Annual Report

Water and Nutrient Research: In-field and Offsite Strategies

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NUTRIENT AND WATER MANAGEMENT PROJECT 2010-2014

Much of Iowa is characterized by relatively flat, poorly-drained areas which with extensive subsurface drainage, have became some of the most valuable, productive land in the State. However, this drained land has also become a source of significant NO_3 loss because of the changes in land-use and hydrology brought about by tile drainage. While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammonium-nitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of NO_3 are increased. This is due mostly to an increase in volume and the “short-circuiting” of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of NO_3 (and less denitrification) in the soil profile.

The problem of excess nutrient loads can probably be ameliorated by a combination of in field and off site practices, but the limitations and appropriateness of alternative practices must be understood and outcomes must be measurable. Promising in field practices include nutrient management, drainage management, and alternative cropping systems. Nitrate-removal wetlands are a proven edge-of-field practice for reducing nitrate loads to downstream water bodies and are a particularly promising approach in tile drained landscapes. Strategies are needed that can achieve measurable and predictable reductions in the export of nutrients from tile drained landscapes. The principal objectives of this project are (1) to evaluate the performance of nutrient management, drainage management, and alternative cropping systems with respect to profitability and export of water and nutrients (nitrate-nitrogen and total phosphorus) from tile drained systems and (2) to evaluate the performance of nitrate-removal wetlands in reducing nitrate export from tile drained systems.

This annual report describes activities related to objectives 1 and 2 along with outreach activities that were directly related to this project. Results for crop year 2012 are described.

Gilmore City Project Site

Treatments

The specific treatments investigated at the Gilmore City Research Facility are listed in Table 1. All treatments except the forage and kura treatments (Table 1) consist of 8 plots with 4 in soybeans and 4 in corn each year. The forage and kura treatments have 4 plots each.

Table 1. Treatments at the Gilmore City Research Facility for Crop Years 2010-2014.

Treatment Number*	Tillage	Cover Crop	Nitrogen Application Time	Nitrogen Application Rate (lb/acre)
1,2	Conventional tillage	–	Fall (Aqua-Ammonia)	150
3,4	Conventional tillage	–	Spring (Urea)	150
5,6	Conventional tillage	–	Spring (Aqua-Ammonia)	150
7,8	Conventional tillage	Rye planted after harvest of corn and beans	Spring (Aqua-Ammonia)	150
9,10	No-till	–	Spring (Aqua-Ammonia)	150
11,12	No-till	Rye planted after harvest of corn and beans	Spring (Aqua-Ammonia)	150
13,14	Conventional	–	Spring – Poly coated urea	150
15,16	Conventional	–	Late season side-dress	150
17	Kura clover - Corn		-	150
18	Orchardgrass + Red/Ladino clover		-	no fertilizer

* within the corn and soybean rotation treatments, odd numbers are soybean and receive no nitrogen.

The treatments included allow for varied comparisons. This includes the following comparisons:

- Timing of nitrogen application (treatments 1,2 vs. 5,6 vs. 15,16)
- Potential impacts of tillage (treatments 5,6 vs. 9,10)
- Source of nitrogen (treatments 3,4 vs. 5,6 vs. 13,14)
- Cropping practices through the use of a winter cover crop
    - Performance of winter rye cover crop when used in a conventional tillage system (treatments 5,6 vs. 7,8) or no-till system (treatments 9,10 vs. 11,12)
- Impacts of complete conversion to perennial cover crop (kura clover) and perennial vegetation (forage hay/pasture vegetation) (treatments 17 and 18 vs. other treatments)

Experimental studies over a period of five years will be used to evaluate the effects of reducing nitrogen application rate on water quality and crop yield. In addition the impacts of fall fertilizer application compared to spring application will be evaluated. Inclusion of the no-till as part of the in-field monitoring allows for evaluating impacts of tillage system on crop yield and water quality. Inclusion of cover crops and harvestable perennials allows for evaluating alternative cropping practices and rotations and their impacts on water quality exiting the subsurface drainage system. Evaluation of the performance of these practices is important through field monitoring for considering progressive methods for minimizing nutrient transport from tile-drained landscapes.

The concentration and loading of nutrients exiting the various treatments will be monitored and evaluated on an annual basis and for the five year study period, 2010-2014. In addition, crop yield will be documented each year to evaluate treatment effects on yield, specifically whether there are declines in annual yield at the lower nitrogen rate applications. The evaluation of the treatment effects will be for the study period but each year will be analyzed to evaluate treatment effects on a yearly basis and after the completion of this phase of the research study. It is understood that climatic variability plays a significant role in the leaching of nutrients in the tile drained landscape. Based on this, it is important to have numerous years of leaching data to evaluate the treatment effects both from a production (crop yield) perspective and a nutrient leaching perspective. The multiple years of data allows for evaluating how the treatments respond under varying climatic conditions and after subsequent years with similar cropping practices. Also, these multiple years of data allow for additional characterization of tile flow under varied precipitation conditions and allow for further understanding of the hydrology of the site.

Agronomic Activities

Agronomic field activities in 2012 were completed in a timely manner prior to and during the crop season. Rye for 2012 was seeded on October 12, 2011. Fall fertilization was completed on November 11, 2011. Chisel plowing was performed on November 17, 2011. Seedbed preparation for corn and soybean was completed on May 8, 2012. Corn was seeded on May 10 and soybean was seeded on May 16. Urea and ESN were applied on April 25. Aqua-ammonia was applied on June 19. Rye cover crop in corn plots was sprayed to eliminate rye on April 12. Soybean rye cover crop plots were sprayed to eliminate rye on May 9. Corn was harvested on October 4, 2012 and soybean was harvested on September 25, 2012.

Weed Control

Round Up ready crops were used at the site. Dual II and Python were used for pre-plant weed control and were broadcast on May 9. Application of Buccaneer and Cadet were on May 30 for corn and soybean. Cultivation for weed control was not incorporated into the weed management system in 2012.

Precipitation

Precipitation was recorded by the weather station at the site. The total precipitation in 2012 was about 12” lower than normal (Table 2). Overall, the monthly precipitation in the spring was close to normal while there was very limited precipitation after May.

Table 2. Precipitation in 2010-2012 at the research site and comparisons to norms and amounts at local NOAA weather stations.

	2010	2011	2012	Normal*
	------------------------------	inches	-------------------------	
Jan	0.97	0.01	0.09	0.91
Feb	1.04	1.15	1.56	0.70
Mar	1.74	0.25	1.84	2.20
Apr	2.44	3.39	4.04	3.09
May	2.08	4.01	2.85	3.94
Jun	13.99	7.29	3.69	4.37
Jul	9.23	2.89	1.16	4.37
Aug	5.17	0.86	0.98	4.60
Sep	4.47	0.93	2.05	3.16
Oct	0.61	0.17	1.52	2.17
Nov	1.56	0.30	0.47	1.86
Dec	0.42	1.00	0.56	1.37
Total	43.69	22.25	20.81	32.74

* From: Climatological Data for Iowa, National Climate Data Center for Pocahontas Iowa 1971-00.

Drainage

Treatment plot sampling pumps were installed during late March, 2012. Drainage started during this period and the first samples were collected on March 27th. Samples were collected on a weekly basis from March to July. Nearly all drainage ceased after the first week of July. Due to the limited precipitation only 177 water samples were collected in 2012. Table 3 lists drainage volumes by treatment in 2012 with statistical differences at p=0.05. The spring nitrogen application with no-till treatment in the corn year had the highest drainage while the Kura clover treatment had the lowest drainage (Table 3). Overall, there were statistical differences among treatments for drainage in 2012 (LSD=1.0 inches). Average drainage for all treatments was 0.9 inches. With 16.76” of precipitation between April and November and using an overall drainage volume of 0.92”, approximately 5% of the precipitation became subsurface drainage, which is extremely low compared to the drainage/precipitation ratios in the previous years for this site (Table 4). The site was winterized on November 24, 2012.

Table 3. Subsurface drainage volumes with statistical differences at p=0.05, by treatment in 2010-2012.

Treatment	Description	2010	2011	2012
		-----------------	inches	------------------
1	CP-FA-150-S	16.6b	8.6b	0.8bcde
2	CP-FA-150-C	20.0b	8.0b	0.4de
3	CP-SPUREA-150-S	26.0ab	7.7b	1.4abcd
4	CP-SPUREA-150-C	17.6b	10.4ab	0.5de
5	CP-SP-150-S	16.5b	10.3ab	1.8ab
6	CP-SP-150-C	23.4b	10.2ab	1.2abcd
7	CP-rye-150-S	16.7b	15.3a	1.6abc
8	CP-rye-150-C	24.4b	9.6ab	0.7cde

9	NT-SP-150-S	40.3a	9.3ab	1.1abcde
10	NT-SP-150-C	29.2ab	8.5b	2.0a
11	NT-rye-150-S	19.5b	10.5ab	0.6cde
12	NT-rye-150-C	22.2b	11.3ab	0.9bcde
13	CP-SPPOLY-150-S	16.2b	7.9b	0.5de
14	CP-SPPOLY-150-C	16.7b	9.5ab	0.5de
15	CP-SIDEDRESS-150-S	18.7b	10.2ab	1.3abcd
16	CP-SIDEDRESS-150-C	23.8b	10.0ab	0.9bcde
17	Kura clover	24.5b	8.4b	0.1e
18	Orchardgrass + Red/Ladino clover	17.2b	11.4ab	0.4de
LSD		15.3	6.7	1.0
Average drainage		21.4	9.8	0.9
Standard deviation		10.0	1.8	0.5
Average for corn treatments		21.5	9.5	0.8
Average for soybean treatments		21.3	10.0	1.1

Table 4. Average drainage for each month over all treatments with totals and percentage as drainage for April-November in 2010-2012.

