

**Manitoba Sustainable Agriculture Practices Program (MSAPP)  
Research & Development Projects  
2009-2010**

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**Project Title**

Soil organic carbon in long-term crop rotation and management studies in south central Manitoba and the Red River Valley.

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**Objective / Background**

This project addresses a considerable knowledge gap in understanding the effects of crop rotation and management on soil organic carbon levels for central Manitoba and the Red River Valley. Current assessments of management impacts on soil organic carbon come from drier regions of Canada and the U.S., and from areas not having the fairly unique conditions of the Red River Valley. To address the knowledge gap, two long-term crop rotation and management studies will be used; one at Glenlea (south of Winnipeg) in the Red River Valley and one at Carman (south central Manitoba). Specifically, this project will determine soil organic carbon levels affected by:

- annual and mixed annual-perennial rotations
- organic and conventional crop management
- restoration of soil to native grassland prairie

Both sites have established prairie plots to determine potential C accumulation rates for the soil systems and to contrast these to the agricultural management. The Carman site also has continuous fallow plots to determine the level of stable organic carbon to serve as a baseline. The results of the study will be readily used in recommendation of management practices to increase soil carbon sequestration specific to south central Manitoba and the Red River Valley. It will also be used in modeling efforts to provide predictions of future carbon building scenarios at the Manitoba and national scale.

### Carman Long-term Crop Rotation and Management Study

The Carman rotation was established in 2000 to investigate the role of perennial crops in no-till cropping systems. The soil type is Denham loamy sand. Two crop rotations are included: 1. oat-flax-wheat-canola, and two years of alfalfa hay-flax-wheat. All rotation phases appear each year. Seeding is conducted with a no-till disc drill, hence soil disturbance is extremely low. The experimental design is a randomized complete block with three replicates.

In addition to the cropping plots, each replicate contains a Restored Prairie native grass planting. Three cool season species (northern wheatgrass, slender wheatgrass, western wheatgrass) and three warm season species (indian grass, switchgrass, big bluestem) were established at the beginning of the study. Also, each replicate contains a “no-crop” plot, an experimental unit that has been continuously fallowed since 2000. This treatment serves as a benchmark for stable soil C measurements.

### Glenlea Long-term Crop Rotation and Management Study

The Glenlea rotation was established in 1992. For the past 17 years, we have compared two different crop rotations under conventional and organic management. The experimental design is a factorial randomized split plot replicated three times. Crop rotation is the main plot effect and management (Organic and Conventional) the split effect. The soil type is a Red River clay.

The “Grain-only” rotation includes wheat-flax-oat-soybean under conventional management and wheat-flax-oat-legume green manure under organic management. The “Alfalfa-grain” rotation includes two years of alfalfa hay followed by wheat and flax, and the same Alfalfa-grain rotation is used under both conventional and organic management. All rotation phases appear each year. Conventional plots are fertilized according to soil test recommendations. The plots are 4 m by 25 m in size.

In addition to the cropping plots, each replicate contains a 1 acre Restored Prairie native grass planting. Three cool season species (northern wheatgrass, slender wheatgrass, western wheatgrass) and three warm season species (indian grass, switchgrass, big bluestem) were established at the beginning of the study.

### **Project progress**

Soil sampling, soil processing and analysis have been completed. Preliminary analysis of results has been completed and presented here. Our collaborator, Dr. Lindsay Bell, took this project on during his stay as a Visiting Scientist in the Department of Plant Science. We wish to credit Dr. Bell with the arrangement of sampling, processing and data analysis.

## Results & Observations

Six soil variables were determined in this project. Total C, organic C and calcium carbonate were measures of stored carbon in soil. Soil bulk density was determined to estimate kg C per ha soil to 1.2m depth. Olsen P and total N were determined as soil fertility measures. Generally, all variables were significant for effect of treatments and sample depth (Table 1). As expected with a large number of treatments and depth as factors, interaction effects were significant except with total N. A closer examination of findings for each study site follows.

**Table 1.** Statistical significance of effects of farming system and soil depth on soil carbon, phosphorus and nitrogen concentration at two long-term experiments in Manitoba, Canada.

