Crop Rotations with Annual and Perennial Forages Under No-Till Soil Management

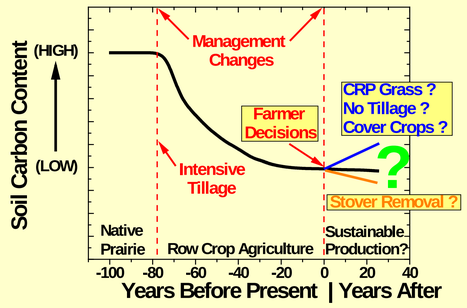
Conservation agriculture is enhanced when soil C is maintained or increased.

Research objectives were to measure soil chemical and physical properties as well as yield and seed component responses in maize and soybean to diverse crop rotations that maintain or enhance soil C.

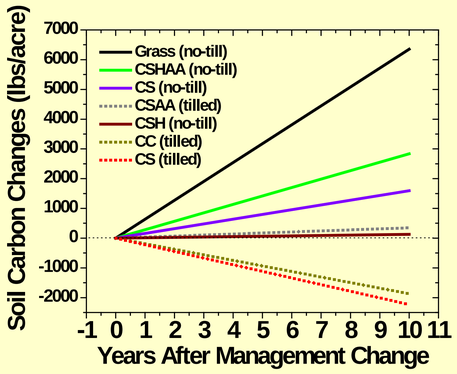
A Call to Action:

Develop crop and soil management practices that improve soil quality and enhance soil C.

Decisions farmers make each year have dramatic effect on soil C:



Crop rotations with perennial forages maintain (in tilled soil) or increase (under no-till) soil C:



How do these rotations impact other soil properties and crop productivity?

Diverse Crop Rotation Experiment

- No-till experiment established in 1996
- Crops production practices used were common to this region.
- Corn (C) and soybeans (S) are important grain crops usually grown in 2-year rotation.
- Oat/pea hay (O/P) and alfalfa (A) are important forage crops.

Rotation Treatments

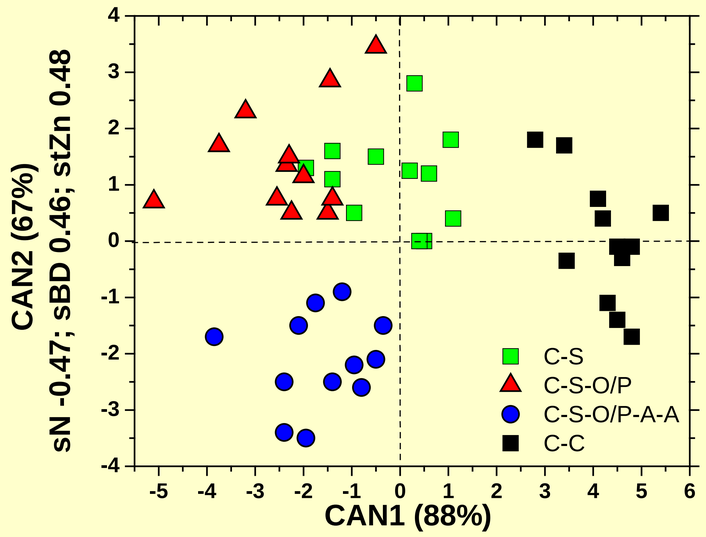
C-C = continuous corn
C-S = corn-soybean
C-S-O/P = corn-soybean-oat/pea hay
C-S-O/P-A-A= corn-soybean-oat/pea hay-alfalfa-alfalfa

Walter Riedell and Shannon Osborne

USDA Agricultural Research Service
Brookings SD, USA

Results

Discriminant analysis across rotations: maize data



gYield -0.67; gTW, -0.59; spH -0.52; gZn 0.31

Figure 1.

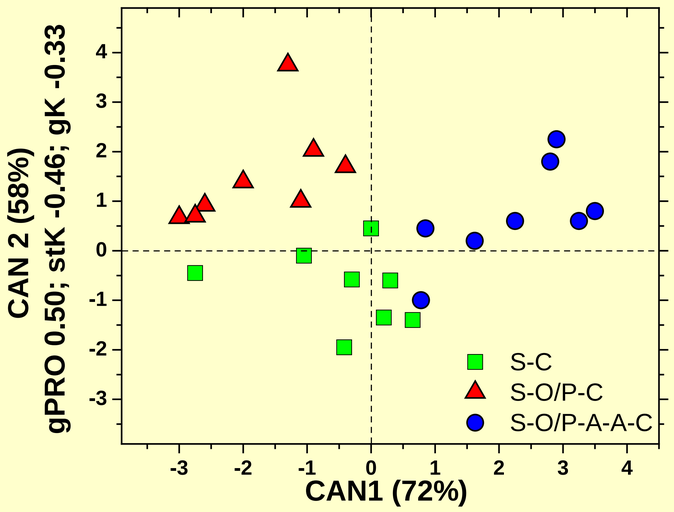
Discriminant analysis plot of canonical discriminant functions derived from soil, maize crop stover, maize grain yield, and grain components within crop rotation treatments.