	2010			2011			2012		
month	precipitation	drainage	percentage	precipitation	drainage	percentage	precipitation	drainage	percentage
	-----inches------		%	------inches------		%	-----inches-----		%
April	2.76	0.24	9	3.39	3.4	100	4.04	0.02	<1
May	3.19	0.76	24	4.01	2.4	60	2.85	0.32	11
June	13.03	13.13	101	7.29	8.2	112	3.69	0.31	8
July	6.94	1.33	19	2.89	2.5	87	1.16	0.27	23
August	3.36	1.17	35	0.86	0.1	12	0.98	0	0
September	4.27	0.23	5	0.93	0	0	2.05	0	0
October	0.55	0.10	18	0.17	0	0	1.52	0	0
November	1.63	2.00	123	0.30	0	0	0.47	0	0
Total	35.73	18.96	53	19.8	16.6	84	16.76	0.92	5

Nitrate Concentrations and Losses

Previous history of current plot treatments quite likely has influenced the nitrate-nitrogen concentrations observed during 2012. As observed in 2011, the highest nitrate concentrations in 2012 were recorded for the spring nitrogen application with conventional tillage treatment in the corn year and lowest concentrations were found in the perennial systems, specifically the orchardgrass/clover treatment; all other values were between these treatments values. Annual flow-weighted concentrations ranged from 1.0 to 14.9 mg L^{-1}. Individual plot/replication, flow weighted averages ranged from 1.2 to 20.0 mg L^{-1} and were recorded within the aforementioned treatments. The spring nitrogen application had significantly higher NO_3-N concentrations than the late season side-dress. Conventional tillage had significantly higher concentrations than no-till within the soybean year but showed no significant difference within the corn year. The nitrogen sources (aqua-ammonia, urea, and poly coated urea) did not exhibit any significantly different effects on NO_3-N concentrations for both crops. Treatments of rye cover crop had significantly lower nitrate concentrations within the soybean year under conventional tillage than the comparable treatments without cover crop (treatments 5, 6), but showed no significant difference under no-till in both crops. Table 5 lists the statistical differences among all treatments at the p=0.05 level.

Table 5. Average annual flow-weighted nitrate concentrations by treatment in 2010-2012 with statistical significance at p=0.05.

Treatment	Description	2010	2011	2012
		--------------	nitrate N (mg/L)	------------
1	CP-FA-150-S	10.3ef	10.1bcde	9.2abcd
2	CP-FA-150-C	13.0bcde	11.4bcd	10.7abc
3	CP-SPUREA-150-S	11.4def	12.1abc	13.0ab
4	CP-SPUREA-150-C	13.1bcde	11.7bcd	10.8abc
5	CP-SP-150-S	22.7a	12.7ab	14.9a
6	CP-SP-150-C	14.8b	15.4a	14.3a
7	CP-rye-150-S	11.8cdef	9.3cde	4.9cde
8	CP-rye-150-C	11.1ef	8.4de	8.4abcd
9	NT-SP-150-S	10.8ef	11.1bcd	7.1bcde
10	NT-SP-150-C	13.4bcde	7.4e	10.7abc
11	NT-rye-150-S	11.0ef	8.9cde	9.0abcd
12	NT-rye-150-C	11.0ef	8.8cde	10.0abc
13	CP-SPPOLY-150-S	15.4bc	10.6bcde	10.4abc
14	CP-SPPOLY-150-C	11.9bcde	11.5bcd	9.6abcd
15	CP-SIDEDRESS-150-S	14.1bcd	12.1abc	9.7abcd
16	CP-SIDEDRESS-150-C	11.9bcde	9.2cde	9.8abcd
17	Kura clover	9.0f	8.3de	3.2de
18	Orchardgrass + Red/Ladino clover	1.9g	2.4f	1.0e
	LSD	4.0	3.4	6.8

Table 6 lists NO_3-N losses by treatment in 2012. Losses were calculated by multiplying subsurface drainage effluent concentration by drainage volume. Due to the inherent variability between experimental plots and among treatments, loss calculations for one year may not be the best indicator of treatment effect. Overall, nitrate-N losses in 2012 were very small due to the low drainage amount. Losses in 2012 ranged from 0.1 to 5.2 lbs NO_3-N for the orchardgrass/clover treatment and spring nitrogen application with conventional tillage treatment in the soybean year of the rotation, respectively. All statistical comparisons are listed in Table 6.

Table 6. Average annual flow-weighted nitrate losses by treatment in 2010-2012 with statistical significance at p=0.05.

Treatment	Description	2010	2011	2012
		------------ nitrate-N (lbs/acre) ------------		
1	CP-FA-150-S	38.6cd	18.5bc	1.2de
2	CP-FA-150-C	60.1abc	17.7bc	1.2de
3	CP-SPUREA-150-S	69.4abc	20.8abc	3.9abc
4	CP-SPUREA-150-C	49.7bcd	25.7ab	1.5de
5	CP-SP-150-S	90.9ab	29.7ab	5.2a
6	CP-SP-150-C	75.3abc	34.8a	3.3abcd
7	CP-rye-150-S	44.8bcd	30.9ab	1.6de
8	CP-rye-150-C	47.4bcd	17.0bc	1.7cde
9	NT-SP-150-S	106.4a	21.7abc	2.4bcde
10	NT-SP-150-C	88.7ab	18.6bc	4.5ab
11	NT-rye-150-S	48.9abc	21.1abc	1.3de
12	NT-rye-150-C	61.6abc	21.6abc	1.6de
13	CP-SPPOLY-150-S	66.2abc	19.9abc	1.3de
14	CP-SPPOLY-150-C	46.4bcd	23.5abc	1.1de
15	CP-SIDEDRESS-150-S	60.6abc	26.4ab	2.7bcd
16	CP-SIDEDRESS-150-C	61.0abc	19.8abc	2.0cde
17	Kura clover	49.4bcd	15.4bc	0.1e
18	Orchardgrass + Red/Ladino clover	5.2d	8.1c	0.2e
	LSD	49.5	15.5	2.3

Reactive Phosphorus Concentrations and Losses

Total reactive phosphorus (TRP) concentrations were measured in tile drainage samples that were also tested for NO_3-N. Table 7 lists flow-weighted TRP concentrations in 2012 for each treatment. Table 8 lists loss by year and treatment in grams per acre. The measured TRP includes both dissolved and suspended orthophosphate. This test measures the form most available to plants and is a useful indicator of potential water quality impacts such as algae blooms and weed growth in surface waters. Overall, the levels of phosphorus leaving the plots and limits were low, ranging from 1.9-127.0 µg L^{-1} (Table 7). Due to the large variation among plots there was no significant difference in TRP concentrations among the treatments.

Table 7. Average annual flow-weighted TRP concentrations by treatment in 2010-2012 with statistical significance at p=0.05.

Treatment	Description	2010	2011	2012
			----------- TRP (ug/L) ------------	
1	CP-FA-150-S		14.2ab	81.2ab
2	CP-FA-150-C		22.6ab	51.6ab
3	CP-SPUREA-150-S		7.4b	15.1b
4	CP-SPUREA-150-C		15.3ab	8.0b
5	CP-SP-150-S		8.4b	7.4b
6	CP-SP-150-C		11.6b	13.1b
7	CP-rye-150-S		9.2b	22.4ab

8	CP-rye-150-C	42.4a	5.0b
9	NT-SP-150-S	7.1b	4.9b
10	NT-SP-150-C	7.3b	13.4b
11	NT-rye-150-S	8.3b	126.7a
12	NT-rye-150-C	8.8b	127.0a
13	CP-SPPOLY-150-S	33.3ab	4.5b
14	CP-SPPOLY-150-C	9.3b	10.8b
15	CP-SIDEDRESS-150-S	5.4b	18.3ab
16	CP-SIDEDRESS-150-C	9.1b	33.8ab
17	Kura clover	7.7b	38.8ab
18	Orchardgrass + Red/Ladino clover	6.0b	1.9b
	LSD	28.3	109.2

Table 8. Average annual flow-weighted TRP losses by treatment in 2010-2012 with statistical significance at p=0.05.