Source of variation	Bulk density (g cm <sup>-3</sup> )	Tot C (%)	Org C (%)	Calcium carbonate (%)	Olsen P (ppm)	Tot N (%)
<i>Carman</i>						
System	**	***	***	***	***	**
Depth	***	***	***	***	***	***
System x Depth	***	***	***	***	***	ns
<i>Glenlea</i>						
System	***	***	***	***	***	ns
Depth	***	***	***	***	***	***
System x Depth	****	***	***	***	***	ns

ns – not significant, \*\*\* - P<0.01, \*\* - P<0.05

### ***Carman Study***

The results for total C and organic C were surprising. We expected the Alfalfa-grain treatment to have the highest value compared to the Grain-only treatment and the Fallow treatment to have the lowest value (Table 2). Rather the Grain-only treatment had the highest organic C amounts and the Restored Prairie the lowest.

**Table 2.** Total soil carbon, soil organic carbon, total nitrogen and total Olsen P in the top 1.2 m of soil profile under Restored Prairie, Fallow, and Alfalfa-grain and Grain-only crop rotation after 9 years at Carman, southern Manitoba, Canada.

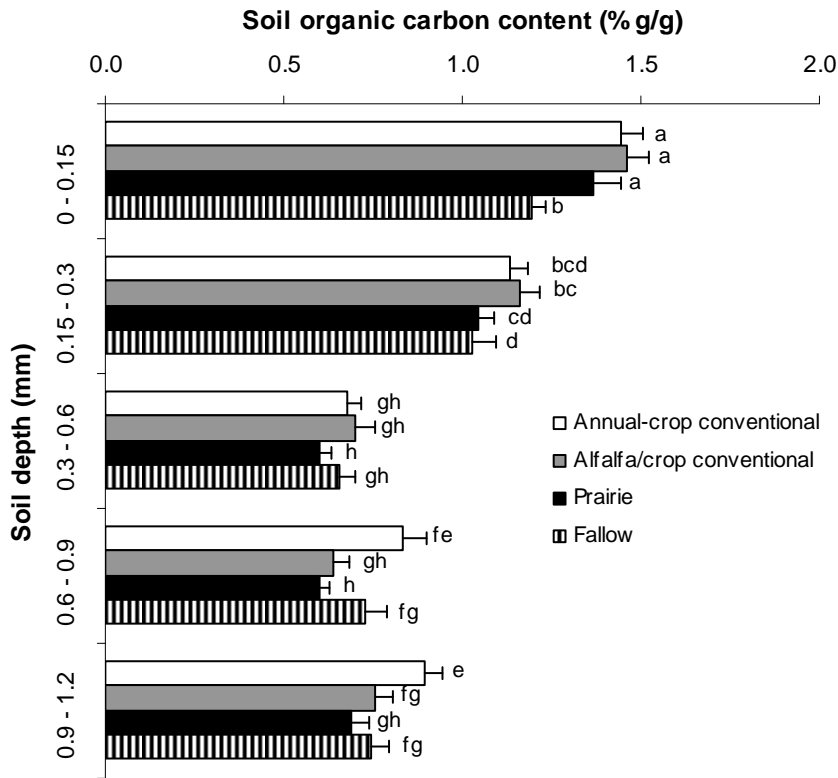
Farming system	Tot C (t ha <sup>-1</sup> )	Org C (t ha <sup>-1</sup> )	Tot N (t ha <sup>-1</sup> )	Olsen P (kg ha <sup>-1</sup> )
Grain-only	281 ± 10 a	160 ± 7 a	6.8 ± 0.5	38.5 ± 2.3 b
Fallow	258 ± 9 ab	143 ± 7 bc	7.2 ± 0.4	58.8 ± 2.3 a
Alfalfa-grain	250 ± 10 bc	146 ± 6 b	7.8 ± 0.7	46.6 ± 5.2 b
Restored Prairie	230 ± 12 c	134 ± 5 c	6.6 ± 0.4	44.4 ± 3.3 b

Bulk density values increased with depth (Table 3). The Restored Prairie and Fallow treatments had highest bulk densities at the 600-900 and 900-1200 mm depths. There are two options to estimate soil organic C because of differences in bulk densities between treatments. Organic C in Table 2 was estimated to a constant depth of 1.2 m for each treatment. Another approach is to calculate soil organic C based on equivalent mass of soil. The latter assumes plots started out with the same soil organic C and bulk densities but bulk density of treatments has changed with management. Our team is currently in discussion in how to rework the estimates on a similar soil mass per ha basis. The additional estimates will be available for the coming MSAPP workshop.

