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 2011 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.

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)

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.

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 2011 were completed in a timely manner prior to and during the crop season. Rye for 2011 was seeded on October 13, 2010. Fall fertilization was completed on November 29, 2010. Chisel plowing was performed on November 29, 2010. Seedbed preparation for corn and soybean was completed on May 9, 2011. Corn was seeded on May 10 and soybean was seeded on May 11. Urea and ESN were applied on May 6. Aqua-ammonia was applied on June 16. Rye cover crop in corn plots was sprayed to eliminate rye on May 2. Soybean rye cover crop plots were sprayed to eliminate rye on May 11. Corn was harvested on October 14-15, 2011 and soybean was harvested on October 6-7, 2011.

Weed Control

Round Up ready crops were used at the site. Establish herbicide was used for pre-plant weed control and was broadcast on May 18. Application of Buccaneer Plus was on June 24 for corn and soybean. Cultivation for weed control was not incorporated into the weed management system in 2011.

Precipitation

Precipitation was recorded by the weather station at the site. The total precipitation in 2011 was about 10.5” lower than normal (Table 2). Overall, the monthly precipitation in the first half year was close to normal while there was very limited precipitation in the second half year, much lower than normal.

Table 2. Precipitation in 2011 at the research site and comparisons to norms at local NOAA weather stations.

	mm	inches	Normal* inches
Jan	0.3	0.01	0.91
Feb	29.2	1.15	0.70
Mar	6.4	0.25	2.20
Apr	86.1	3.39	3.09
May	101.9	4.01	3.94
Jun	185.2	7.29	4.37
Jul	73.4	2.89	4.37
Aug	21.8	0.86	4.60
Sep	23.6	0.93	3.16
Oct	4.3	0.17	2.17
Nov	7.6	0.30	1.86
Dec	25.4	1.00	1.37
Total	565.2	22.25	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, 2011. Drainage started during this period and the first samples were collected on April 5th. Samples were collected on at least a weekly basis, and for most plots, drainage was sufficient for sampling through early July. Nearly all drainage ceased after the first week of July since little rain has been fallen after. Table 3 lists drainage volumes by treatment in 2011 with statistical differences at p=0.05. Twelve of the eighteen treatments had one of four replications removed due to erroneous (usually excessive) drainage volume values. All other replications were used in statistical analysis. The conventional tillage with late season sidedress treatment in the soybean year had the highest drainage while the fall nitrogen application with conventional tillage treatment had the lowest drainage (Table 3). Overall, a few statistical differences among treatments were noted for drainage in 2011 (LSD=6.7 inches). Average drainage for all treatments was 9.8 inches. With 19.84” of precipitation between April and November and using an overall drainage volume of 9.8”, approximately 49% of the precipitation became subsurface drainage (Table 4). June had more drainage than precipitation, likely caused by drainage delay from the previous month’s precipitation (see Table 4). The site was winterized on December 9, 2011.

Table 3. Subsurface drainage volumes with statistical differences at p=0.05, by treatment in 2011.

Treatment	Description	Drainage (inches)
1	CP-FA-150-S	8.6b
2	CP-FA-150-C	8.0b
3	CP-SPUREA-150-S	7.7b
4	CP-SPUREA-150-C	10.4ab
5	CP-SP-150-S	10.3ab
6	CP-SP-150-C	10.2ab
7	CP-rye-150-S	15.3a
8	CP-rye-150-C	9.6ab
9	NT-SP-150-S	9.3ab
10	NT-SP-150-C	8.5b
11	NT-rye-150-S	10.5ab
12	NT-rye-150-C	11.3ab
13	CP-SPPOLY-150-S	7.9b
14	CP-SPPOLY-150-C	9.5ab
15	CP-SIDEDRESS-150-S	10.2ab
16	CP-SIDEDRESS-150-C	10.0ab
17	Kura clover	8.4b
18	Orchardgrass + Red/Ladino clover	11.4ab
LSD		6.7
Average drainage		9.8
Standard deviation		1.8
Average for corn treatments		9.5
Average for soybean treatments		10.0

Table 4. Average drainage for each month over all treatments for April- November 2011.

month	precipitation	drainage
	------inches------	
April	3.39	3.4
May	4.01	2.4
June	7.29	8.2
July	2.89	2.5
August	0.86	0.1
September	0.93	0
October	0.17	0
November	0.30	0
Total	19.8	16.6

Nitrate Concentrations and Losses

Previous history of current plot treatments quite likely has influenced the nitrate-nitrogen concentrations observed during 2011. The highest nitrate concentrations in 2011 were recorded for the spring nitrogen application with conventional tillage treatment in the corn year and lowest 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 2.4 to 15.4 mg L^{-1}. Individual plot/replication, flow weighted averages ranged from 0.7 to 19.6 mg L^{-1} and were recorded within the aforementioned treatments. The spring nitrogen application had significantly higher NO_3-N concentrations than the fall application and the late season side-dress. Conventional tillage had significantly higher concentrations than no-till within the corn year but showed no significant difference within the soybean year. The nitrogen sources (aqua-ammonia, urea, and poly coated urea) did not exhibit any significantly different effects on NO_3-N concentrations for the soybean year, while aqua-ammonia treatment had significantly higher concentrations than other two nitrogen sources treatment for the corn year. Treatments of rye cover crop had significantly lower nitrate concentrations in both crops under conventional tillage than the comparable treatments without cover crop (treatments 5, 6), but showed no significant difference under no-till. 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 2011 with statistical significance at p=0.05.

