-10 cm						
CS1, 3, 4, 5*	3.8	0.0001	3.7	0.0001	3.9	0.5600
CS2, CS6	3.2		2.7		3.8	

	% POM-C					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS1, 3, 4, 5*	17	0.0002	17	0.0023	17	0.0100
CS2, CS6	18.8		18.9		18.8	
5-10 cm						
CS1, 3, 4, 5*	13	0.0001	13.7	0.0001	12.2	0.0010
CS2, CS6	10.6		10.3		10.8	

*** CS5 was present at ARS, but not LAC so is only included in contrasts at ARS**

Table 5c. Linear contrasts comparing the effect of high crop diversity vs. low crop diversity on soil organic matter characteristics

	Total g C/kg of soil					
	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3, CS6	36.1	0.0001	33.8	0.0001	38.4	0.6500
CS1, CS4	32.1		28.6		35.6	
5-10 cm depth						
CS3, CS6	31.1	0.1060	28.5	0.1900	33.7	0.3400
CS1, CS4	29.6		26.9		32.2	

	g POM-C/kg of soil					
	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3, CS6	7.1	0.0001	7.1	0.0001	7.1	0.4900
CS1, CS4	5.6		4.4		6.8	
5-10 cm depth						
CS3, CS6	4	0.5400	3.8	0.0300	4.1	0.4100
CS1, CS4	3.9		3.5		4.3	

	% POM-C					
	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3, CS6	19.5	0.0001	21.2	0.0001	17.8	0.1000
CS1, CS4	17.3		15.7		19	
5-10 cm depth						
CS3, CS6	13	0.4900	13.8	0.4400	12.1	0.0080
CS1, CS4	13.3		13.2		13.3	

Table 5d. Linear Contrasts comparing the effect of high crop diversity vs low crop diversity on soil organic matter within dairy and grain systems

Total g SOC/kg soil in dairy systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS6	41.7	0.0001	37.7	0.0001	45.7	0.0170
CS4	34.7		28.9		40.5	

g POM-C/kg of soil in dairy systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS6	9.2	0.0001	8.3	0.0010	10.04	0.0120
CS4	6.6		4.5		8.74	

% POM-C in dairy systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS6	22.4	0.0001	22.6	0.0001	22.3	0.6300
CS4	18.7		15.6		21.8	

Total g SOC/kg of soil in grain systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3	30.5	0.4700	29.9	0.3700	31.1	0.8500
CS1	29.5		28.4		30.7	

g POM-C/kg of soil in grain systems

	Combined analysis		ARS analysis		LAC analysis	
0-5 cm depth	mean	probability	mean	probability	mean	probability
CS3	5	0.2400	5.94	0.0001	4.09	0.1100
CS1	4.7		4.42		4.91	

% POM-C in grain systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3	16.5	0.4100	19.8	0.0001	13.2	0.0070
CS1	15.9		15.8		16.1	