Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen to the Mississippi River Basin

Matt Helmers

Department of Agricultural and Biosystems Engineering, Iowa State University

Why? And why now?

- Iowa's productive soils and cropping systems also contribute to water quality concerns
- Society and EPA expect more from cities, industry and agriculture
- Gulf Hypoxia Task Force requires plan to reduce N and P load to Gulf by 45%
- EPA requests strategy that emphasizes state implementation of new and existing N and P practices for point and non-point sources

Nutrient Reduction Strategy – Science Team

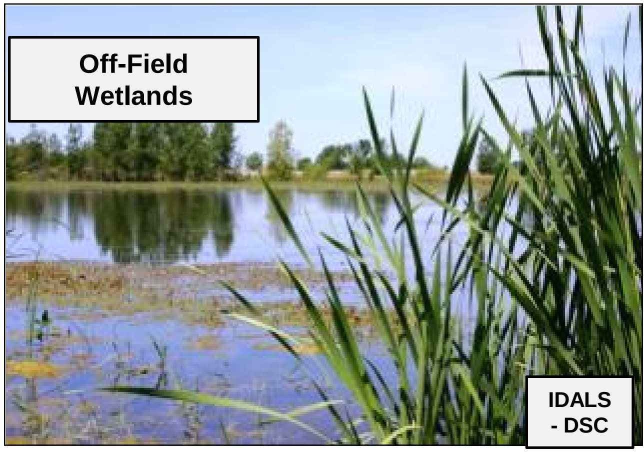
- Matt Helmers – ISU – N Team Lead
- Tom Isenhart – ISU – P Team Lead
- John Lawrence – ISU
- John Sawyer – ISU
- Antonio Mallarino – ISU
- William Crumpton – ISU
- Rick Cruse – ISU
- Mike Duffy – ISU
- Reid Christianson – ISU
- Phil Gassman – ISU
- Dean Lemke – IDALS
- Shawn Richmond – IDALS
- Jim Baker – IDALS/ISU
- Keith Schilling – IDNR
- Calvin Wolter – IDNR
- Dan Jaynes – USDA-ARS
- Mark Tomer – USDA-ARS
- John Kovar – USDA-ARS
- David James – USDA-ARS
- Eric Hurley – USDA-NRCS
- *Mark David – Univ. of Illinois*
- *Gyles Randall – Univ. of Mn*
- *Katie Flahive - USEPA*

Approach

1. Establish baseline – existing conditions
   - Major Land Resource Areas used to aggregate conditions
2. Extensive literature review to assess potential performance of practices
   - Outside peer review of science team documents (practice performance and baseline conditions)
3. Estimate potential load reductions of implementing nutrient reduction practices (scenarios)
   - “Full implementation” and “Combined” scenarios
4. Estimate cost of implementation and cost per pound of nitrogen and phosphorus reduction

Approach

- The N evaluation primarily focused on practices that limit or control nitrate-N losses from agricultural land.



Off-Field Wetlands

IDALS - DSC

Winter Cover Crops

Off-Field Bioreactors

Iowa NRCS

Nitrogen or Phosphorus?

Nitrogen moves primarily as nitrate-N with water

Phosphorus moves primarily with eroded soil

Practice Review Process

- Established an overall list of potential practices based on input of overall science team
- Shortened the list through detailed discussion of N team to those expected to have greatest potential for nutrient reduction and for which there was water quality data – reviewed by overall science team
- New and emerging practices could be added in future

Nitrogen Reduction Strategies Considered

- Row crop of choice (C/S vs CC)
- Nitrogen application rate
- Nitrogen source – manure or commercial
- Timing of nitrogen application
- Use of nitrogen stabilizers
- Cover crops (rye/oat)
- Living mulches (e.g. kura clover)
- Extended rotations
- Perennial cover/Perennial biomass crops/Grazed pastures
- Drainage water management
- Shallow drainage
- Wetlands Bioreactors
- Buffers

Nitrogen Reduction Strategies Not Considered – Lack of data or limited impact

- Green manure
- Continuous soybean
- Tillage and residue management
- Erosion control practices and structures
- Nitrogen source
- New nitrogen stabilizers (e.g., time release nitrogen)
- Placement of nitrogen
- Two-stage ditches
- Interaction of nutrient management practices
- Re-saturated buffers