Treatment	Description	2010	2011	2012
		----------- TRP (g/acre) ------------		
1	CP-FA-150-S		14.4b	3.4ab
2	CP-FA-150-C		10.0b	1.5bc
3	CP-SPUREA-150-S		5.5b	1.4bc
4	CP-SPUREA-150-C		14.2b	0.5c
5	CP-SP-150-S		7.8b	1.3bc
6	CP-SP-150-C		12.4b	0.8c
7	CP-rye-150-S		17.5b	3.9a
8	CP-rye-150-C		61.5a	0.4c
9	NT-SP-150-S		6.0b	0.8c
10	NT-SP-150-C		8.5b	2.1abc
11	NT-rye-150-S		9.0b	0.9c
12	NT-rye-150-C		9.8b	1.2bc
13	CP-SPPOLY-150-S		33.4ab	0.2c
14	CP-SPPOLY-150-C		9.1b	0.7c
15	CP-SIDEDRESS-150-S		5.2b	2.2abc
16	CP-SIDEDRESS-150-C		7.5b	0.8c
17	Kura clover		7.2b	0.4c
18	Orchardgrass + Red/Ladino clover		6.7b	0.1c
	LSD		39.5	2.4

Stalk Nitrate Test

Corn stalk nitrate test sampling protocols were followed to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 9. Stalks were sampled on September 20. Stalk nitrate values can be divided into four categories: low (less than 250 mg/L-N), marginal (250-700), optimal (700 and 2000 mg/L-N), and excess (greater than 2000 mg/L-N). Only conventional tillage with spring aqua-ammonia application or sidedress treatments were in the marginal range, all other treatments were in the optimal range.

Table 9. Stalk nitrate test concentrations in 2010-2012.

Treatment	Description	2010	2011	2012
		--------- nitrate-N* (mg/L) ---------		
2	CP-FA-150-C	83	199	1694
4	CP-SPUREA-150-C	228	1092	1262
6	CP-SP-150-C	574	671	384
8	CP-rye-150-C	141	623	1161
10	NT-SP-150-C	344	614	1222
12	NT-rye-150-C	731	411	891
14	CP-SPPOLY-150-C	121	1146	716
16	CP-SIDEDRESS-150-C	538	225	646
17	Kura	704	424	1629

* low (less than 250 mg/L-N) marginal (250-700) optimal (700-2000 mg/L-N).

Yields

Corn and soybean yields, by treatment, are listed in Tables 10 and 11. Corn and soybean yields were impacted by the severe drought in 2012. Corn yields from the kura clover treatment were close to zero (1.4 bu/acre) and excluded from statistical analysis. Corn yields of other treatments in 2012 ranged from 127 to 161 bu/acre (Table 10). The highest corn yield was for the spring urea application with conventional tillage treatment while the lowest corn yield was for the rye cover crop with no-till treatment. Soybean yields ranged from 24-39 bu/acre (Table 11). The conventional tillage with sidedress treatment had significantly higher soybean yields than the conventional tillage with fall nitrogen application treatment.

Table 10. Corn yield by treatment in 2010-2012 with statistical significance at p=0.05.

Treatment	Description	2010	2011	2012
		--------- yield (bu/acre) ----------		
2	CP-FA-150-C	169a	161abc	159a
4	CP-SPUREA-150-C	178a	175ab	161a
6	CP-SP-150-C	186a	180a	141ab
8	CP-rye-150-C	180a	150c	145ab
10	NT-SP-150-C	177a	159abc	131b
12	NT-rye-150-C	177a	154bc	127b
14	CP-SPPOLY-150-C	175a	177ab	145ab
16	CP-SIDEDRESS-150-C	185a	168abc	148ab
17	Kura	69b	64d	/
	LSD	18	25	25

Table 11. Soybean yield by treatment in 2010-2012 with statistical significance at $p=0.05$.

Treatment	Description	2010	2011	2012
		--------- yield (bu/acre) ----------		
1	CP-FA-150-S	59a	45a	24b
3	CP-SPUREA-150-S	59a	42abc	31ab
5	CP-SP-150-S	59a	42abc	33ab
7	CP-rye-150-S	57a	42abc	24ab
9	NT-SP-150-S	57a	37c	27ab
11	NT-rye-150-S	60a	37bc	28ab
13	CP-SPPOLY-150-S	60a	45a	36ab
15	CP-SIDEDRESS-150-S	59a	43ab	39a
	LSD	6	7	14

Summary

The total precipitation in 2012 was about 12” lower than normal. Overall, the monthly precipitation in the spring was close to normal while there was very limited precipitation since May, much lower than normal.

Overall little drainage occurred in 2012 due to the severe drought conditions. Average drainage for all treatments was 0.9 inches. The spring nitrogen application with no-till treatment in the corn year had the highest drainage while the Kura clover treatment had the lowest drainage. Approximately only 5% of the precipitation became subsurface drainage during the drainage season (April-November).

The highest nitrate concentrations in 2012 were recorded for the spring nitrogen application with conventional tillage treatment in the corn year and lowest concentrations were found in the perennial systems, specifically the orchardgrass/clover treatment; all other values were between these treatments values. Annual flow-weighted concentrations ranged from 1.0 to 14.9 mg L^{-1}. Individual plot/replication, flow weighted averages ranged from 1.2 to 20.0 mg L^{-1} and were recorded within the aforementioned treatments. The spring nitrogen application had significantly higher NO_3-N concentrations than the late season side-dress. Conventional tillage had significantly higher concentrations than no-till within the soybean year but showed no significant difference within the corn year. The nitrogen sources did not exhibit any significantly different effects on NO_3-N concentrations for both crops. Treatments of rye cover crop had significantly lower nitrate concentrations within the soybean year under conventional tillage than the comparable treatments without cover crop, but showed no significant difference under no-till in both crops.

Overall, nitrate-N losses in 2012 were very small due to the low drainage amount. Losses in 2012 ranged from 0.1 to 5.2 lbs NO_3-N for the orchardgrass/clover treatment and spring nitrogen application with conventional tillage treatment in the soybean year of the rotation, respectively

Overall, the levels of phosphorus leaving the plots and limits were low, ranging from 1.9-127.0 µg L^{-1}. Due to the large variation among plots there was no significant difference in TRP concentrations among the treatments.

Only conventional tillage with spring aqua-ammonia application or sidedress treatments were in the marginal range, all other treatments were in the optimal range.

During 2012 the corn and soybean yields were likely impacted by the severe drought throughout most of the year. Corn yields from the kura clover treatment were close to zero (1.4 bu/acre). Corn yields of other treatments in 2012 ranged from 127 to 161 bu/acre (Table 10). The highest corn yield was for the spring urea application with conventional tillage treatment while the lowest corn yield was for the rye cover crop with no-till treatment. Soybean yields ranged from 24-39 bu/acre. The conventional tillage with sidedress treatment had significantly higher soybean yields than the conventional tillage with fall nitrogen application treatment.

Pekin Project Site

Drainage management practices are being evaluated at the Pekin school drainage facility. There are a total of nine plots at this facility. Three different management practices are being be utilized and evaluated. The treatments include the following:

- 3 – plots with conventional drainage (**FF**).
- 3 – plots with controlled drainage with free flow in the spring (April –May) and fall (September-October) (**CDV**). The outlet control will be set at 2 ft below the ground surface except during free flow.
- 3 – plots with controlled drainage with no free flow (**CDF**). This treatment would be used to represent a system similar to shallow drainage. The outlet control will be set at 2 ft below the ground surface.

These three treatments are being evaluated to investigate the impacts of drainage management practices on drainage volume, nutrient concentrations in the subsurface drainage, and grain yield. Again, these factors will be evaluated over the five year term of this project. Since significant climate variability exists and the response of variable weather conditions on drainage management systems is needed it is important to evaluate the treatment response over the entire duration of the project phase. In addition to drainage management practices, flow from two plots flows through a passive biofilter. One of the plots is a FF plot and one is a CDF plot. The concentration of nutrients entering and exiting the biofilter is being monitored to document any reductions as a result of the passive biofilter.

Precipitation and Drainage

The total precipitation during the drainage season (April to October) in 2012 was 17.6 inches which is slightly below the historical average of 27.3 inches (Figure 1). Overall, only 12% of precipitation became conventional subsurface drainage due to the dry field conditions in 2012. The shallow drainage system drainage volume yielded substantially less with 4% of precipitation. The controlled drainage system was reduced to 7% of precipitation. Respectively, drainage volumes were 2.1, 1.2, and 0.7 inches for conventional drainage, controlled drainage, and shallow drainage (Figure 2). The outlets on control drainage plots were lowered to 48” below the ground surface from March 28 through June 22, 2012.

Nitrate-Nitrogen Concentrations

Water samples were collected from early April to Late June in 2012. Listed in Table 12 are flow-weighted NO_3-N concentrations for all treatments for all monitoring years. Average annual flow-weighted NO_3-N concentrations were 4.55, 8.05, and 4.98 mg/ for conventional drainage, controlled drainage, and shallow drainage, respectively. The use of a wood-based bioreactor constructed at the time of subsurface drain installation and consisting of wood chips surrounding the drain line decreased the concentrations being released from the standard installation, conventional drainage treatment (Figure 3). Results from the bioreactor collecting drainage from the shallow management scheme are presented in Figures 6. Due to minimal drainage volumes, no sample was taken for effluent drainage for the shallow management scheme in 2012.