Treatment	Description	nitrate N (mg/L)
1	CP-FA-150-S	10.1bcde
2	CP-FA-150-C	11.4bcd
3	CP-SPUREA-150-S	12.1abc
4	CP-SPUREA-150-C	11.7bcd
5	CP-SP-150-S	12.7ab
6	CP-SP-150-C	15.4a
7	CP-rye-150-S	9.3cde
8	CP-rye-150-C	8.4de
9	NT-SP-150-S	11.1bcd
10	NT-SP-150-C	7.4e
11	NT-rye-150-S	8.9cde
12	NT-rye-150-C	8.8cde
13	CP-SPPOLY-150-S	10.6bcde
14	CP-SPPOLY-150-C	11.5bcd
15	CP-SIDEDRESS-150-S	12.1abc
16	CP-SIDEDRESS-150-C	9.2cde
17	Kura clover	8.3de
18	Orchardgrass + Red/Ladino clover	2.4f
	LSD	3.4

Table 6 lists NO_3-N losses by treatment in 2011. 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. Losses in 2011 ranged from 8.1 to 34.8 lbs NO_3-N for the orchardgrass/clover treatment and the spring nitrogen application with conventional tillage treatment in the corn year of the rotation, respectively (N applied on May 6-June 16, 2011 in the corn year). All statistical comparisons are listed in Table **Error! Reference source not found.**6.

Table 6. Average annual flow-weighted nitrate losses by treatment in 2011 with statistical significance at p=0.05.

Treatment	Description	nitrate-N (lbs/acre)
1	CP-FA-150-S	18.5bc
2	CP-FA-150-C	17.7bc
3	CP-SPUREA-150-S	20.8abc
4	CP-SPUREA-150-C	25.7ab
5	CP-SP-150-S	29.7ab
6	CP-SP-150-C	34.8a
7	CP-rye-150-S	30.9ab
8	CP-rye-150-C	17.0bc
9	NT-SP-150-S	21.7abc
10	NT-SP-150-C	18.6bc
11	NT-rye-150-S	21.1abc
12	NT-rye-150-C	21.6abc
13	CP-SPPOLY-150-S	19.9abc
14	CP-SPPOLY-150-C	23.5abc
15	CP-SIDEDRESS-150-S	26.4ab
16	CP-SIDEDRESS-150-C	19.8abc
17	Kura clover	15.4bc
18	Orchardgrass + Red/Ladino clover	8.1c
	LSD	15.5

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 2011 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 5.4-42.4 µg L^{-1} (Table 7). The conventional tillage with rye cover crop had significantly higher TRP concentrations and annual loss than most of other treatments.

Table 7. Average annual flow-weighted TRP concentrations by treatment in 2011 with statistical significance at p=0.05.

Treatment	Description	TRP (ug/L)
1	CP-FA-150-S	14.2ab
2	CP-FA-150-C	22.6ab
3	CP-SPUREA-150-S	7.4b
4	CP-SPUREA-150-C	15.3ab
5	CP-SP-150-S	8.4b
6	CP-SP-150-C	11.6b
7	CP-rye-150-S	9.2b
8	CP-rye-150-C	42.4a
9	NT-SP-150-S	7.1b
10	NT-SP-150-C	7.3b
11	NT-rye-150-S	8.3b
12	NT-rye-150-C	8.8b
13	CP-SPPOLY-150-S	33.3ab
14	CP-SPPOLY-150-C	9.3b
15	CP-SIDEDRESS-150-S	5.4b
16	CP-SIDEDRESS-150-C	9.1b
17	Kura clover	7.7b
18	Orchardgrass + Red/Ladino clover	6.0b
	LSD	28.3

Table 8. Average annual flow-weighted TRP losses by treatment in 2011 with statistical significance at p=0.05.

Treatment	Description	TRP (g/acre)
1	CP-FA-150-S	14.4b
2	CP-FA-150-C	10.0b
3	CP-SPUREA-150-S	5.5b
4	CP-SPUREA-150-C	14.2b
5	CP-SP-150-S	7.8b
6	CP-SP-150-C	12.4b
7	CP-rye-150-S	17.5b
8	CP-rye-150-C	61.5a
9	NT-SP-150-S	6.0b
10	NT-SP-150-C	8.5b
11	NT-rye-150-S	9.0b
12	NT-rye-150-C	9.8b
13	CP-SPPOLY-150-S	33.4ab
14	CP-SPPOLY-150-C	9.1b
15	CP-SIDEDRESS-150-S	5.2b
16	CP-SIDEDRESS-150-C	7.5b
17	Kura clover	7.2b
18	Orchardgrass + Red/Ladino clover	6.7b
	LSD	39.5

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 28. 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 urea or poly coated urea as nitrogen source treatments were in the optimal range, all other treatments were in the marginal to low range.

Table 9. Stalk nitrate test concentrations in 2011.

Treatment	Description	nitrate-N* (mg/L)
2	CP-FA-150-C	199
4	CP-SPUREA-150-C	1092
6	CP-SP-150-C	671
8	CP-rye-150-C	623
10	NT-SP-150-C	614
12	NT-rye-150-C	411
14	CP-SPPOLY-150-C	1146
16	CP-SIDEDRESS-150-C	225
17	Kura	424

* 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 might be impacted by the extended drought starting from July. Excluding the kura clover treatment, corn yields of each treatment in 2011 ranged from 150 to 180 bu/acre (Table 10). The highest corn yield was for the spring nitrogen application with conventional tillage treatment while the lowest corn yield was for the fall nitrogen application with conventional tillage treatment. Soybean yields ranged from 37-45 bu/acre (Table 11). The conventional tillage with fall nitrogen application and the conventional tillage with poly coated urea as nitrogen source treatments had significantly higher soybean yields than the no-till treatments.

Table 10. Corn yield by treatment in 2011 with statistical significance at p=0.05.

Treatment	Description	yield (bu/acre)
2	CP-FA-150-C	161abc
4	CP-SPUREA-150-C	175ab
6	CP-SP-150-C	180a
8	CP-rye-150-C	150c
10	NT-SP-150-C	159abc
12	NT-rye-150-C	154bc
14	CP-SPPOLY-150-C	177ab
16	CP-SIDEDRESS-150-C	168abc
17	Kura	64d
	LSD	25

Table 11. Soybean yield by treatment in 2011 with statistical significance at p=0.05.