Nitrogen Reduction Practices

	Practice	% Nitrate-N Reduction [Average (Std. Dev.)]	% Corn Yield Change
Nitrogen Management	Timing (Fall to spring)	6 (25)	4 (16)
	Nitrogen Application Rate	Depends on starting point	
	Nitrification Inhibitor	9 (19)	6 (22)
	Cover Crops (Rye)	31 (29)	-6 (7)
Land Use	Perennial – Land retirement	85 (9)	
	Perennial – Energy Crops	72 (23)	
	Extended Rotations	42 (12)	7 (7)
Edge-of-Field	Drainage Water Mgmt.	33 (32)*	
	Shallow Drainage	32 (15)*	
	Wetlands	52	
	Bioreactors	43 (21)	
	Buffers	91 (20)**	

*Load reduction not concentration reduction

**Concentration reduction of that water interacts with active zone below the buffer

Nitrogen Reduction Scenarios

	Practice/Scenario	Nitrate-N Reduction	Cost of N Reduction	Total Equal Annualized Cost
		% (from baseline)	($/lb)	(million $/yr)
Nitrogen Management	Baseline			
	Cover crops (rye) on ALL CS and CC acres	28	5.96	1,025
	Reducing nitrogen application rate from background to the MRTN 133 lb N/ac on CB and to 190 lb N/ac on CC (in MLRAs where rates are higher than this)	9	-0.58	-32
	Sidedress all spring applied N	4	0.00	0
	Using a nitrification inhibitor with all fall applied fertilizer	1	-1.53	-6
	Moving fall anhydrous fertilizer application to spring preplant	0.1	-74.36	-149

Target Load Reduction from NPS for Hypoxia Goal ~41%

Nitrogen Reduction Scenarios

	Practice/Scenario	Nitrate-N Reduction	Cost of N Reduction	Total Equal Annualized Cost
		% (from baseline)	($/lb)	(million $/yr)
Edge-of-Field	Baseline			
	Installing wetlands to treat 45% of the ag acres	22	1.38	191
	Installing denitrification bioreactors on all tile drained acres	18	0.92	101
	Installing Buffers on all applicable lands	7	1.91	88
	Installing Controlled Drainage on all applicable acres	2	1.29	18

Target Load Reduction from NPS for Hypoxia Goal ~41%

Nitrogen Reduction Scenarios

	Practice/Scenario	Nitrate-N Reduction	Cost of N Reduction	Total Equal Annualized Cost
		% (from baseline)	($/lb)	(million $/yr)
Land Use Changes	Baseline			
	Perennial crops (Energy crops) on ~6.5 million acres	18	21.46	2,318
	Pasture and Land Retirement on ~1.9 million acres	7	9.12	365
	Extended rotation on ~1.9 million acres	3	2.70	54

Target Load Reduction from NPS for Hypoxia Goal ~41%

Example Combination Scenarios that Achieve N and P Goal From NPS

		N	P	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
Name	**Combined Scenario**	**% Reduction from baseline**				
NCS1	MRTN Rate, 60% Acreage with Cover Crop, 27% of ag land treated with wetland and 60% of drained land has bioreactor	42	30	3,218	756	36
NCS3	MRTN Rate, 95% of acreage in all MLRAs with Cover Crops, 34% of ag land in MLRA 103 and 104 treated with wetland, and 5% land retirement in all MLRAs	42	50	1,222	1,214	58

Future Needs

- Nitrogen and Phosphorus Teams identified many future research needs on new and emerging practices for nutrient reduction
- There is a need for monetizing economic benefits that might be derived from improved water quality or other ecosystems services. These could be compared to the cost of nutrient reduction practice implementation.
- To assess potential landscape-scale changes, there is a need for better tracking of practices currently in place and put in place in the future, including but not limited to land use, crop rotations, nutrient applications, tillage, and conservation practices.

Summary

- Process has identified practices that have greatest potential for nitrate-N load reduction
- Process has estimated potential field-level costs associated with practice implementation
- To achieve goals will require a combination of practices
- N versus P requires different practices
- Multiple benefits of practices will need to be considered
- *Knowing the starting point is still a challenge and knowing what is being done on the land could (would) improve estimates of progress that can be made*