Corn and Soybean Yields

Historically, corn yields have been relatively low at the Pekin research fields, when compared to state and county averages. Corn yields were 143, 147, and 139 bu/acre in 2012 for the controlled, conventional, and shallow drainage fields, respectively (Figure 5).

Soybean yields in 2012 were comparable to previous years with 41, 42 and 39 bu/ac for the controlled, conventional, and shallow drainage fields, respectively (Figure 6).

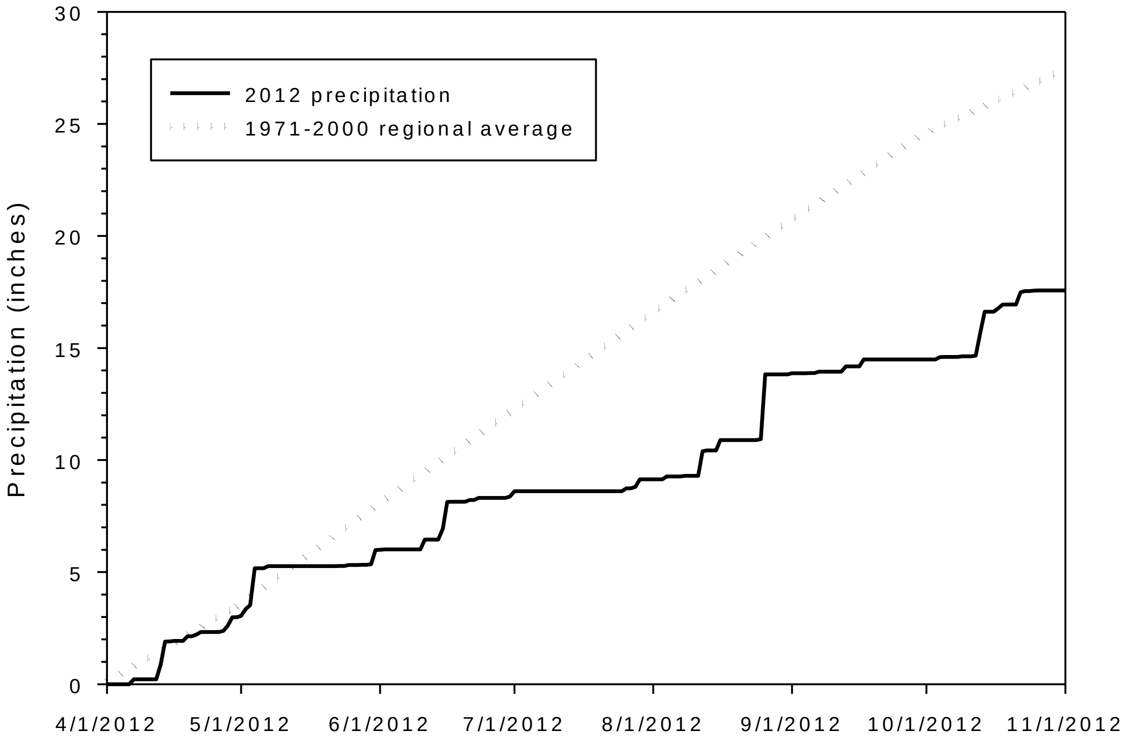

Figure 1. Precipitation during the drainage season in 2012 compared to the 30-year regional average.

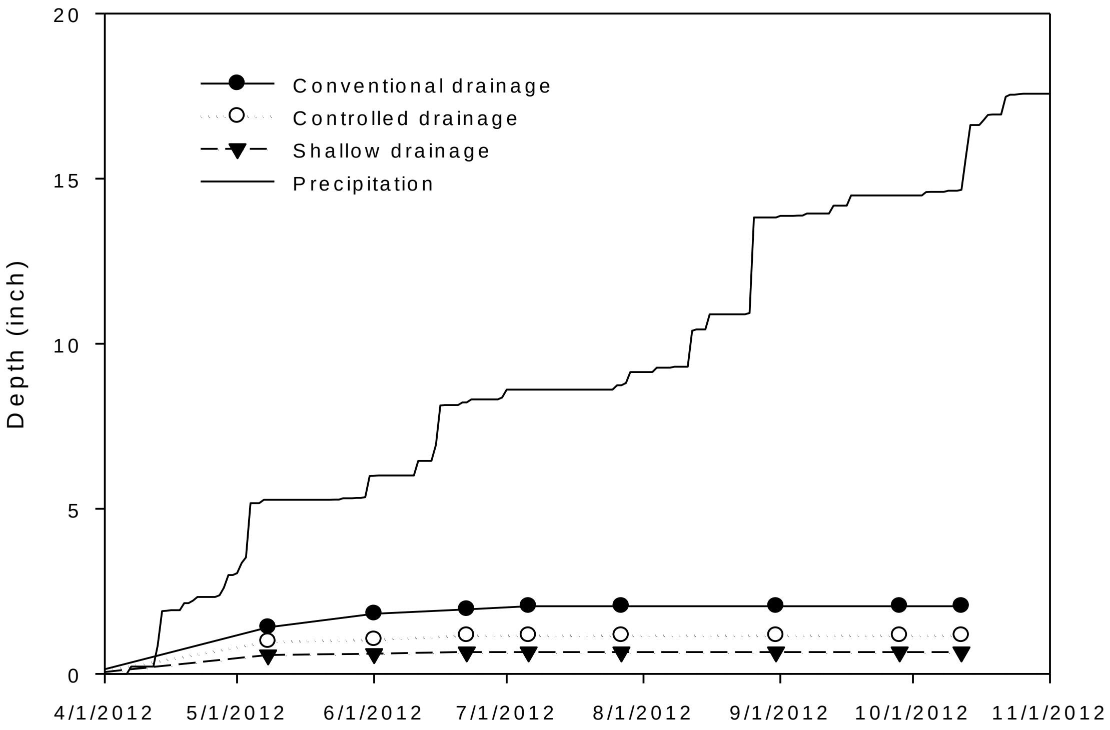

Figure 2. Precipitation and subsurface drainage at the Pekin site during the drainage season in 2012.

Table 12. Flow-weighted nitrate concentration for all treatments (mg/L).

	Conventional		**Controlled**		**Shallow**	
	Average	Std. Dev.	**Average**	Std. Dev.	**Average**	Std. Dev.
2005	6.71	1.16	6.40	2.14	4.57	2.49
2006	6.92	0.59	7.20	1.44	6.72	1.86
2007	10.69	1.98	12.08	2.75	12.88	1.63
2008	6.23	2.97	5.17	3.32	5.95	2.05
2009	6.39	2.83	7.35	2.23	7.88	1.47
2010	3.20	2.13	3.24	1.86	3.77	0.67
2011	4.41	1.45	5.78	0.47	5.95	1.16
2012	4.55	0.94	8.05	1.53	4.98	1.97

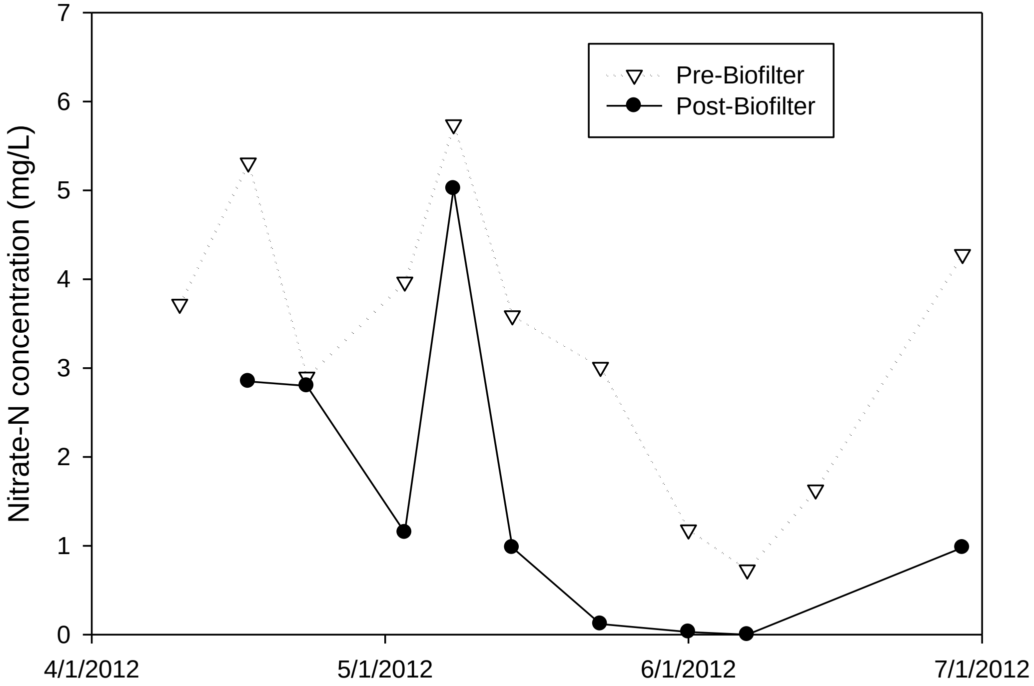

Figure 3. 2012 Conventional drainage bio-filter nitrate data.