Treatment	Description	yield (bu/acre)
1	CP-FA-150-S	45a
3	CP-SPUREA-150-S	42abc
5	CP-SP-150-S	42abc
7	CP-rye-150-S	42abc
9	NT-SP-150-S	37c
11	NT-rye-150-S	37bc
13	CP-SPPOLY-150-S	45a
15	CP-SIDEDRESS-150-S	43ab
	LSD	7

Summary

The total precipitation in 2011 was about 10.5” lower than normal (Table 2). Overall, the monthly precipitation in the first half year was close to normal while there was very limited precipitation in the second half year, much lower than normal.

Overall, a few statistical differences among treatments were noted for drainage in 2011. The conventional tillage with late season sidedress treatment in the soybean year had the highest drainage while the fall nitrogen application with conventional tillage treatment had the lowest drainage. Average drainage for all treatments was 16.6”. Approximately 49% of the precipitation became subsurface drainage between April 1 and November 29.

The highest nitrate concentrations in 2011 were recorded for spring nitrogen application with conventional tillage treatment which had corn in 2011 and lowest were found in the perennial systems, specifically the orchardgrass/clover treatment; all other values were between these treatments values. Annual flow-weighted nitrate concentrations ranged from 2.4 to 15.4 mg L^{-1}. Individual plot/replication, flow weighted averages ranged from 0.7 to 19.6 mg L^{-1} and were recorded within the aforementioned treatments. The spring nitrogen application had significantly higher NO_3-N concentrations than the fall application and the late season side-dress. Conventional tillage had significantly higher concentrations than no-till within the corn year but showed no significant difference within the soybean year. The nitrogen sources (aqua-ammonia, urea, and poly coated urea) did not exhibit any significantly different effects on NO_3-N concentrations for the soybean year, while aqua-ammonia treatment had significantly higher concentrations than other two nitrogen sources treatment for the corn year. Treatments of rye cover crop had significantly lower nitrate concentrations in both crops under conventional tillage than the comparable treatments without cover crop, but showed no significant difference under no-till. Nitrate losses in 2011 ranged from 8.1 to 34.8 lbs NO_3-N for the orchardgrass/clover treatment and the spring nitrogen application with conventional tillage treatment in the corn year of the rotation, respectively.

Overall, the levels of phosphorus leaving the plots and limits were low, ranging from 5.4-42.4 µg L^{-1}. The conventional tillage with rye cover crop had significantly higher TRP concentrations and annual loss than most of other treatments.

During 2011 the corn and soybean yields were likely impacted by the extended drought starting from mid-July. Excluding the kura clover treatment, corn yields of each treatment in 2011 ranged from 150 to 180 bu/acre. The highest corn yield was for the spring nitrogen application with conventional tillage treatment while the lowest corn yield was for the fall nitrogen application with conventional tillage treatment. Soybean yields ranged from 37-45 bu/acre. The conventional tillage with fall nitrogen application and the conventional tillage with poly coated urea as nitrogen source treatments had significantly higher soybean yields than the no-till treatments.

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 in 2011 was 33.6 inches which is slightly below the historical average of 35.9 inches (Figure 1). Overall, 48% of precipitation became conventional subsurface drainage. The shallow drainage system drainage volume yielded substantially less with 3% of precipitation. The controlled drainage system was reduced to 24% of precipitation. Respectively, drainage volumes were 8.3, 8.1, and 1.0 inches for each of the three systems (Figure 2). The outlets on control drainage plots were lowered to 48" below the ground surface from March 24 through July 19 and September 18 through December 7. It should be noted that the outlets on controlled drainage plots were lowered somewhat late in the spring compared to the previous years, which might in part cause a similar drainage volume for the controlled drainage as the conventional drainage in 2011.

Nitrate-Nitrogen Concentrations

Water samples were collected from late March to early July in 2011. Listed in Table 12 are flow-weighted NO_3-N concentrations for all treatments for all monitoring years. NO_3-N concentrations between treatments were very similar, ranging from 4.41 to 5.95 mg/L, which are lower than the values in previous years. 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, only one sample was taken for effluent drainage for the shallow management scheme in 2011.

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 142, 131, and 143 bu/acre for the controlled, conventional, and shallow drainage fields, respectively (Figure 5).

Soybean yields in 2011 were comparable to previous years with 35, 35 and 37 bu/ac for the controlled, conventional, and shallow drainage fields, respectively (Figure 6).

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 13. 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). All treatments were in the low range, suggesting more N could be used in the next year.