Session This Afternoon

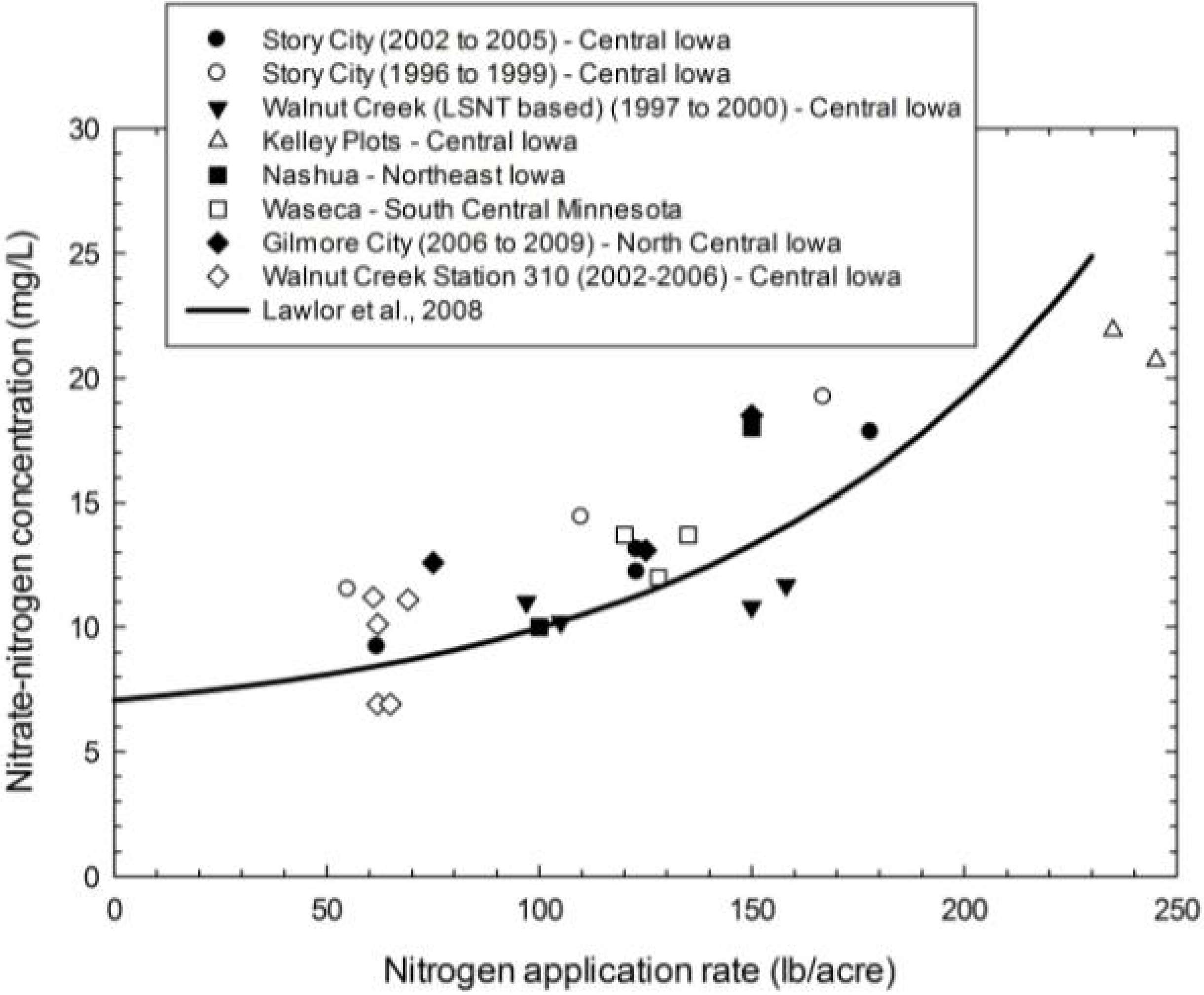
- New Technologies for In-Field Nitrogen Management - John Sawyer
- Drainage Water Management and Shallow Drainage: How Can It Help? – Randy Hoyt
- Re-saturating Riparian Buffers in Tile-Drained Landscapes to Reduce Nitrate Loading to Streams – Dan Jaynes
- Practical Aspects of Woodchip Bioreactors for Edge-of-Field Nitrate Reductions – Keegan Kult

DISCUSSION

Nitrogen Application Rate

Practice	**Comments**	**% Nitrate-N Reduction^{+}**			**% Corn Yield Change**
		Min	Average (SD)	Max	Average (SD)
Nitrogen Application Rate	Reduce to Maximum Return to Nitrogen value 133 lb N/ac for CS and 190 lb N/ac for CC	0	10	27	-1

