Partial Nitrogen and Phosphorus Balance in Drainage Water Quality Plots, 2008–2015

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Introduction

The primary objective of this project is to determine the impact of swine manure applications to corn and soybean on nitrate leaching to groundwater. Another purpose of this long-term experimental study is to develop and recommend appropriate manure and nutrient management practices to producers to minimize water contamination potential and enhance the use of swine manure as an organic fertilizer. A third component is to determine the potential effects of rye as a cover crop to reduce nitrate loss to shallow groundwater. As part of the study, partial nitrogen (N) and phosphorus (P) balances were calculated to determine whether the cropping systems were in positive or negative N and P balance over time.

Materials and Methods

Table 1 identifies the treatments established in 2007 on 36 one-acre plots. Comparisons begin in 2008 to eliminate previous treatment effects. Five treatments compare the effect of timing and source of N on subsurface drainage water quality and crop yields in a corn-soybean (CS) rotation, and two treatments compare the effect of manure use on water quality under continuous corn (CC) rotation with and without stover removal. The spring-applied urea-ammonium nitrate (UAN) with cover crop and fall-applied manure treatments are done using no-till, and the rest of the treatments use fall chisel plow (cornstalks only) and spring field cultivation as the method of tillage.

Liquid swine manure was obtained from a growing-finishing swine facility. Manure application rates were estimated with an initial sampling from the manure pit. Actual N and P application rates were determined with manure samples taken from the agitated manure application tank the day the manure was applied. Table 2 shows the actual amounts of N and P applied with manure by year for all treatments. The SU150 treatment received spring applications of either 28 percent or 32 percent UAN at a target rate of 150 lb N ac^{-1} approximately three weeks after corn was planted. The SU150 treatment also received applications of 51 lb P_2O_5 ac^{-1} using triple superphosphate fertilizer in the fall of 2010, 2012, and 2014, to maintain soil-test P near optimum levels for crops. No additional P was applied to plots receiving manure.

Partial N and P budgets were developed using data from the research site. Total N and P applied is the eight-year average from swine manure, UAN, and P_2O_5 fertilizer applications. Biological N fixation (BNF) in soybeans is estimated using midrange values from Salvagiotti et al., (2008). An estimate of 58 percent of total plant N uptake (81% of grain N) from BNF was used for unfertilized soybeans, and a value of 52 percent of total plant N uptake (72% of grain N) from BNF in fertilized soybeans was used for the FM150/100 treatment. Total N and P removed is the sum of N exported in grain, stover

(FM200CC-S only), and losses via drainage water. Not accounted for were atmospheric deposition, denitrification, erosion, and other fluxes.

Results and Discussion

The partial N budget in Table 3 shows negative N balances in the SU150, FM150, and FM150NT treatments. The SU150NT+R treatment had a zero balance due to lower yields, and thus lower grain N removal compared with the treatments with negative balances. The FM150/100 treatment showed a positive balance since it received a higher annual average rate of applied N than the other treatments, which offset the lower N fixation estimate for fertilized soybeans. The CC treatments both showed positive N balances. This reflects the higher rate of N application in these treatments as well as less grain N removed with corn relative to soybeans. The actual N balance could vary considerably from these estimates depending on BNF and other fluxes, but the partial budgets reflect systems that could be roughly in balance over time. Soil test data indicate TC levels in all treatments were stable to slightly increasing over time (not shown). This suggests soil N levels also are relatively stable given soil C:N ratios typically do not change substantially.

The P budgets shown in Table 4 follow the same trend, with slightly negative balances in CS rotations with the exception of FM150/100, and positive balances in the CC treatments. Soil Bray-P levels (Table 5) correlate with the P budget, with Bray-P decreasing in CS rotations with the exception of FM150/100, and increasing in FM200CC. The exception is FM200CC-S, which has a positive P budget but showed no significant change in Bray-P over eight years.

Table 1. Experimental treatments for the crop years 2008 through 2015 water quality study at the Iowa State University Northeast Research Farm, Nashua, Iowa. SU = spring UAN, FM = fall manure, NT = no-till, CC = continuous corn, +R = rye cover crop, -S = stover removal.

Treatment	Timing and source of N	N rate, lb ac^{-1}	Crop rotation	Tillage
SU150	Spring UAN	150	Corn	Chisel plow corn fall
	-	-	Soybean	Field cultivate both spring
SU150NT+R	Spring UAN	150	Corn + rye cover	No-till
	-	-	Soybean + rye cover	No-till
FM150	Fall manure	150	Corn	Chisel plow corn fall
	-	-	Soybean	Field cultivate both spring
FM150/100	Fall manure	150	Corn	Chisel plow corn fall
	Fall manure	100	Soybean	Field cultivate both spring
FM150NT	Fall manure	150	Corn	No-till
	-	-	Soybean	No-till
FM200CC	Fall manure	200	Corn	Chisel plow fall
	Fall manure	200	Corn	Field cultivate spring
FM200CC-S	Fall manure	200	Corn + stover removal	Chisel plow fall
	Fall manure	200	Corn + stover removal	Field cultivate spring

Table 2. Actual amounts of N and P, applied with manure by treatment for the crop years 2008 through 2015. FM = fall manure, NT = no-till, CC = continuous corn, -S = stover removal.