Values in parentheses represent the total variation explained by each discriminant function.

Loadings of dependent variables which contributed significantly to discrimination between crop rotations on each discriminant function are also presented on the X and Y axis labels.

(gY, grain yield; gTW, grain test weight; spH, soil pH; gZn, grain Zn; sN, preseason soil nitrate-N; sBD, soil bulk density; stZn, stover Zn).

Discriminant analysis across rotations: soybean data



gYield 0.50; sBD -0.49; sN 0.41; gZn 0.44

Figure 2.

Discriminant analysis plot of canonical discriminant functions derived from soil, soybean crop stover, soybean grain yield, and grain components within crop rotation treatments.

(gY, grain yield; sBD, soil bulk density; sN, preseason soil nitrate-N; ; gZn, grain Zn; gPRO, grain protein; stK, stover K; gK, grain K).

Applications for Conservation Agriculture

Alfalfa included in rotation increased soil nitrate-N, reduced soil bulk density, increased grain yield and protein in both maize and soybean phases.

Soils, maize and soybean in oat/pea hay in rotation behaved similarly to the C-S rotation in many parameters, but had slightly greater maize yields.

Research results and demonstration help equip farmers with knowledge of soil and crop responses to diverse rotations under no-till soil management.

This provides decision support for farmers to adopt the conservation agriculture paradigm on their farms.

Multivariate Results Summary

Loadings of soil, stover, and grain data which contributed significantly to discrimination between crop rotations on each canonical discriminant function. These were used to discriminate between crop rotation treatments for the maize phase or the soybean phase of the crop rotation study.

	Maize		Soybean	
Variable (units) †	CAN 1‡	CAN 2¶	CAN 1	CAN2
Soil NO_3-N (kg ha^{-1})	-	-0.47	0.41	-
Soil bulk density (g cm^3)	-	0.46	-0.49	-
Soil pH	0.52	-	n/a	n/a
Stover K (g kg^{-1})	0.26	-	-	-0.46
Stover Mg (g kg^{-1})	-0.32	-	-	0.48
Stover Ca (g kg^{-1})	-	0.23	-	-
Stover Zn (mg kg^{-1})	-	0.48	-	-
Grain yield (kg ha^{-1})	-0.67	-	0.50	-
Grain protein (g kg^{-1})	-	-0.29	-	0.51
Grain Zn (mg kg^{-1})	0.31	-	0.44	-

† Variables and units are from the soil (Tables 1 and 4), stover (Tables 2 and 5), and grain (Tables 3 and 6) data sets for the maize phase and the soybean phase.
‡ First canonical discriminant function on Figures 1 and 2.
¶ Second canonical discriminant function on Figures 1 and 2.

For Figs. 1 and 2, the larger the percentage of total variation explained, the greater contribution of the canonical discriminant function to discrimination between groups.

For the table above, the correlation between individual values and the canonical functions between each axis (i.e. loading) allows determination of the characteristics of the soil, plant, and yield data separating rotation treatments.

Univariate results

Table 1. Residual soil NO_3-N, P, K, pH, and bulk density (BD) under different crop rotation treatments. Soil samples were taken in the late fall of the year preceding the maize phase of the rotation. Values represent data combined across all years of the study.

Rotation	NO_3-N†	P	K	pH	BD
	kg ha^{-1}	mg kg^{-1}	mg kg^{-1}		g cm^3
C-C‡	46 a§	15 a	116 bc	6.5 b	1.47 ab
C-S	27 b	12 ab	121 ab	6.9 ab	1.48 a
C-S-H	28 b	10 ab	107 c	7.3 a	1.46 ab
C-S-H/A-A-A	38 ab	6 b	108 c	7.2 a	1.37 b

† Residual soil NO_3-N was measured on cores taken from 0 to 60 cm depth while the remaining measures were made on 0- to 15-cm soil cores.
‡ Rotation treatments: C-C, continuous maize, C-S, maize-soybean 2-yr rotation; C-S-H, maize-soybean-oat/pea hay 3-yr rotation; C-S-H/A-A-A-C, maize-soybean-oat/pea hay-alfalfa-alfalfa 5-yr rotation.
§ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).

Table 2. Concentrations of N, P, K, Ca, Mg and Zn in maize stover harvested from plots managed under different crop rotation treatments. Stover was harvested just prior to grain harvest with the combine. Values represent data combined across all years of the study.