Nitrogen Rate

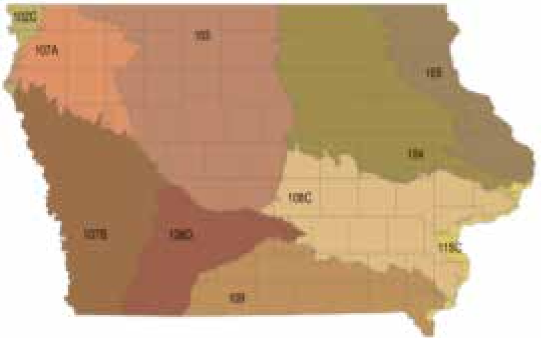


- This practice involves reducing nitrogen application rate to the Maximum Return to Nitrogen (MRTN) rate, which is 133 lb/ac for corn-soybeans and 190 lb/ac for continuous corn @ $5/bu corn and $0.50/lb N
- *Still Questions on Starting Point*

Estimated Nitrogen Application Rate – Manure + Fertilizer (2008 Estimates)

	Rate on CB	**Rate on CC**
MLRA	lb N/ac	lb N/ac
102C	182	232
103	154	204
104	144	194
105	131	181
107A	184	234
107B	139	189
108C	163	213
108D	120	170
109	142	192
115C	146	196
Iowa Total	151	201

Maximum return to nitrogen from corn following soybean with $5/bushel corn and $0.5/lb of N = 133 lb-N/acre (190 lb-N/acre for CC)



Impact of Crop and Fertilizer Price on MRTN

Corn Price ($/bu)	Fertilizer Price ($/lb)	Price Ratio	MRTN for Corn following Soybean (lb-N/acre)	Profitable Range (lb-N/acre)
5.00	0.5	0.10	133	123-147
6.00	0.5	0.08	141	130-152
7.00	0.5	0.07	145	135-157
7.00	0.6	0.09	140	130-151

Timing of Nitrogen Application

Practice	Comments	% Nitrate-N Reduction			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Timing of Nitrogen Application	Moving from Fall to Spring Pre-plant Application	-80	6 (25)	43	4 (16)
	Spring pre-plant/sidedress 40-60 split Compared to Fall Applied	-60	5 (28)	33	10 (7)
	Sidedress Compared to Pre-plant Application	-95	7 (37)	45	0 (3)
	Sidedress – Soil Test Based Compared to Pre-plant	-29	4 (20)	45	13 (22)

Different studies for different timing effects

Nitrification Inhibitor

Practice	Comments	% Nitrate-N Reduction			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Nitrification Inhibitor	Nitrapyrin in Fall – Compared to Fall Applied without Nitrapyrin	-33	9 (19)	33	6 (22)

Source – Manure Compared to Commercial

Practice	Comments	% Nitrate-N Reduction			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Source	Liquid Swine Manure Compared to Spring-Applied Fertilizer	-9	4 (11)	25	0 (13)
	Poultry Manure Compared to Spring Applied Fertilizer	-32	-3 (20)	21	-2 (14)

Cover Crops and Living Mulches

Practice	Comments	% Nitrate-N Reduction			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Cover Crops	Rye	-10	31 (29)	94	-6 (7)
	Oat	26	28 (2)	30	-5 (1)
	Living mulch – e.g. kura clover	12	41 (16)	53	-9 (32)


Land Use
Cover Crops

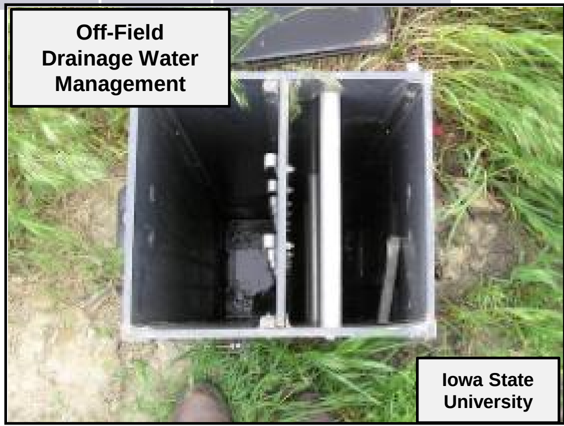
Iowa State University

Extended Rotations, Energy Crops, and Land Retirement

Practice	Comments	% Nitrate-N Reduction⁺			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Land Use	Energy Crops Compared to Spring- Applied Fertilizer	26	72 (23)	98	
	Land Retirement (CRP) Compared to Spring- Applied Fertilizer – Assume Grazed Pastures Similar	67	85 (9)	98	
	Extended rotations (At least 2 years of alfalfa in a 4 or 5 year rotation)	24	42 (12)	62	7 (7)