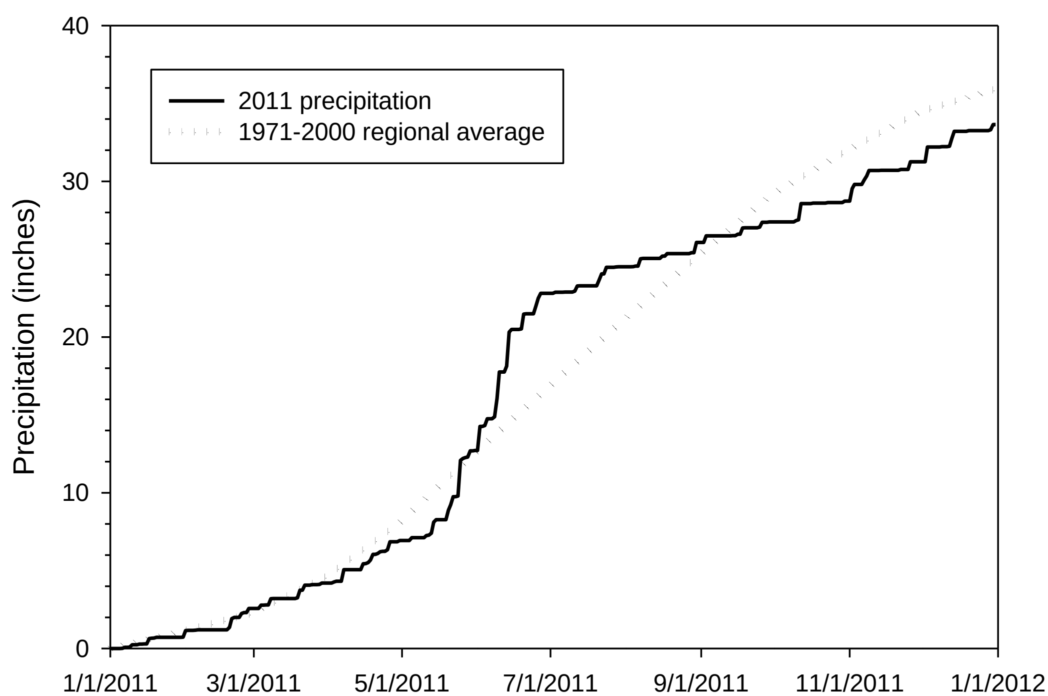

Figure 1. Precipitation in 2011 compared to the 30-year regional average.

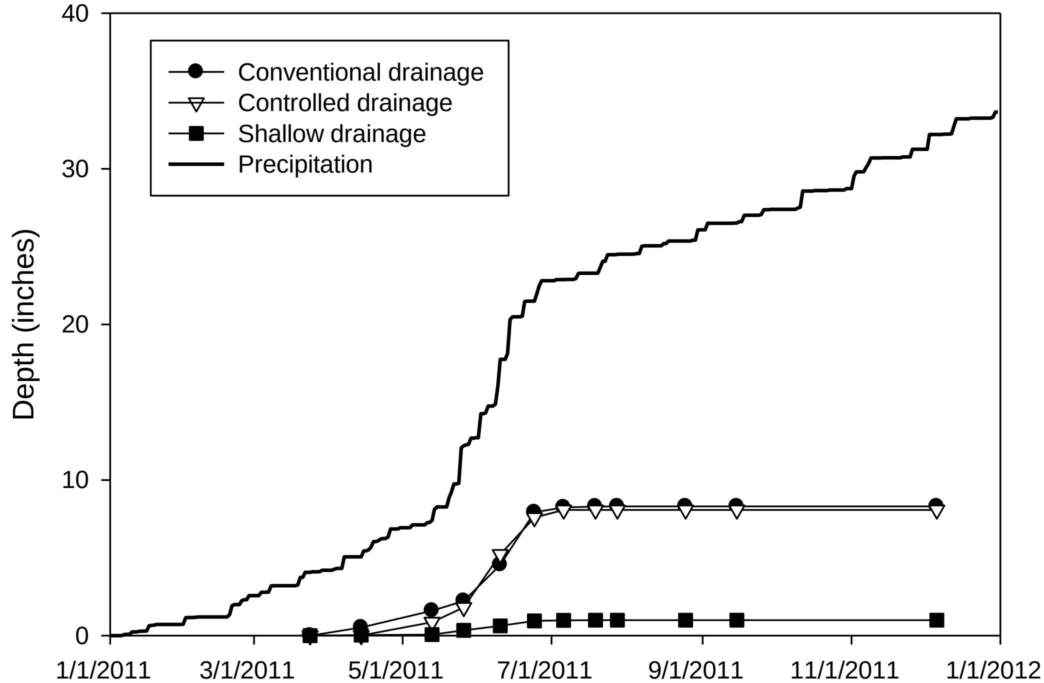

Figure 2. Precipitation and subsurface drainage at the Pekin site in 2011.

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

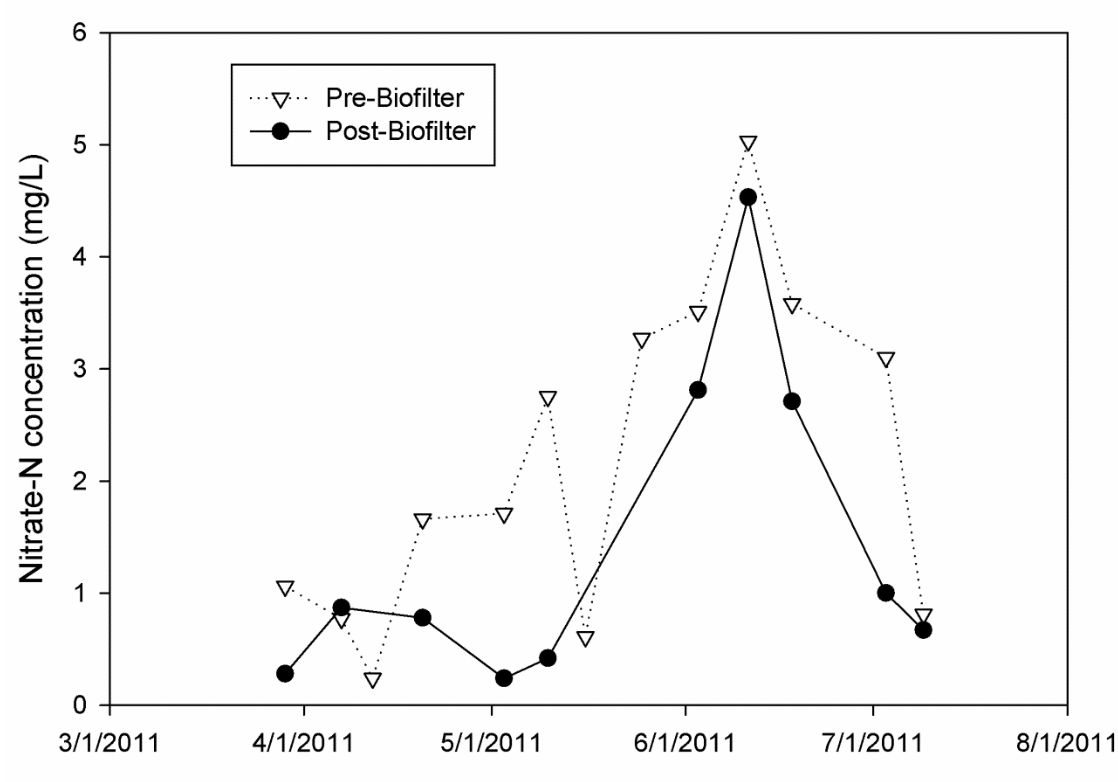

Figure 3. 2011 Conventional drainage bio-filter nitrate data.