**Table 3.** Soil bulk density (g cm<sup>-3</sup>) in the soil profile to 1.2 m depth under Restored Prairie, Fallow, and Alfalfa-grain and Grain-only crop rotation after 9 years at Carman, southern Manitoba, Canada. Letters denote significant differences between treatment x depths (LSD = 0.053).

Depth (mm)	Grain-only	Alfalfa-grain	Restored Prairie	Fallow
0-150	1.364 bc	1.351 b	1.244 a	1.388 bc
150-300	1.382 bc	1.373 bc	1.358 b	1.364 bc
300-600	1.467 de	1.360 b	1.399 bc	1.415 cd
600-900	1.523 fgh	1.484 ef	1.562 h	1.545 gh
900-1200	1.508 efg	1.552 gh	1.575 h	1.549 gh

For the 0-150mm depth, soil organic C was lower with the Fallow treatment compared to the two cropped treatments (Figure 1). This is reasonable because the Fallow treatment did not provide input of C as crop residues and roots to soil. The Grain-only rotation had higher soil organic C than the other treatments largely because of high concentrations at 600-900 and 900-1200 mm depths (Figure 1). It should be noted that a substantial amount of soil organic C was present at the lowest depths for all treatments.



**Figure 1.** Soil organic carbon content (% g g<sup>-1</sup>) in the soil profile to 1.2 m depth under Restored Prairie, Fallow, and Alfalfa-grain and Grain-only crop rotation after 9 years at Carman, southern Manitoba, Canada. Letters denote significant differences between treatment x depths (LSD = 0.121).

**Glenlea Study**

The results for soil organic C were again surprising. We expected the Conventional treatments to have higher values and the Alfalfa-grain Conventional to be the treatment with greatest soil organic C. Rather the Organic treatments had higher soil organic C than the Conventional treatments (Table 4). The Alfalfa-grain Organic was the treatment with highest soil organic C. The Restored Prairie had soil organic C content similar to that for the Conventional cropping treatments.

**Table 4.** Total soil carbon, soil organic carbon, total nitrogen and total Olsen P in the top 1.2 m of soil profile under Grain-only and Alfalfa-grain rotations managed Organically and Conventionally, and Restored Prairie after 18 years at Glenlea, southern Manitoba, Canada.