Drainage Water Management and Shallow Drainage

Practice	Comments	% Nitrate-N Reduction$^+$			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Drainage Design and Mgmt	Controlled Drainage (Load reduction but no concentration reduction)	-11	33 (32)	98	
	Shallow Drainage (Load reduction but no concentration reduction)	5	32 (15)	54	



Off-Field Drainage Water Management

Iowa State University

Subsurface Drainage Bioreactors

Practice	Comments	% Nitrate-N Reduction$^+$			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Subsurface Drainage Bioreactor		12	43 (21)	75	

Off-Field Bioreactors

Iowa NRCS

Targeted Wetland Restoration/Construction and Buffers

Practice	Comments	% Nitrate-N Reduction^{+}			% Corn Yield Change
		Min	Average (SD)	Max	Average (SD)
Wetlands	Targeted Water Quality	11	52	92	
Buffers	Only for water that interacts with active root zone below buffer	33	91 (20)	99	

Off-Field Wetlands

IDALS - DSC

Nitrogen Reduction Practices

	Practice	% Nitrate-N Reduction [Average (Std. Dev.)]
Nitrogen Management	Timing (Fall to spring)	6 (25)
	Source (Liquid swine compared to commercial)	4 (11)
	Nitrogen Application Rate	Depends on starting point
	Nitrification Inhibitor	9 (19)
	Cover Crops (Rye)	31 (29)
Land Use	Perennial – Land retirement	85 (9)
	Perennial – Energy Crops	72 (23)
	Living Mulches	41 (16)
	Extended Rotations	42 (12)
Edge-of-Field	Drainage Water Mgmt.	33 (32)*
	Shallow Drainage	32 (15)*
	Wetlands	52
	Bioreactors	43 (21)
	Buffers	91 (20)**

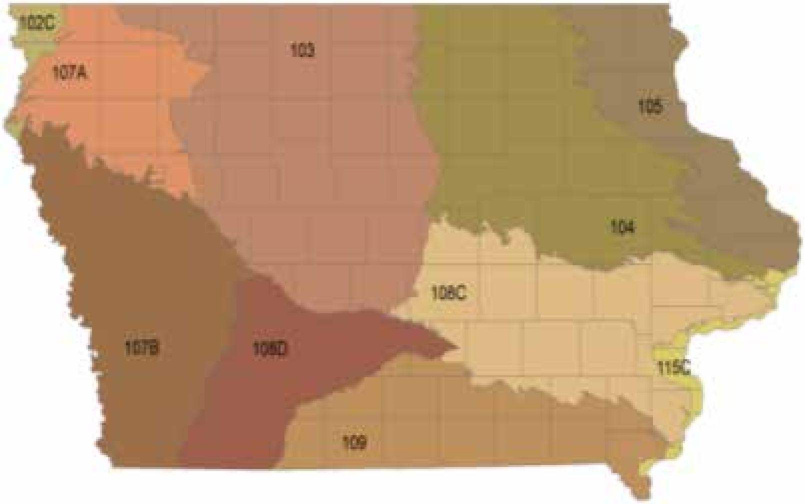
*Load reduction not concentration reduction