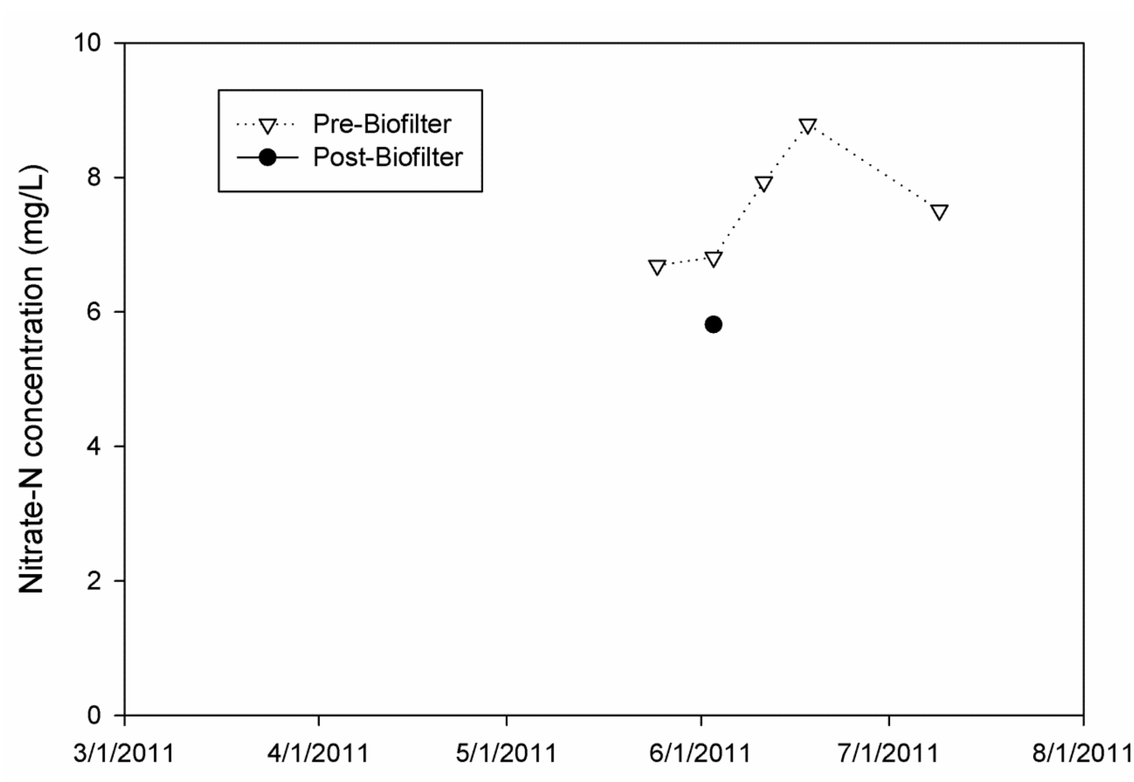

Figure 4. 2011 Shallow drainage bio-filter nitrate data.

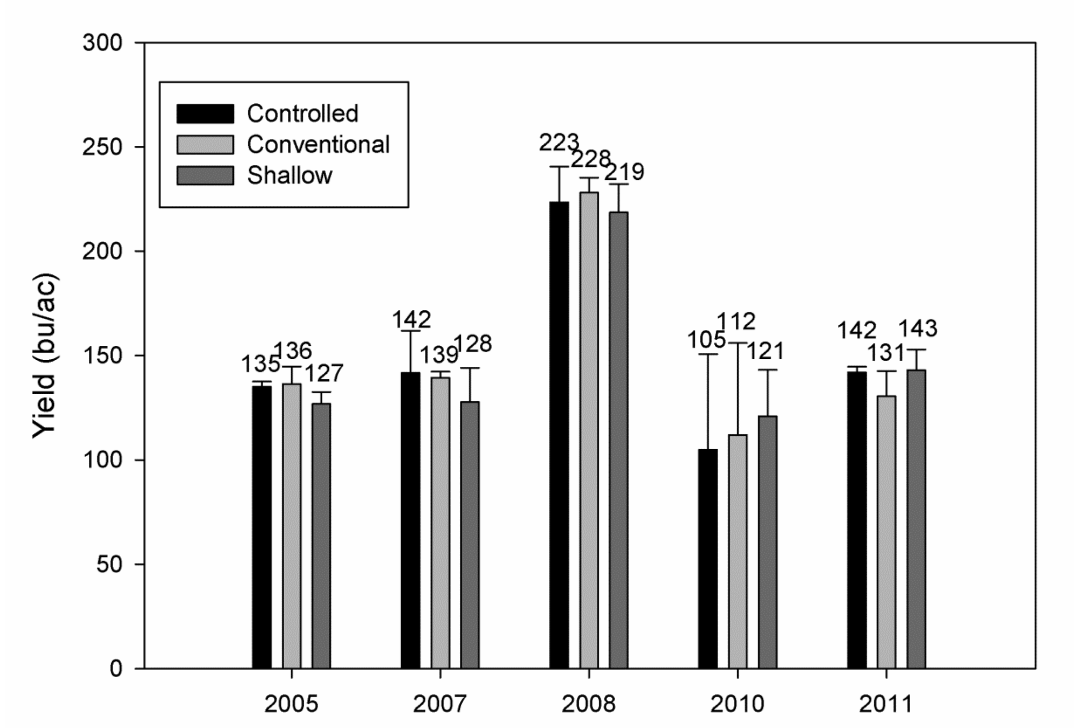

Figure 5. Corn yields at the Pekin site.