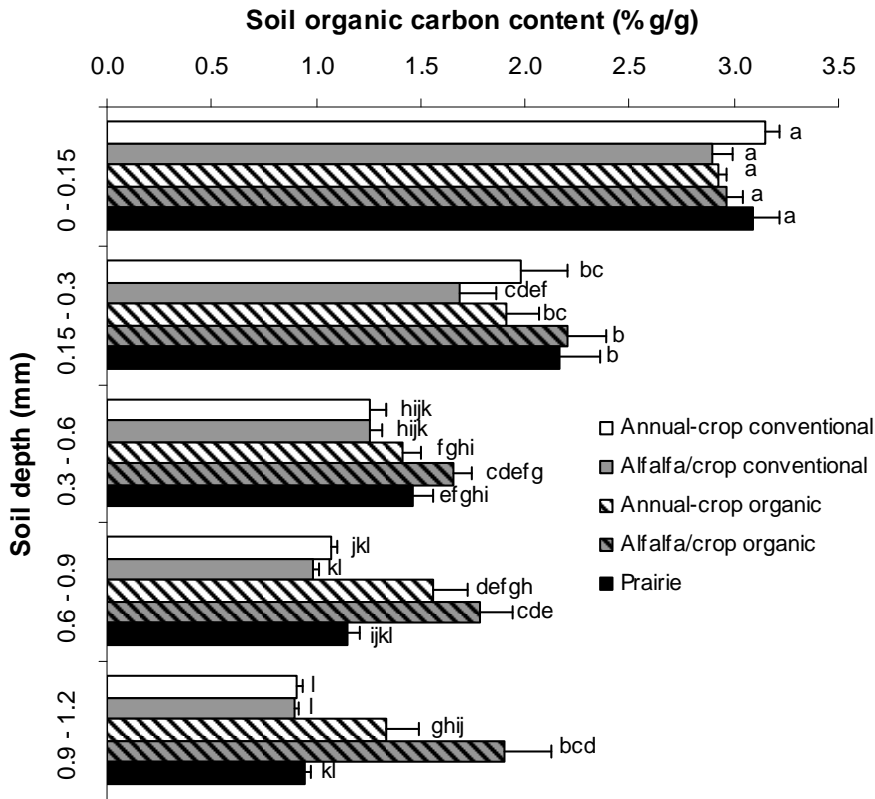
Farming system	Tot C (t ha <sup>-1</sup> )	Org C (t ha <sup>-1</sup> )	Tot N (t ha <sup>-1</sup> )	Olsen P (kg ha <sup>-1</sup> )
Alfalfa-grain organic	477 ± 34 a	330 ± 23 a	8.42 ± 0.83	24 ± 1 c
Grain-only organic	399 ± 17 b	275 ± 15 b	9.89 ± 3.13	64 ± 5 a
Alfalfa-grain conventional	316 ± 9 c	206 ± 6 c	7.93 ± 0.81	42 ± 3 b
Grain-only conventional	310 ± 8 c	223 ± 6 c	8.38 ± 0.75	63 ± 6 a
Restored Prairie	307 ± 7 c	229 ± 7 c	8.93 ± 0.98	59 ± 4 a

Soil bulk density again increased with depth (Table 5). Again the highest bulk densities were for the two deepest soil depths and for the Organic cropping treatments. As these highest bulk densities are again associated with the treatments of highest soil organic C, we are also working on estimating soil organic C levels based on a common soil mass.

**Table 5.** Soil bulk density (g cm<sup>-3</sup>) in the soil profile to 1.2 m depth under Grain-only and Alfalfa-grain rotations managed Organically and Conventionally, and Restored Prairie after 18 years at Glenlea, southern Manitoba, Canada. Letters denote significant differences between treatment x depths (LSD = 0.053).

Depth (mm)	Grain-Only Conventional	Grain-only Organic	Alfalfa-grain Conventional	Alfalfa-grain Organic	Restored Prairie
0-150	1.093 a	1.097 a	1.072 a	1.112 a	1.063 a
150-300	1.246 bc	1.254 c	1.281 cd	1.292 cd	1.199 b
300-600	1.327 def	1.356 efg	1.319 de	1.377 fgh	1.280 cd
600-900	1.414 hi	1.493 kl	1.383 gh	1.503 kl	1.359 efg
900-1200	1.436 ij	1.475 jk	1.383 gh	1.539 l	1.357 efg

As for the Carman study, the treatments with highest soil organic C per ha also had the highest concentration of soil organic C (Figure 2). The 600-900 and 900-1200 mm depths for the Organic treatments had the higher soil organic C concentrations than the Conventional cropping treatments and the Restored Prairie.



**Figure 2.** Soil organic carbon content ( $\% \text{ g g}^{-1}$ ) in the soil profile to 1.2 m depth under Grain-only and Alfalfa-grain rotations managed Organically and Conventionally, and Restored Prairie after 18 years at Glenlea in southern Manitoba, Canada. Letters denote significant differences between treatment x depths (LSD = 0.121).

**Next steps**

Our next step is to reanalyze the results based on a common soil mass per ha to estimate soil organic C. This is needed because of the difference in soil bulk density, particularly at deeper depths, between treatments. We will have those results available for the MSAPP workshop. Until we have examined the alternate estimates of soil organic c we are not in the position to suggest further research.