**Concentration reduction of that water interacts with active zone below the buffer

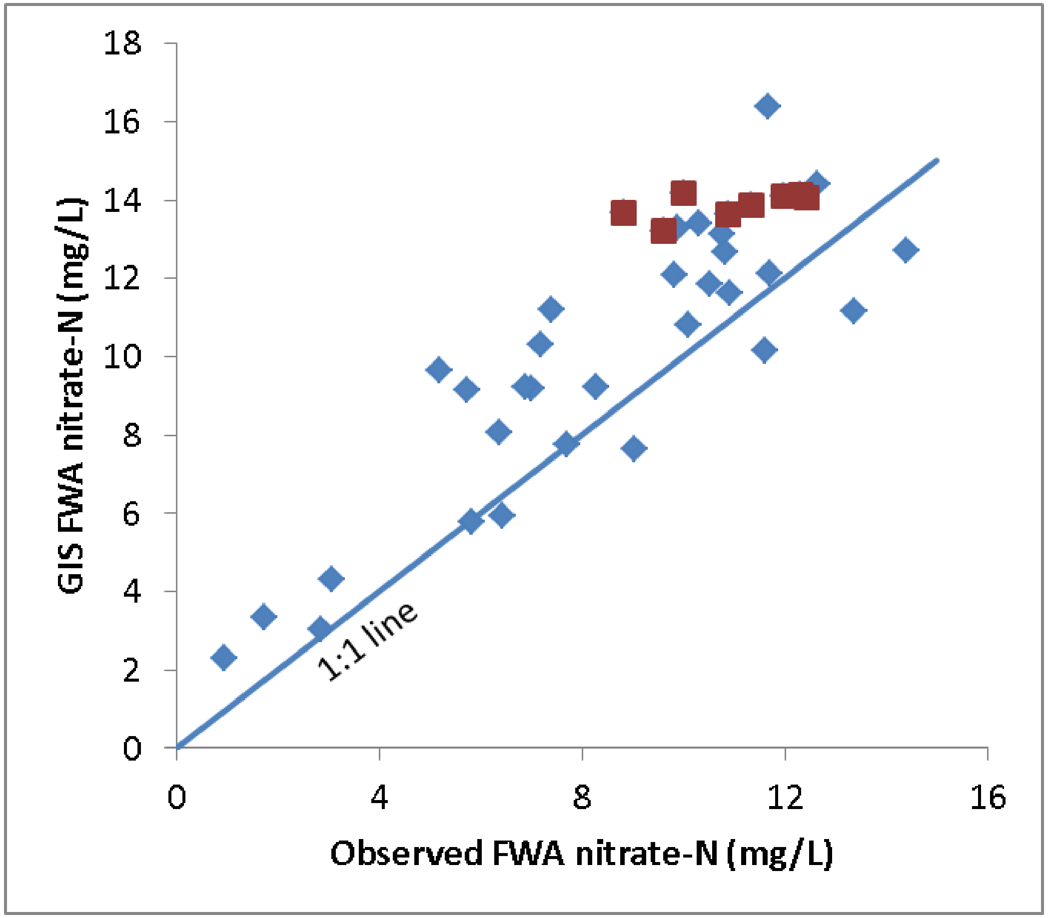
Load Estimation

- Nitrate-N concentration estimated from land use and nitrogen management
- Nitrate-N load for each MLRA a product of the nitrate-N concentration and water yield (estimated surface and subsurface flow)

MLRA	Water Yield
	in/yr
103	10.4
104	11.9
105	11.3
107A	7.1
107B	8.2
108C	11.2
108D	9.8
109	12.0



Nitrate-N Comparison



- Nitrate concentrations estimated based on land use and N application rates overestimate the observed nitrate concentrations by about 17% on the basis of a least squares statistical model.
- This 17% difference could be largely explained by in stream loss of nitrate and by dilution due to surface runoff.
- Overall, empirically based modeling approach to predict impacts of practice implementation (83% subsurface flow and 17% surface runoff

Nitrogen Practices – Potential Load Reduction

Target Load Reduction from NPS
for Hypoxia Goal ~41%

Nitrogen Reduction Scenarios

	Practice/Scenario	Nitrate-N Reduction	Potential Area Impacted by Practice
		% (from baseline)	(million acres)
Nitrogen Management	Baseline		
	Cover crops (rye) on ALL CS and CC acres	28	21.0
	Reducing nitrogen application rate from background to the MRTN 133 lb N/ac on CB and to 190 lb N/ac on CC (in MLRAs where rates are higher than this)	9	18.9
	Cover crops (rye) on all no-till acres	6	5.1
	Sidedress all spring applied N	4	13.5
	Using a nitrification inhibitor with all fall applied fertilizer	1	2.2
	Moving fall anhydrous fertilizer application to spring preplant	0.1	5.7

Target Load Reduction from NPS for Hypoxia Goal ~41%

Nitrogen Reduction Scenarios

	Practice/Scenario	Nitrate-N Reduction % (from baseline)	Potential Area Impacted by Practice (million acres)
Edge-of-Field	Baseline		
	Installing wetlands to treat 45% of the ag acres	22	12.8
	Installing denitrification bioreactors on all tile drained acres	18	9.9
	Installing Buffers on all applicable lands	7	0.4*
	Installing Controlled Drainage on all applicable acres	2	1.8