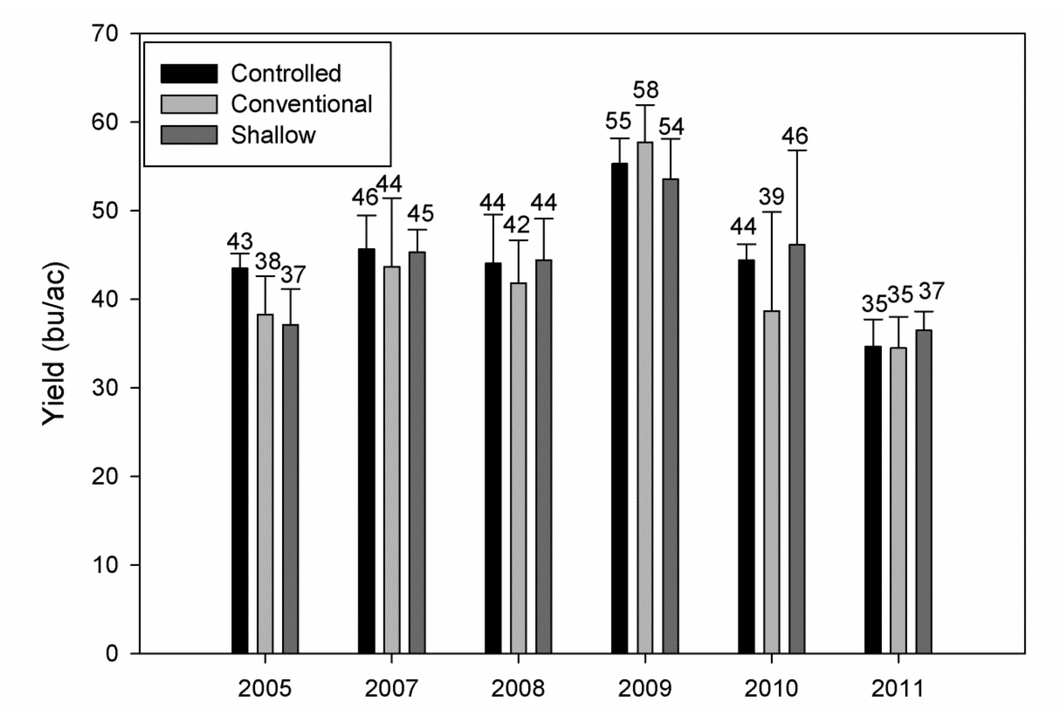

Figure 6. Soybean yields at the Pekin site.

Table 13. Stalk nitrate test concentrations in 2011.

Treatment	nitrate-N* (mg/L)
Conventional drainage	<20
Controlled drainage	<20
Shallow drainage	45

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

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 2011 Monitoring

Five wetlands were monitored for the Iowa CREP during 2011 (Figure 7). These include AA, AL, JM, KS, and LICA wetlands. AA, AL, JM, and KS wetland monitoring included wetland inflow and/or outflow measurements, wetland pool elevation and 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 when temperatures were sufficiently above freezing to allow water to be pumped through tubing by the automated equipment. Grab samples were collected throughout the year during approximately weekly site visits at inflow and outflow locations and daily auto-samples were collected from about mid to late March through mid November. Inflow and outflow ceased during August at each wetland. Weekly to bi-monthly grab samples were collected at the LICA wetland. All water samples were assayed for nitrate-N concentration.

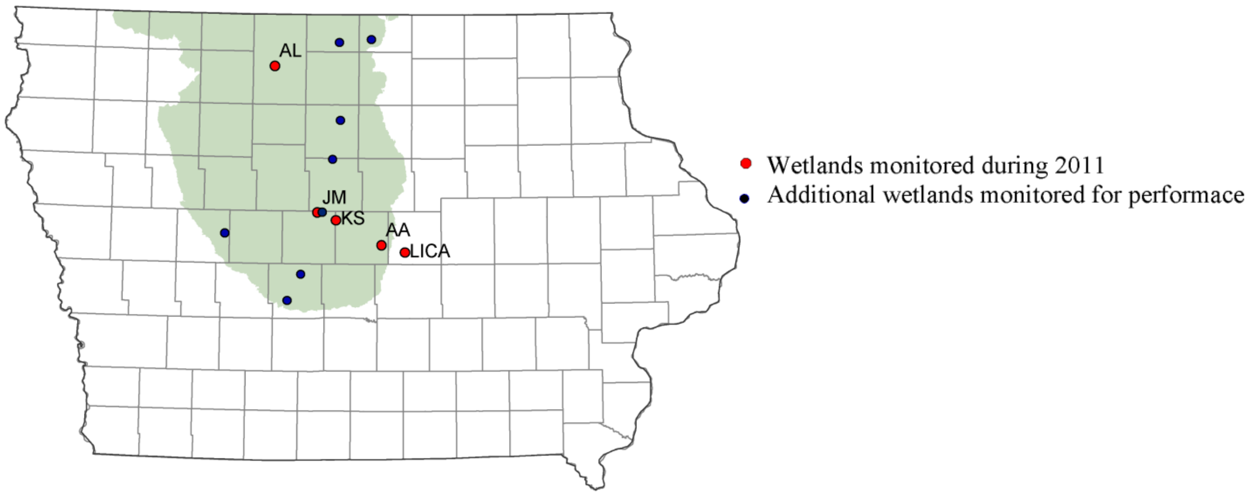

Figure 7. Wetlands monitored during 2011 and wetlands monitored during prior years and utilized for performance evaluation (see Figure 9).

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 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. 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. Depending on the stream width and depth, one manual discharge measurement takes about five to forty minutes to complete and provides an accurate measure of discharge at a known stream depth and time.