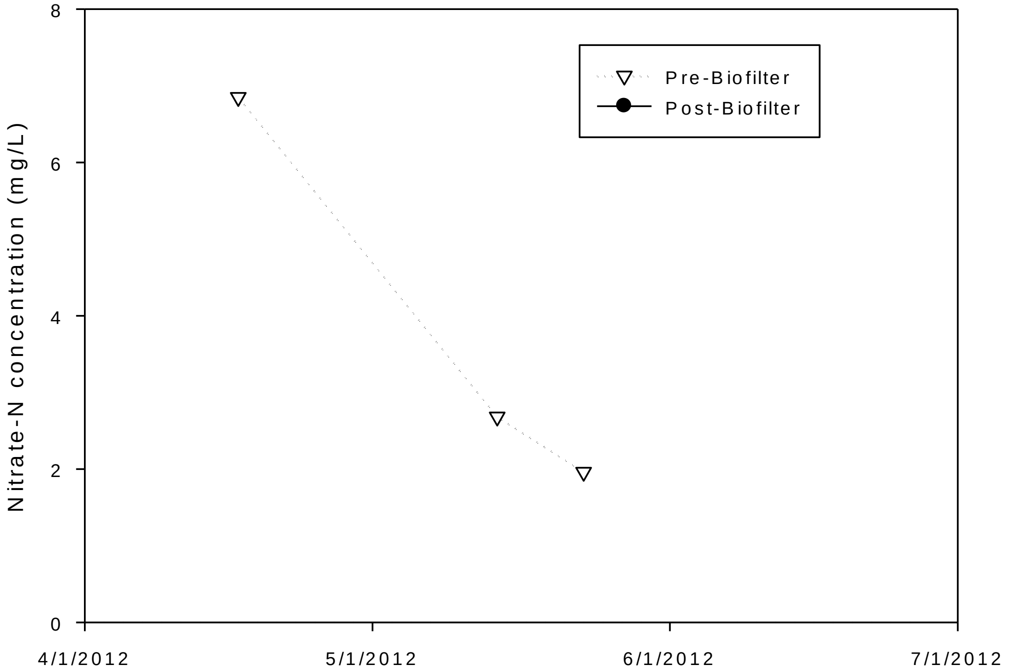

Figure 4. 2012. Shallow drainage bio-filter nitrate data. There was no bioreactor effluent sample in 2012.

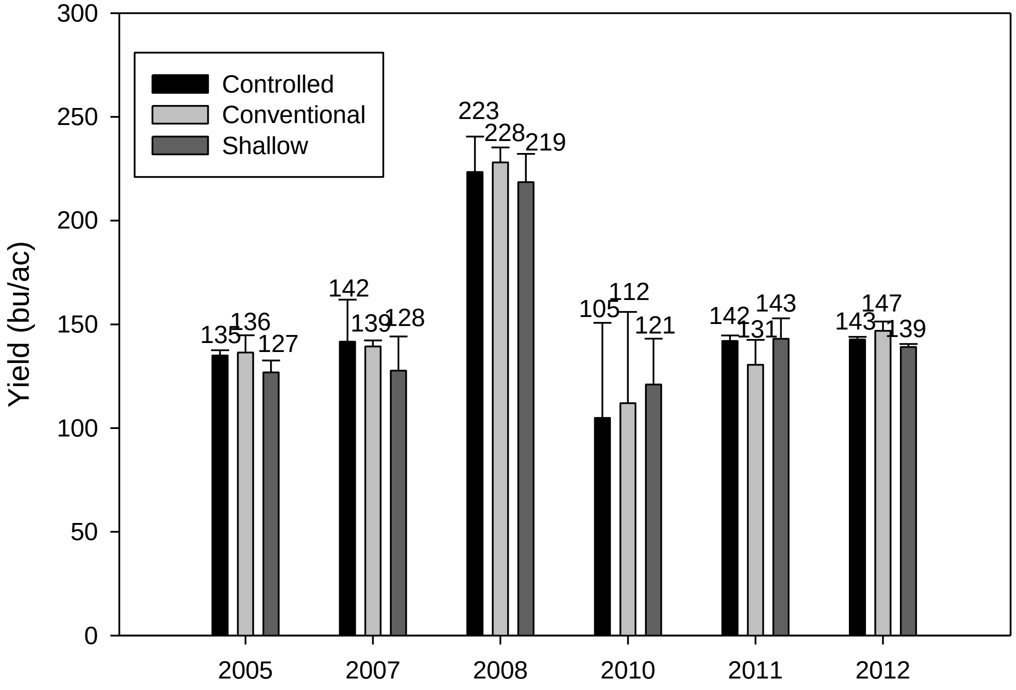

Figure 5. Corn yields at the Pekin site.

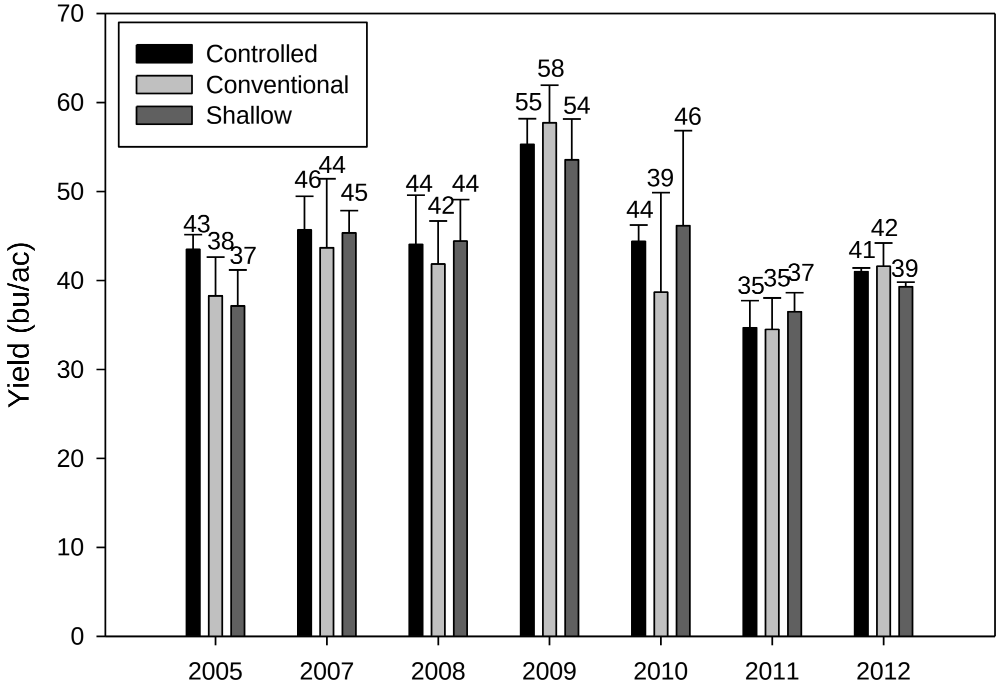

Figure 6. Soybean yields at the Pekin site.

Crawfordsville Project Site

Since 2007 drainage water management research has been conducted at the Southeast Research Farm near Crawfordsville, IA. In 2012 this site was added to this project. This project is evaluating the impacts of drainage and drainage water management on crop yields and subsurface drainage volume. The site consists of Taintor (silty clay loam, fine, smectitic, mesic Vertic Argiaquolls) and Kalona (silty clay loam, fine, smectitic, mesic Vertic Endoaquolls) soils. The research site has 8 plots with two replications for each treatment (figure 7). Individual plots ranged in size from approximately 3 to 6 ac in size for a total project area of 42 ac. The eight plots included two undrained plots, two plots with conventional drainage, two plots with shallow drainage, and two plots with controlled drainage. The conventional and controlled drainage plots had tiles installed to a 4 ft depth with a drain spacing of 60 ft. Shallow drainage plots had tiles installed to a 2.5 ft depth with a 40 ft spacing. All drained plots were designed to have a maximum drainage coefficient of 0.75 in/day.