* Area of Buffer

Target Load Reduction from NPS for Hypoxia Goal ~41%

Nitrogen Reduction Scenarios

	Practice/Scenario	Nitrate-N Reduction	Potential Area Impacted by Practice
		% (from baseline)	(million acres)
Land Use Changes	Baseline		
	Perennial crops (Energy crops) equal to pasture/hay acreage from 1987. Take acres proportionally from all rowcrop. This is in addition to current pasture.	18	5.9
	Pasture and Land Retirement to equal acreage from 1987 (in MLRAs where 1987 was higher than now). Take acres from rowcrops proportionally	7	1.9
	Doubling the amount of extended rotation acreage (removing from CS and CC proportionally)	3	1.8

Target Load Reduction from NPS for Hypoxia Goal ~41%

Combined Nitrogen Reduction Scenarios - EXAMPLES

	Scenario	Practice/Scenario	**Nitrate-N Reduction**	**Phosphorus Reduction**
			% (from baseline)	% (from baseline)
	BS	Baseline		
Combination Scenarios	NCS1	Combined Scenario (MRTN Rate, 60% Acreage with Cover Crop, 27% of ag land treated with wetland and 60% of drained land has bioreactor)	42	30
	NCS2	Combined Scenario (MRTN Rate, 100% Acreage with Cover Crop in all MLRAs but 103 and 104, 45% of ag land in MLRA 103 and 104 treated with wetland, and 100% of tile drained land in MLRA 103 and 104 treated with bioreactor)	39	40

Target Load Reduction from NPS for Hypoxia Goal ~41% for N and ~29% for P

Combined Nitrogen Reduction Scenarios - EXAMPLES

	Scenario	Practice/Scenario	**Nitrate-N Reduction**	**Phosphorus Reduction**
			% (from baseline)	% (from baseline)
	BS	Baseline		
Combination Scenarios	NCS3	Combined Scenario (MRTN Rate, 95% of acreage in all MLRAs with Cover Crops, 34% of ag land in MLRA 103 and 104 treated with wetland, and 5% land retirement in all MLRAs)	42	50
	NCS4	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 85% of all tile drained acres treated with bioreactor, 85% of all applicable land has controlled drainage, 38.25% of ag land treated with a wetland)	42	0

Target Load Reduction from NPS for Hypoxia Goal ~41% for N and ~29% for P

Combined Nitrogen Reduction Scenarios - EXAMPLES

			Nitrate-N Reduction	Phosphorus Reduction
	Scenario	Practice/Scenario	% (from baseline)	% (from baseline)
	BS	Baseline		
Combination Scenarios	NCS5	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 65% of all tile drained acres treated with bioreactor, 65% of all applicable land has controlled drainage, 29.25% of ag land treated with a wetland, and 15% of corn-soybean and continuous corn acres converted to perennial-based energy crop production)	41	11
	NCS6	Combined Scenario (MRTN Rate, 25% Acreage with Cover Crop, 25% of acreage with Extended Rotations, 27% of ag land treated with wetland, and 60% of drained land has bioreactor)	41	19

Target Load Reduction from NPS for Hypoxia Goal ~41% for N and ~29% for P

Combined Nitrogen Reduction Scenarios - EXAMPLES

	Scenario	Practice/Scenario	Nitrate-N Reduction	Phosphorus Reduction
			% (from baseline)	% (from baseline)
	BS	Baseline		
Combination Scenarios	NCS7	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 70% of all tile drained acres treated with bioreactor, 70% of all applicable land has controlled drainage, 31.5% of ag land treated with wetland, and 70% of all agricultural streams have a buffer)	42	20
	NCS8	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 70% of all tile drained acres treated with bioreactor, 70% of all applicable land has controlled drainage, 31.5% of ag land treated with a wetland, and 70% of all agricultural streams have a buffer) - Phosphorus reduction practices (phosphorus rate reduction on all ag land, Convert 90% of Conventional Tillage CS & CC acres to Conservation till and Convert 10% of Non-No-till CS & CC ground to No-Till)	42	29