Wetland bathymetry data were used to characterize wetland volume and area as functions of wetland depth. These relationships were used in numeric modeling of water budgets and nitrate mass balances to estimate nitrate loss. 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 moderate to high during the winter, but flow is generally low so that mass loading is typically low during the winter (Figure 8). The spring melt often results in a high flow event during February or March but nitrate concentrations in the melt water and associated surface runoff are typically low. Nitrate concentrations increase to their highest levels during high flow periods in spring and early summer, may decline with declining flow in mid to late summer, and generally increase again if there is increased flow during late summer or fall. 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. 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 8. In addition, Figure 8 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling using 2011 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 9). For comparison, percent nitrate removal measured for wetlands monitored during 2004 to 2011 illustrates reasonably good correspondence between observed and modeled performance. (Figure 3 differs from presentations in prior reports because the average hydraulic loading rate for observed wetlands was recalculated to include only those days having inflow (and hence, nitrate loading) to the wetland.) The percent nitrate removal and corresponding hydraulic loading are determined for the period of record having daily sample concentrations. Because discharge was not measured and daily samples were not collected at the LICA wetland, the percent removal for that site is not shown in Figure 3. However, on the basis of weekly grab sample concentration data and estimated water yield, this wetland appears to have about 22% nitrate removal efficiency.

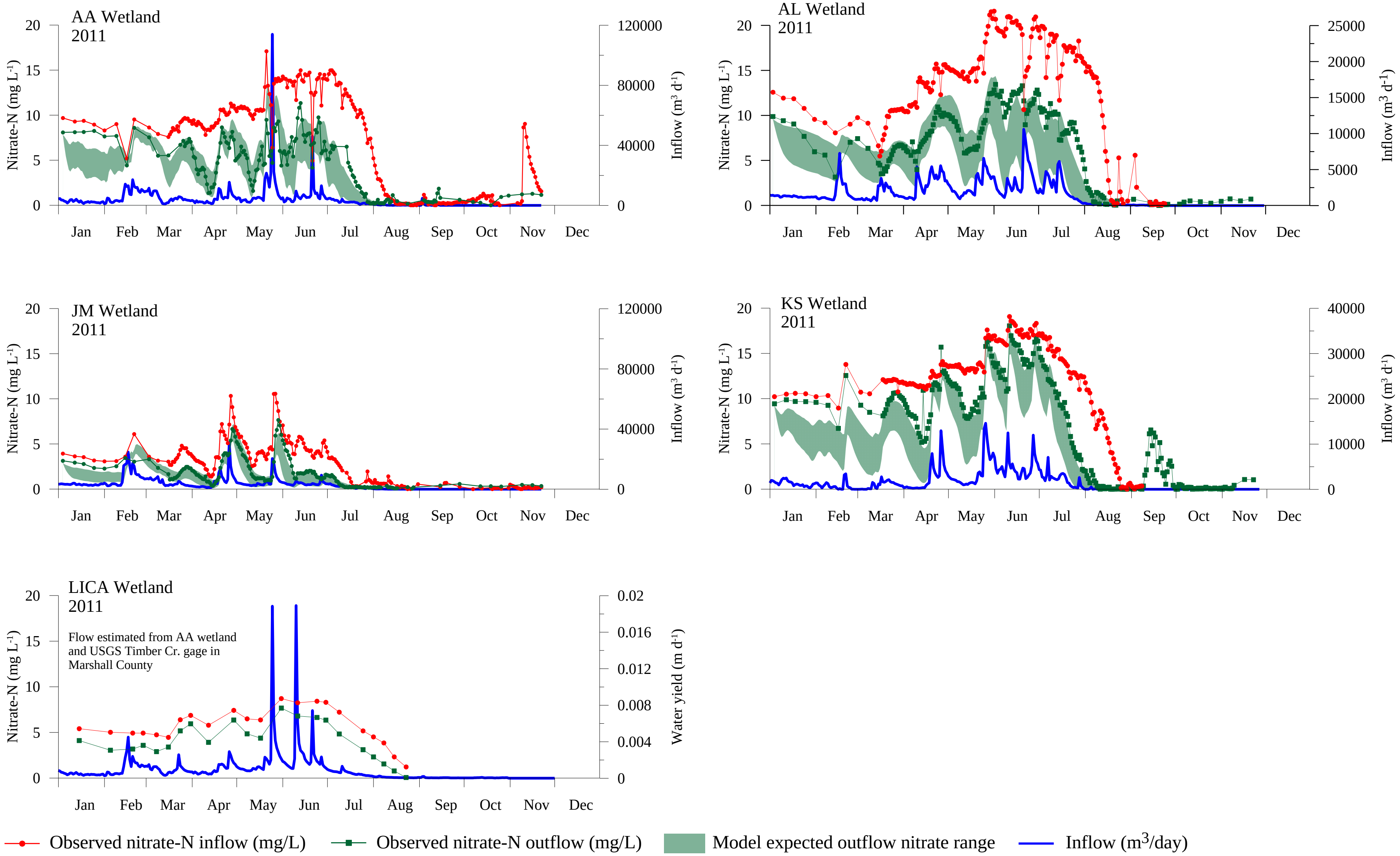

Figure 8. Measured and modeled nitrate concentrations and flows for wetlands monitored during 2011.