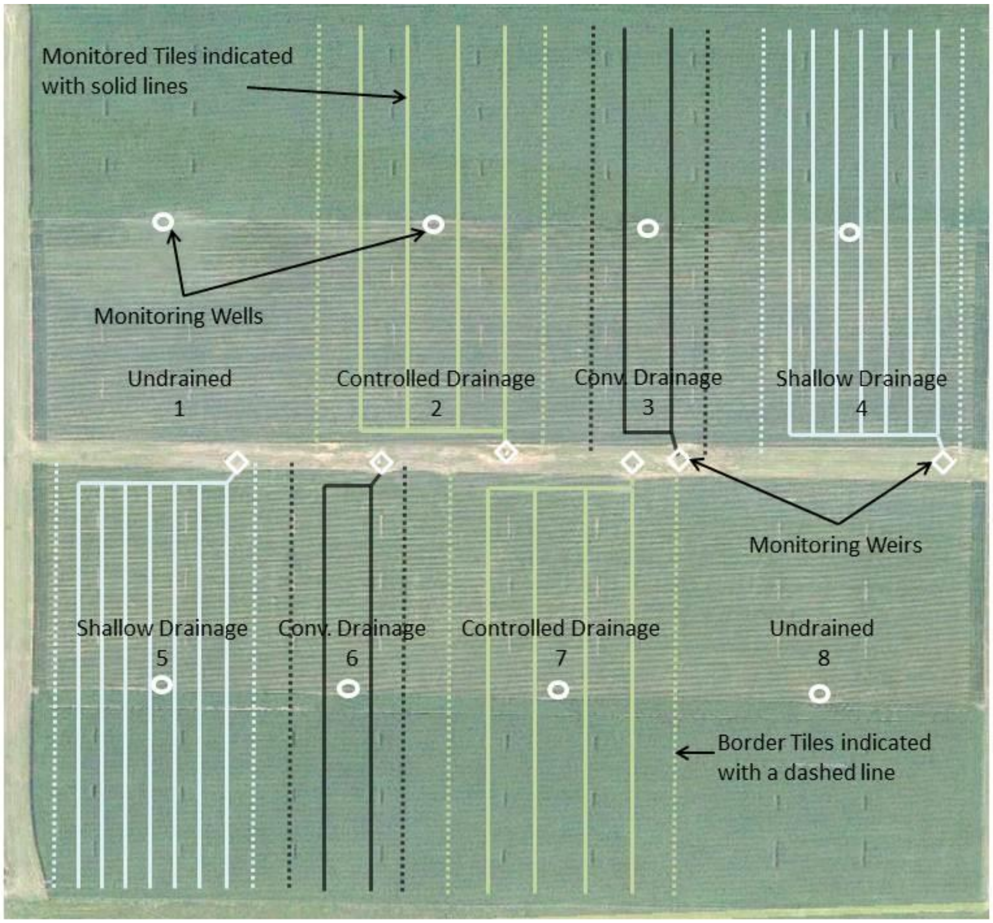

Figure 7. Aerial view of plots and layout of drainage treatments at the Crawfordsville, IA research site.

During the study period (2007-2012), the precipitation has been near the 30-yr average or above in 4 of the six years. However, 2011 and 2012 were drier than normal (Table 13). Overall the implementation of shallow or controlled drainage reduced the subsurface drainage volume from the system (Table 14). However, controlled or shallow drainage did not increase crop yield

(Figures 8 and 9) but yields were improved by the use of drainage systems over the undrained conditions.

Table 13. Precipitation at the Crawfordsville, IA research site

	30 yr Av	2007	2008	2009	2010	2011	2012
	mm						
Jan.	31	22	8	—	41	—	5
Feb.	41	45	3	—	7	—	46
Mar.	62	92	23	108	74	46	16
Apr.	85	127	136	57	113	46	63
May	123	85	136	151	151	96	125
June	120	191	159	219	321	144	98
July	118	107	85	123	129	208	13
Aug.	100	191	97	248	119	33	118
Sept.	109	51	207	35	189	26	61
Oct.	76	98	60	182	30	45	76
Nov.	63	15	5	68	34	15	32
Dec.	46	—	—	41	27	—	6
Year	972	1024	918	1232	1234	659	659

Table 14. Drainage at the Crawfordsville, IA research site

	Drainage (in)						
Treatment	2007	2008	2009	2010	2011	2012	6-Yr Avg.
Conventional Drainage	9.8 a	9.8 a	18.9 a	20.1 a	13.0 a	5.1 a	11.8 a
Controlled Drainage	7.1 a	9.1 a	9.1 b	13.0 b	5.1 b	2.0 b	7.1 b
Shallow Drainage	7.1 a	7.1 a	7.9 b	11.0 b	3.1 b	2.0 b	5.9 b

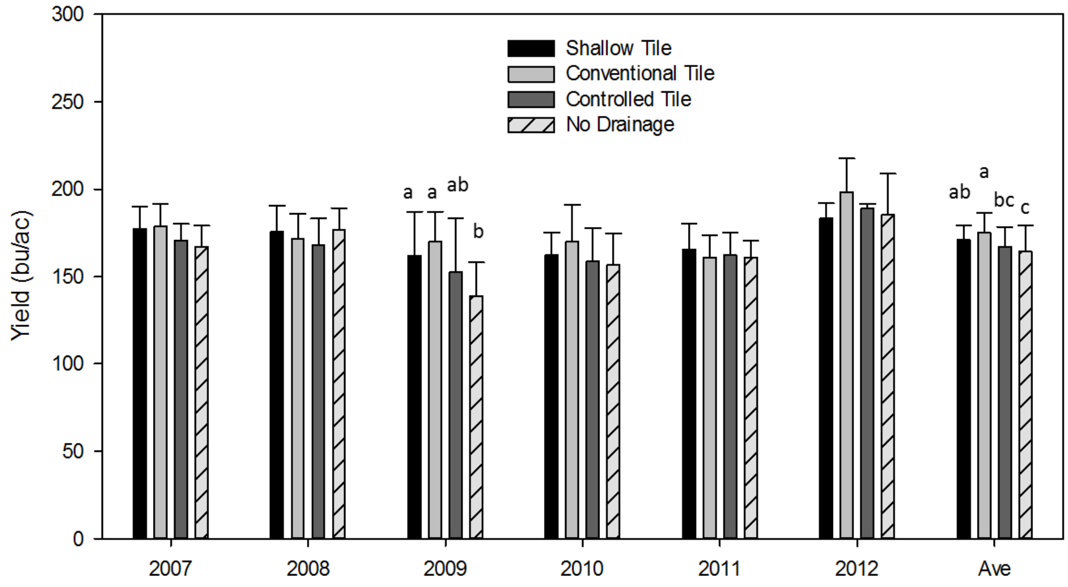

Figure 8. Corn Yield at the Crawfordsville, IA research site.

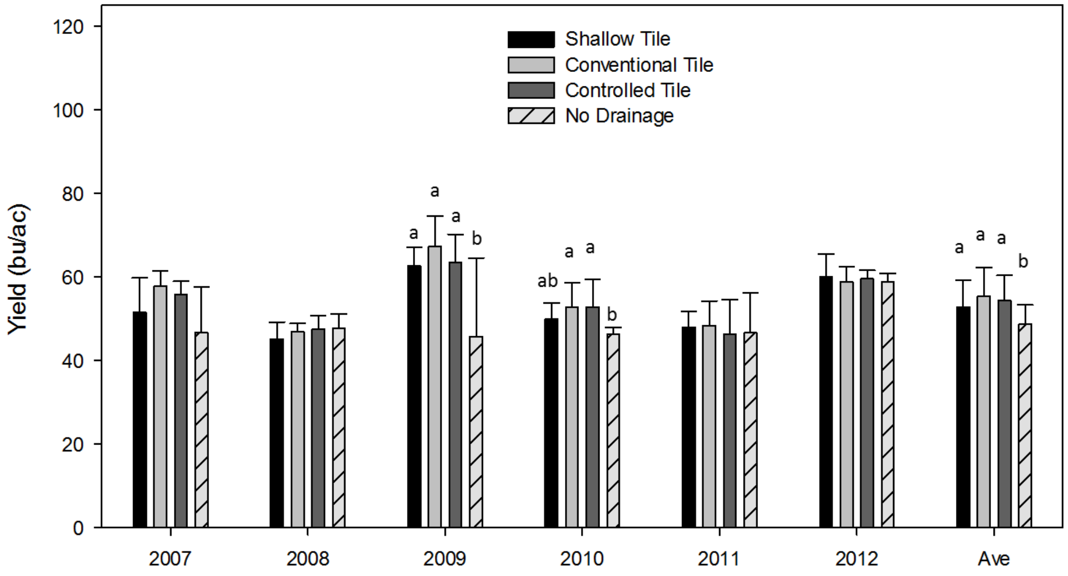

Figure 9. Soybean Yield at the Crawfordsville, IA research site.

Wetlands Monitoring and Evaluation

A unique aspect of the Iowa CREP is that nitrate reduction is not simply assumed based on wetland acres enrolled, but is calculated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a representative subset of wetlands is monitored and mass balance analyses performed to document nitrate reduction. By design, the wetlands selected for monitoring span the 0.5% to 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a 2 to 3 fold range in average nitrate concentration. The wetlands thus provide a broad spectrum of those factors most affecting wetland performance: hydraulic loading rate, residence time, nitrate concentration, and nitrate loading rate. In addition to documenting wetland performance, this will allow continued refinement of modeling and analytical tools used in site selection, design, and management of CREP wetlands.