Target Load Reduction from NPS for Hypoxia Goal ~41% for N and ~29% for P

Future Needs

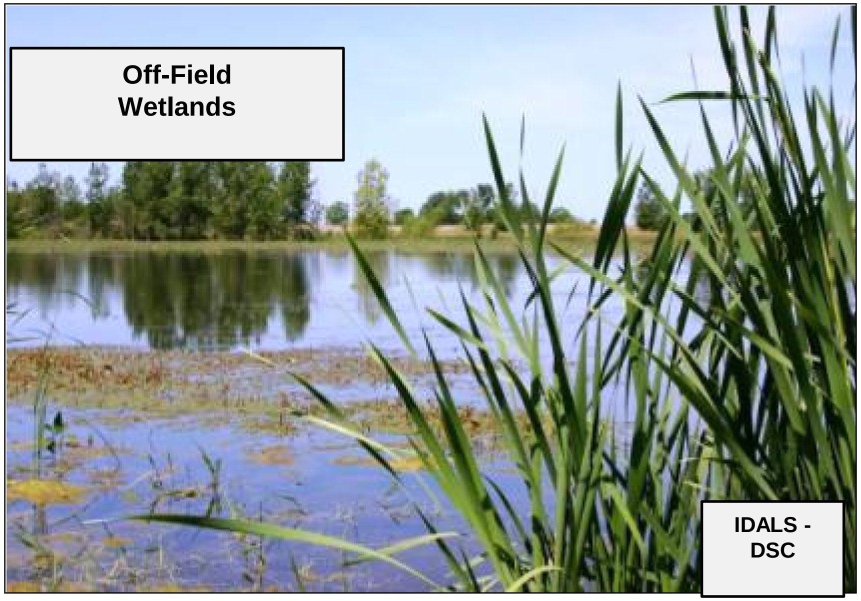
- Variable nitrogen rate application
- In-season sensor-based nitrogen application
- Nitrogen and manure additives, inhibitors, and slow release products
- Better estimates of actual nitrogen application rates (including fertilizer and manure), and on a geographic-specific basis.
- Two-stage ditch designs
- Directing tile drainage water through riparian buffers

Future Needs Continued

- Overall nitrate reduction with combinations of practices
- Large scale monitoring of nitrate transport as impacted by single and combination of nitrate reduction practices
- Large scale modeling to estimate nitrate-N transport with models like the Root Zone Water Quality Model (RZWQM)
- Integration and comparison to USGS SPARROW modeling
- Developing cover crop systems that do not reduce yields for the following corn crop
- Need for water quality and yield impacts of living mulches, specifically bluegrass

Future Needs Continued

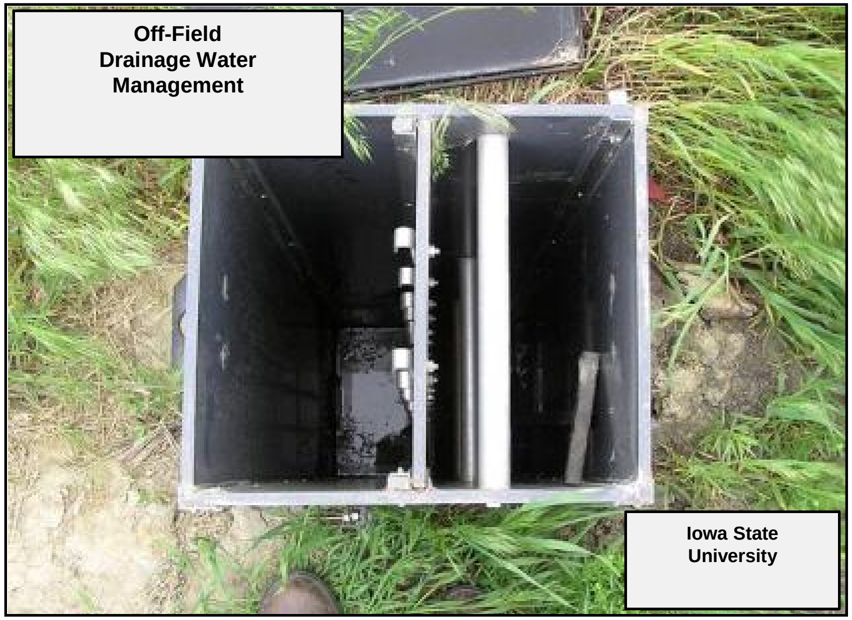
- There is a need for monetizing economic benefits that might be derived from improved water quality or other ecosystems services. These could be compared to the cost of nutrient reduction practice implementation.
- To assess potential landscape-scale changes, there is a need for better tracking of practices currently in place and put in place in the future, including but not limited to land use, crop rotations, nutrient applications, tillage, and conservation practices.



Off-Field Wetlands

IDALS - DSC

Winter Cover Crops



Off-Field Drainage Water Management

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Off-Field Bioreactors

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