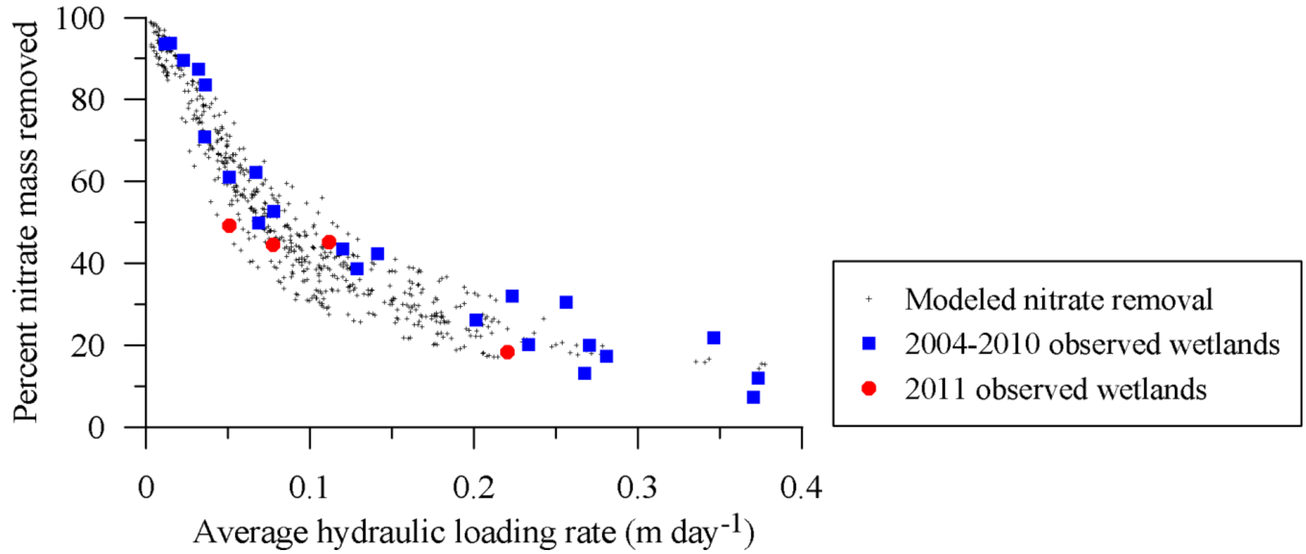

Figure 9. Modeled nitrate removal efficiencies for CREP wetlands based on 1980 to 2005 input conditions and measured nitrate removal efficiencies for CREP wetlands during 2004 to 2011.

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 2011 Iowa CREP wetlands and exclude wetlands smaller than the 2.5 acre minimum size required by Iowa CREP criteria.

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

12th Annual IA-MN Drainage Research Forum
November 22, 2011 – Coordinated with Dr. Gary Sands from the University of Minnesota and Chris Hay from South Dakota State University the forum in Spirit Lake, IA. There were 95 attendees consisting of producers, contractors, and agency representatives from Iowa and Minnesota.

Oral Presentations at Extension Related Meetings

December 15, 2011 – Presentation on "Water quality impacts of drainage" at Drainage Workshop in Iowa Falls, IA (55 attendees)

November 30, 2011 – Presentation on "Nitrate loss in subsurface drainage as affected by nitrogen application rate and timing under a corn-soybean rotation system" at the Integrated Crop Management Conference in Ames, IA (250 attendees)

June 29, 2011 – Presentation on "Tile and field drainage issues" at the Northeast Iowa Research and Demonstration Farm Field Day (135 attendees)

June 22, 2011 – Presentation on "Water quality impacts of land use" at the Ag-Based Renewable Energy Workshop near Ames, IA (35 attendees)

April 20, 2011 – Presentation on "Nitrogen management and water quality" as part of the Iowa Learning Farms conservation webinar (209 views of the webinar)

March 17, 2011 – Presentation on "Water quality impacts of drainage" at Drainage Workshop in Pomeroy, IA (35 attendees)

March 16, 2011 – Presentation on "Water quality impacts of drainage" at Drainage Workshop in Garner, IA (40 attendees)

March 10, 2011 – Presentation on "Water quality impacts of drainage" at Drainage Workshop in Paullina, IA (15 attendees)

February 11, 2011 – Presentation on "Farmland drainage issues and system layouts" at the North Central Iowa Crop and Land Stewardship Clinic in Iowa Falls, IA (75 attendees)

February 8, 2011 – Presentation on "Impacts of subsurface drainage in crop production" at the Pioneer North America Production Agronomy Conference in Johnston, IA (150 attendees)

February 8, 2011 – Presentation on "Subsurface drainage design considering crop production and the environment" at the Agribusiness Association of Iowa Annual Conference in Des Moines, IA (50 attendees)

January 25, 2011 – Presentation on "Arguments for and against drainage" at Crop Advantage Series Meeting in Carroll, IA (65 attendees)

January 18, 2011 – Presentation on "Drainage research results" at Crop Advantage Series Meeting in Storm Lake, IA (40 attendees)

January 12, 2011 – Presentation on "Farm drainage research" at Crop Advantage Series Meeting in Mason City, IA (125 attendees)

Technical Papers (Peer-reviewed)

Lawlor, P.A., M.J. Helmers, J.L. Baker, S.W. Melvin, and D.W. Lemke. 2011. Comparison of liquid swine manure and ammonia nitrogen application timing on subsurface drainage water quality in Iowa. *Trans. ASABE* 54(3): 973-981.

Qi, Z., M. J. Helmers, R. Malone, and K. Thorp. 2011. Simulating long-term impacts of winter rye cover crop on hydrologic cycling and nitrogen dynamics for a corn-soybean crop system. *Trans. ASABE* 54(5): 1575-1588.

Qi, Z., M.J. Helmers, R.D. Christianson, and C.H. Pederson. 2011. Nitrate-nitrogen losses through subsurface drainage under various agricultural land covers. *Journal of Environmental Quality* 40: 1578-1585.

Qi, Z., M. J. Helmers, and A. Kaleita. 2011. Soil water dynamics under various land covers in Iowa. *Agricultural Water Management* 98(4): 665-674.

Technical Papers, Conference Papers, and Extension Related Publications

Helmers, M.J., R. Christianson, and J. Sawyer. 2011. Nitrate loss in subsurface drainage as affected by nitrogen application rate and timing under a corn-soybean rotation system. *In:* Proceedings of the 23rd Annual Integrated Crop Management Conference (November 30 and December 1, Iowa State University, Ames, IA), pp. 123-128. [Oral Presentation - Helmers]

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.