	2008	2009	2010	2011	2012	2013	2014	2015	2008-2015 avg.
	- - - - - - - - - - - - - - - - Nitrogen from manure, lb N ac^{-1} - - - - - - - - - - - - - - -								
FM150	118	100	126	130	159	160	149	188	141
FM150/100-Corn	126	109	124	127	153	174	155	192	145
FM150/100-Soy	87	82	86	82	79	114	83	91	88
FM150NT	127	98	126	151	153	159	154	202	146
FM200CC	169	149	169	145	208	210	185	226	183
FM200CC-S	162	152	167	178	190	206	189	223	184
	- - - - - - - - - - - - - - - Phosphorus from manure, lb P ac^{-1} - - - - - - - - - - - - - - -								
FM150	20	13	17	33	39	36	43	59	33
FM150/100-Corn	20	15	17	33	38	36	44	61	33
FM150/100-Soy	12	14	12	29	21	23	25	29	21
FM150NT	23	15	19	36	38	34	43	66	34
FM200CC	24	24	25	39	54	46	53	70	42
FM200CC-S	25	22	23	41	54	46	55	71	42

Table 3. Eight-year average partial N balance for the crop years 2008 through 2015. SU = spring UAN, FM = fall manure, NT = no-till, CC = continuous corn, +R = rye cover crop, -S = stover removal.

	- - - - - - - - - - - - - - - - **Corn-soybean rotation** - - - - - - - - - - - - - - - -					- - - - **Continuous corn** - - - -	
	SU150	**SU150NT+R**	**FM150**	**FM150/100**	**FM150NT**	**FM200CC**	**FM200CC-S**
	- **lb N ac^{-1}** -						
+ Applied N	79	79	70	117	73	183	184
+ N fixation soybeans (est)	71	67	80	72	82	-	-
- Grain N (corn)	56.9	48.7	51.1	52.7	46.2	93.1	93.5
- Grain N (soy)	88	83	99	100	101	-	-
- Stover N	-	-	-	-	-	-	15
- Drainage N	13.9	13.6	22.4	26.3	25.1	30.7	23.8
Total N removal	159.3	145.4	172.5	179.2	172.7	123.8	132.5
Annual avg. N balance	-9	1	-23	10	-18	59	52

Table 4. Eight-year average P balance for the crop years 2008 through 2015. SU = spring UAN, FM = fall manure, NT = no-till, CC = continuous corn, +R = rye cover crop, -S = stover removal.

	Corn-soybean rotation					Continuous corn	
	SU150	SU150NT+R	FM150	FM150/100	FM150NT	FM200CC	FM200CC-S
	lb P ac^{-1}						
+ Applied P	9	9	16	28	17	42	42
- Grain P (corn)	12.8	11.1	12.4	12.8	11.6	22.7	23.1
- Grain P (soy)	8.6	8.0	9.5	9.0	9.6	-	-
- Stover P*	-	-	-	-	-	-	3.6
- Drainage P	ns	ns	ns	ns	ns	ns	ns
Total P removal	21.3	19.1	21.9	21.9	21.2	22.7	26.7
Annual avg. P balance	-12.3	-10.1	-5.9	6.1	-4.2	19.3	15.3

*ns = not significant

Table 5. Soil Bray-P test results at five depths in the fall of 2007 and 2015.[1]

		Corn-soybean rotation					Continuous corn	
Treatment		SU150	SU150NT+R	FM150	FM150/100	FM150NT	FM200CC	FM200CC-S
Depth (in)	Year	mg P kg^{-1} soil					mg P kg^{-1} soil	
0-6	2007	21.8b	21.3b	50.9a	20.1b	32.3b	89.0a	115.8a
	2015	13.8c ^	14.0c ^	36.3a	28.8ab ^	23.7bc	124.7a ^	109.7a
6-12	2007	4.6b	5.3b	12.1a	5.5b	11.8a	15.3a	45.2a
	2015	4.3b	4.5b	13.7a	7.7b ^	8.0b	30.3a	36.7a
12-24	2007	3.7a	3.0a	3.7a	3.0a	3.0a	3.5a	5.7a
	2015	3.7a	3.2a	4.3a	3.7a	3.0a	6.3a ^	6.0a
24-36	2007	4.8a	3.4a	3.4a	4.1a	2.4a	3.0a	6.3a
	2015	5.2a	3.5a	3.7a	4.7a	3.2a	4.0a	7.0a
36-48	2007	6.4a	6.0a	5.2a	5.2a	4.6a	3.5b	8.8a
	2015	6.3a	5.3a	5.5a	5.2a	5.0a	4.3a	7.0a

[1]Means with the same lowercase letter within each year and depth are not significantly different at $P \leq 0.05$. Means with ^ indicate significant change within treatment and depth across years. Corn-soybean rotation plots were combined for the statistical analysis. Effects of treatments managed with corn-soybean rotations or continuous corn were evaluated separately.