Rotation	N	P	K	Ca	Mg	Zn
	g kg^{-1}					mg kg^{-1}
C-C†	8.6 a‡	2.7 a	7.1 a	3.2 b	2.1 b	18.6 a
C-S	7.6 bc	1.9 b	6.2 b	3.5 ab	2.3 b	11.8 b
C-S-H	7.0 c	1.7 b	5.6 b	3.7 a	2.5 a	9.9 b
C-S-H/A-A-A	8.1 ab	1.8 b	6.3 b	3.5 ab	2.5 a	14.5 ab

† Rotation treatments: C-C, continuous maize, C-S, maize-soybean 2-yr rotation; C-S-H, maize-soybean-oat/pea hay 3-yr rotation; C-S-H/A-A-A-C, maize-soybean-oat/pea hay-alfalfa-alfalfa 5-yr rotation.
‡ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).

Table 3. Maize yield and seed concentrations of protein, oil, K, and Zn in seed harvested from plots managed under different crop rotation treatments. Values represent data combined across all years of the study.

Rotation	Yield	Test Wt	Protein	Oil	P	K	Zn
	kg ha^{-1}	kg m^{-3}	g kg^{-1}				mg kg^{-1}
C-C†	7119 c‡	668 b	82.5 c	41.9 a	3.17 a	3.93 a	15.8 a
C-S	9366 b	704 a	85.1 bc	41.3 ab	2.84 ab	3.70 ab	14.1 ab
C-S-H	10055 ab	703 a	87.6 ab	40.2 bc	2.80 ab	3.65 ab	12.0 c
C-S-H/A-A-A	10178 a	698 a	90.5 a	39.4 c	2.63 b	3.49 b	14.5 ab

† Rotation treatments: C-C, continuous maize, C-S, maize-soybean 2-yr rotation; C-S-H, maize-soybean-oat/pea hay 3-yr rotation; C-S-H/A-A-A-C, maize-soybean-oat/pea hay -alfalfa-alfalfa 5-yr rotation.
‡ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).

Table 4. Residual soil NO_3-N, K, electrical conductivity (EC), and bulk density (BD) under different crop rotation treatments. Soil samples were taken in the late fall of the year preceding the soybean phase of the rotation. Values represent data combined across both years of the study.

Rotation	NO_3-N†	K	EC	BD
	kg ha^{-1}	mg kg^{-1}	S m^{-1}	g cm^3
S-C‡	60 b§	109 ab	0.042 b	1.38 ab
S-H-C	65 b	101 b	0.049 ab	1.46 a
S-H/A-A-A-C	129 a	111 ab	0.059 a	1.35 b

† Residual soil NO_3-N was measured on cores taken from 0 to 60 cm depth while the remaining measures were made on 0- to 15-cm soil cores.
‡ Rotation treatments: S-C, soybean-maize 2-yr rotation; S-H-C, soybean-oat/pea hay-maize 3-yr rotation; S-H/A-A-A-C, soybean-oat/pea hay-alfalfa-alfalfa 5-yr rotation.
§ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).

Table 5. Concentrations of K, Ca, and Mg in soybean stover harvested from plots managed under different crop rotation treatments. Stover was harvested just prior to leaf drop between the R7 beginning maturity and R8 full maturity stages. Values represent data combined across both years of the study.

Rotation	Biomass	K	Ca	Mg
	kg ha^{-1}	g kg^{-1}		
S-C†	4511 ns	9.6 a‡	15.7 b	6.0 b
S-H-C	4181	7.5 b	16.5 a	6.7 a
S-H/A-A-A-C	4747	9.8 a	15.3 b	6.0 b

† Rotation treatments: S-C, soybean-maize 2-yr rotation; S-H-C, soybean-oat/pea hay-maize 3-yr rotation; S-H/A-A-A-C, soybean-oat/pea hay-alfalfa-alfalfa 5-yr rotation.
‡ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).

Table 6. Soybean yield and seed concentrations of protein, oil, K, and Zn in seed harvested from plots managed under different crop rotation treatments. Values represent data combined across both years of the study.

Rotation	Yield	Protein	Oil	K	Zn
	kg ha^{-1}	g kg^{-1}			mg kg^{-1}
S-C†	2761 b‡	358 b	187 a	17.8 ab	26.6 b
S-H-C	2720 b	364 ab	185 ab	17.3 b	27.3 ab
S-H/A-A-A-C	3044 a	368 a	184 b	17.9 a	29.8 a

† Rotation treatments: S-C, soybean-maize 2-yr rotation; S-H-C, soybean-oat/pea hay-maize 3-yr rotation; S-H/A-A-A-C, soybean-oat/pea hay-alfalfa-alfalfa 5-yr rotation.
‡ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).