Summary of 2012 Monitoring

Seven wetlands were monitored for the Iowa CREP during 2012 (Figure 10). These include AA, AL, DD65, JM, KS, LICA, and SS wetlands. Wetland monitoring included wetland inflow and outflow measurements, wetland pool elevation and water temperature measurements, and collection of weekly grab samples and automated daily samples. Automated samplers were programmed to collect daily composite water samples composed of four six-hour subsamples collected at wetland inflows and outflows. At the AA, AL, JM and KS sites, which had been monitored previously, daily sample collection was initiated between the last week of March and the first week of April. Daily sampling at the DD65, LICA and SS sites, which had not been historically monitored for daily samples, was initiated during May and early June. With the exception of DD65, grab samples were collected throughout the year during approximately weekly site visits at inflow and outflow locations. Grab samples collection at DD65 was initiated in late March, 2012. Inflow and outflow ceased during July at each wetland. All water samples were assayed for nitrate-N concentration.

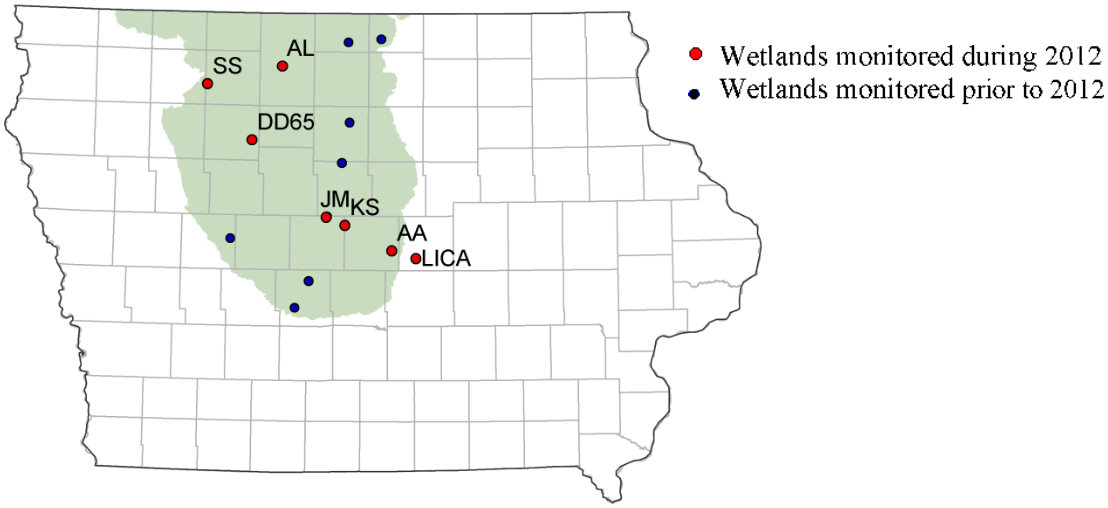

Figure 10. Wetlands monitored during 2012 and wetlands monitored during prior years and utilized for performance evaluation (see Figure 12).

Wetland inflow and/or outflow stations were instrumented with submerged area velocity (SAV) Doppler flow meters for continuous measurement of flow velocity. The SAV measurements were combined with cross-sectional channel profiles and stream depth to calculate discharge as the product of velocity and wetted cross-sectional area. Wetland water levels were monitored continuously using stage recorders in order to calculate pool volume, wetland area, and discharge at outflow structures. The pool discharge equations and SAV based discharge measurements were calibrated using manual velocity-area based discharge measurements collected during weekly site visits during prior monitoring years. Manual velocity-area discharge measurements were determined using the mid-section method whereby the stream depth is determined at 10 cm intervals across the stream and the water velocity is measured at the midpoint of each interval. Velocity was measured with a hand held Sontek Doppler water velocity probe using the 0.6 depth method where the velocity at 0.6 of the depth from the surface is taken as the mean velocity for the interval. The product of the interval velocity and area is summed over intervals to give the discharge.

Wetland bathymetry data were used to characterize wetland volume and area as functions of wetland depth. Because bathymetry data have not been obtained for the DD65, LICA, or SS wetlands, volume and area versus depth relationships generalized from those wetlands having bathymetry data were used for modeling purposes. These bathymetric relationships were used in numeric modeling of water budgets and nitrate mass balances to estimate nitrate loss, hydraulic loading, and residence times. Wetland water temperatures were recorded continuously for numerical modeling of nitrate loss.

Despite significant variation with respect to nitrate concentration and loading rates, the wetlands display similar seasonal patterns. Nitrate concentrations are generally low to moderate during the winter, but flow is generally low so that mass loading is typically low during the winter. The 2011-2012 winter was relatively dry and no winter flow was observed at the AL, JM, and SS wetlands while winter flow was very low at the other wetlands (Figure 11). The spring melt often results in increased flow during late February or March but nitrate concentrations in the melt water and associated surface runoff are typically low to moderate. During 2012, nitrate concentrations increase to their highest levels during increased flow periods in spring and early summer, and generally declined with declining flow in June to July. No flow into or out of any of the wetlands monitored was observed between mid-July and the end of October 2012 (the time of the writing of this report). A nitrate concentration decline is sometimes observed during very high summer flow events and is thought to be associated with surface runoff having low nitrate concentration. In contrast, the spring and summer of 2012 were generally dry, and an increase in concentration was occasionally observed in conjunction with an increase in flow – this is thought to be associated with a flushing of nitrate stored in the soil as water moves through the subsurface to the tile system. These nitrate concentration and flow patterns are consistent with those of CREP wetlands monitored in prior years and represent the likely patterns for future wetlands restored as part of the Iowa CREP.

Nitrate Loss from Wetlands

Mass balance analysis and modeling were used to calculate observed and predicted nitrate removal for each wetland. Inflow and outflow nitrate concentrations for the wetlands are illustrated in Figure 11. In addition, Figure 11 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling using 2012 water budget, wetland water temperature, and nitrate concentration as model inputs.

The monitored wetlands generally performed as expected with respect to nitrate removal efficiency (percent removal) and mass nitrate removal (expressed as kg N ha^{-1} $year^{-1}$). Wetland performance is a function of hydraulic loading rate, hydraulic efficiency, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate and nitrate concentration are especially important for CREP wetlands. The range in hydraulic loading rates expected for CREP wetlands is significantly greater than would be expected based on just the four fold range in wetland/watershed area ratio approved for the Iowa CREP. In addition to spatial variation in precipitation (average precipitation declines from southeast to northwest across Iowa), there is tremendous annual variation in precipitation. The combined effect of these factors means that annual loading rates to CREP wetlands can be expected to vary by more than an order of magnitude, and will to a large extent determine nitrate loss rates for individual wetlands.

Mass balance modeling was used to estimate the variability in performance of CREP wetlands that would be expected due to spatial and temporal variability in temperature and precipitation patterns. The percent nitrate removal expected for CREP wetlands was estimated based on hindcast modeling over the 1980 through 2005 period (Figure 12). For comparison, percent nitrate removal measured for wetlands monitored during 2004 to 2012 illustrates reasonably good correspondence between observed and modeled performance. In Figure 12, the average hydraulic loading rate for observed wetlands was calculated to include only those days having inflow and hence, nitrate loading, to the wetland.

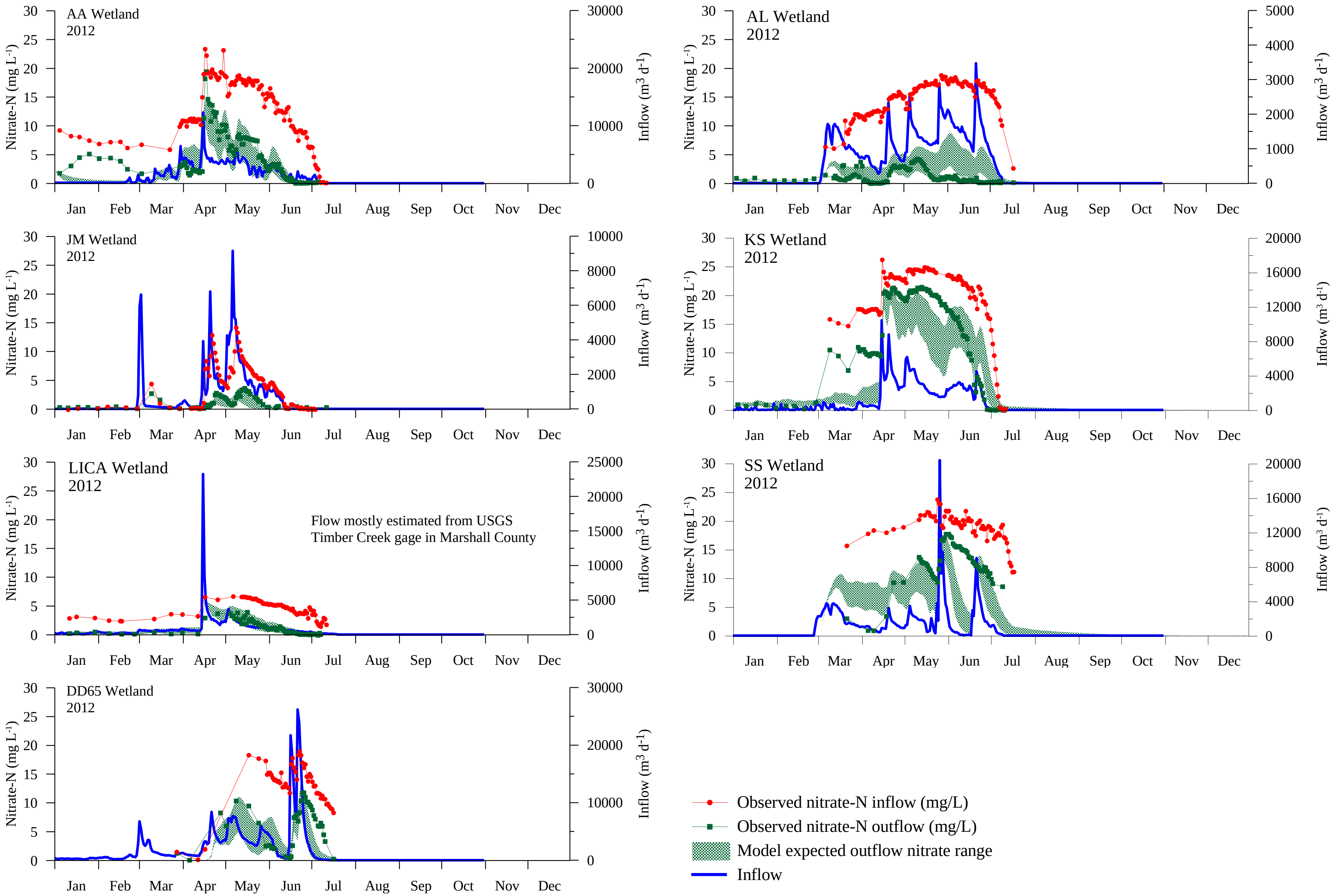

Figure 11. Measured and modeled nitrate concentrations and flows for wetlands monitored during 2012.

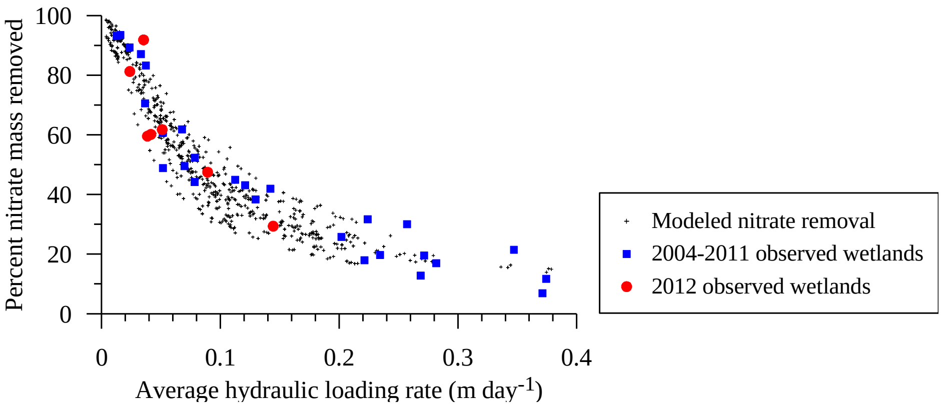

Figure 12. Modeled nitrate removal efficiencies for CREP wetlands based on 1980 to 2005 input conditions and measured nitrate removal efficiencies for CREP wetlands during 2004 to 2012.

Mass nitrate removal rates can vary considerably more than percent nitrate removal among wetlands receiving similar hydraulic loading rates. However, mass removal rates are predictable using models that integrate the effects of hydraulic loading rates, nitrate concentration, temperature, and wetland condition. Crumpton et al. (2006) developed and applied a model that explicitly incorporates hydraulic loading rate, nitrate concentration, and temperature to predict performance of US Corn Belt wetlands receiving nonpoint source nitrate loads. This analysis included comparisons for 38 “wetland years” of available data (12 wetlands with 1-9 years of data each) for sites in Ohio, Illinois, and Iowa, including four IA CREP wetlands (2 low load and 2 high load sites). The analysis demonstrated that the performance of wetlands representing a broad range of loading and loss rates can be reconciled by models explicitly incorporating hydraulic loading rates and nitrate concentrations (Crumpton et al. 2006, 2008). This model will be updated to include the 2004 to 2012 Iowa CREP wetlands and exclude wetlands smaller than the 2.5 acre minimum size required by Iowa CREP criteria.

References

Crumpton, W.G., G.A Stenback, B.A. Miller, and M.J. Helmers. 2006. Potential benefits of wetland filters for tile drainage systems: Impact on nitrate loads to Mississippi River subbasins. US Department of Agriculture, CSREES project completion report. Washington, D.C. USDA CSREES.

Crumpton, W.G., Kovacic, D., Hey, D., and Kostel, J., 2008. Potential of wetlands to reduce agricultural nutrient export to water resources in the Corn Belt. pp. 29-42 in Gulf Hypoxia and Local Water Quality Concerns Workshop, ASABE Pub #913C0308.

Outreach Activities

In addition to the evaluation that is taking place at the project sites in Gilmore City and Pekin we have an active outreach program associated with this project. This includes presentations at technical and Extension related meetings, field days, the Drainage Research Forum, and Extension and scientific publications. The activities and publications that are directly associated with the outreach component of this project are described below.

Events Organized

13th Annual IA-MN Drainage Research Forum
November 20, 2012 – Coordinated with Dr. Gary Sands from the University of Minnesota and Chris Hay from South Dakota State University the forum in Waseca, MN. There were 85 attendees consisting of producers, contractors, and agency representatives from Iowa and Minnesota.

Oral Presentations at Extension Related Meetings

December 6, 2012 – Presentation on “Gilmore City drainage water quality studies” to the Iowa State Soil Conservation Committee in Des Moines, IA (15 attendees)

October 16, 2012 – Presentation “Manure application to soybeans: Water quality impacts” to the Environmental Protection Commission (35 attendees)

September 4, 2012 – Presentation on “Water quality impacts of drainage water management” at Subirrigation Field Day near Paullina, IA (25 attendees)

June 26, 2012 – Presentation on “Impacts of drainage design on water quality and crop production” at Northern Iowa Research Farm Field Day near Kanawha, IA (120 attendees)

March 15, 2012 – Presentation on “Water quality impacts of drainage” at Drainage Workshop in LeMars, IA (25 attendees)

March 13, 2012 – Presentation on “Water quality impacts of drainage” at Drainage Workshop in Mason City, IA (15 attendees)

January 30, 2012 – Presentation on “Water quality impacts of drainage” at Drainage Workshop in New Hampton, IA (65 attendees)

January 9, 2012 – Presentation on “Subsurface drainage design” at the Iowa Land Improvement Contractors Annual Meeting in Des Moines, IA (125 attendees)

December 7, 2012 – Presentation on “Nutrient Reduction Strategy Science Assessment” at the Iowa Drainage District Association Annual Meeting in Fort Dodge, IA (75 attendees)

December 6, 2012 – Presentation on “Iowa Nutrient Reduction Strategy” at the Ag Chem Update in Ames, IA (125 attendees)

December 5, 2012 – Presentation on “Iowa Nutrient Reduction Strategy” at the Ag Chem Update in Iowa City, IA (120 attendees)

December 4, 2012 – Presentation on “Nutrient Reduction Strategy Science Assessment” at the Iowa Farm Bureau Annual Meeting in Des Moines, IA (120 attendees)

November 28, 2012 – Presentation on “Iowa Nutrient Reduction Strategy” at the Integrated Crop Management Conference in Ames, IA (300 attendees)

November 27, 2012 – Presentation on “Nutrient Reduction Strategy Science Assessment” to Extension Agricultural Engineering and Agronomy Field Specialists at Nevada, IA (20 attendees)

November 6, 2012 – Presentation on “Nutrient Reduction Strategy Science Assessment” for Manure Applicator Certification Training (video recording)

June 20, 2012 – Presentation on “Nutrient reduction strategy science assessment” to the Water Resources Coordinating Council in Des Moines, IA (30 attendees)

March 7, 2012 – Presentation on “Iowa Nutrient Reduction Science Assessment: Practice Performance, Scenarios, and Economics” at the Iowa Water Conference in Ames, IA (75 attendees)

Technical Papers (Peer-reviewed)

Helmers, M.J., R. Christianson, G. Brenneman, D. Lockett, and C. Pederson. 2012. Water table, drainage, and yield response to drainage water management in southeast Iowa. *Journal of Soil and Water Conservation* 67(6): 495-501.

Helmers, M.J., X. Xhou, J.L. Baker, S.W. Melvin, and D.W. Lemke. 2012. Nitrogen loss on tile-drained Mollisols as affected by nitrogen application rate under continuous corn and corn-soybean rotation systems. *Canadian Journal of Soil Science* 92: 493-499

Qi, Z., L. Ma, M.J. Helmers, L.R. Ahuja, and R.W. Malone. 2012. Simulating nitrate-nitrogen concentration from a subsurface drainage system in response to nitrogen application rates using RZWQM2. *Journal of Environmental Quality* 41: 289-295. [Short Communication]