NITRATE-N LOSS REDUCTION: SCALE OF IN-FIELD AND EDGE-OF-FIELD PRACTICE IMPLEMENTATION TO REACH WATER QUALITY GOALS

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ABSTRACT

States in the Mississippi River Basin have developed state level nutrient reduction strategies in response to the 2008 Hypoxia Action Plan. The Iowa Nutrient Reduction Strategy was released in 2013 and the Nonpoint Source Nutrient Reduction Strategy Science Assessment reviews potential practice performance in reducing downstream nutrient loss and the scale of implementation that would be necessary to reach the Hypoxia Action Plan goal of a 45% reduction in riverine Nitrogen and Phosphorus. To reach the goals for nitrate-N reduction will require a combination of practices and an extremely high level of implementation of these practices.

INTRODUCTION

The 2008 Hypoxia Action Plan called for states along the Mississippi River to develop nutrient reduction strategies to reduce, mitigate, and control hypoxia in the Gulf of Mexico and improve overall water quality. In October 2010, the Iowa Department of Agriculture and Land Stewardship and the College of Agriculture and Life Sciences at Iowa State University partnered to conduct a technical assessment needed for the development of a statewide strategy to reduce nutrient to streams and the Gulf of Mexico. The team working on this effort consisted of 23 individuals representing five agencies or organizations. Within the overall team, sub-group science teams were formed to focus on nitrogen, phosphorus and hydrology. The goals of the process were to assess nutrient loading from Iowa to the Mississippi River and the potential practices needed to achieve desired environmental goals. As per the 2008 Gulf Hypoxia Action Plan, these goals are a 45% reduction in riverine N and P load. Based on IDNR estimates, nonpoint source load reductions for nitrate-N would need to achieve 41% load reduction in nitrate-N with the remaining 4% coming from point sources. For phosphorus, the nonpoint source load reductions would need to achieve 29%, with the remaining 16% coming from point sources.

In 2013, the Iowa Nutrient Reduction Strategy was released (Full information about the Iowa Nutrient Reduction Strategy can be found at http://www.nutrientstrategy.iastate.edu/). An important component of this is the Nonpoint Source Nutrient Reduction Strategy Science Assessment (Iowa Nutrient Reduction Strategy 2013). This document summarizes a review of nutrient reduction practices' performance and estimates the potential load reduction upon implementing various nutrient reduction practices. While this assessment was conducted for Iowa, similar assessments have been conducted for other states in the Mississippi River Basin and there are many similarities between these strategies.

NITROGEN REDUCTION PRACTICES AND LOAD REDUCTION

Nitrogen reduction practices, ranging from in-field nitrogen management practices to edge-of-field practices to land use change, were reviewed to assess the potential for nitrate-N reduction and impacts on corn yield (Table 1).

To estimate the baseline nitrate-N load, estimates of existing land use, literature estimates of nitrate-N concentrations in tile and subsurface water, and estimates of water yield to streams were used. The loads were calculated for each MLRA in Iowa and loads were accumulated for a statewide load. To assess the impact of the nitrogen practice implementation, the baseline nitrate-N concentrations were adjusted based on literature estimates for each practice. These concentrations were used to compute a scenario load of nitrate-N, which was compared to the baseline load. From this comparison, the estimate of potential nitrate-N load reduction for each standalone practice was developed (Table 2). It is important to note the computed reductions for standalone practices are not additive. In other words, it's not possible to add together reductions from multiple practices.

A review of Table 2 shows that no single practice would achieve nutrient reduction goals other than major land use changes. Instead, a combination of practices will be needed.

SCALE OF IMPLEMENTATION TO REACH WATER QUALITY GOALS

There are endless combinations, but a few combination scenarios are highlighted in Table 3 that would reach reduction goals for nitrate-N. These represent a range of initial investments and annualized cost and benefits. Economic costs of these combination scenarios were computed by considering the cost for implementing the practice and any potential impact on crop yield, specifically corn grain yield. An equal annualized cost (EAC) was computed so those practices with annualized costs and those with large initial capital costs could be appropriately compared. For the capital costs, a design life of 50 years and a discount rate of 4% was used. The price of corn was assumed to be $5/bushel and the cost of nitrogen was assumed to be $0.50/lb N. It is evident that a range of scenarios are possible to achieve the nitrate-N reduction goals and that combinations of practices would be needed, with potential costs varying dramatically depending on which practices are implemented. Additional scenarios are described in the Nonpoint Source Nutrient Reduction Strategy Science Assessment (Iowa Nutrient Reduction Strategy 2013).

One example scenario that is commonly discussed is NCS1 (Table 3), where it is assumed that all corn acres use the Maximum Return to Nitrogen Rate, 60% of corn-soybean and continuous corn acres have cover crops, 27% of all ag land is treated with a wetland, and 60% of the tile drained acres are treated with a bioreactor. This scenario is estimated to have the potential to reduce nitrate-N loading by 125,000 tons/year which is approximately a 42% overall nitrate-N load reduction at an annual cost of approximately $755,518,000. The estimated acres treated by each of these practices is shown in Figure 1. For wetlands, it was assumed that each wetland (10 acres with 35 acres of buffer) treats 1,000 acres of agricultural land which would mean approximately 7,600 wetlands for the scenario noted in Figure 1. For bioreactors, it was assumed that each bioreactor treats 50 acres of subsurface drained land which would mean approximately 120,000 bioreactors for the scenario noted in Figure 1.

From review of Table 3 and Figure 1, it is obvious that reaching the desired reductions in nitrate-N will require a combination of practices that include the best in-field nitrogen management, cropping systems and edge-of-field practices. In addition, the scale of implementation is extremely large and all farmers would need to be involved in some way to reach these goals.

Table 1. Nitrogen reduction practices – potential impact on nitrate-N reduction and corn yield based on literature review. (Table from Iowa Nutrient Reduction Strategy 2013)

	Practice	Comments	% Nitrate-N Reduction+	% Corn Yield Change++
			Average (SD*)	Average (SD*)
Nitrogen Management	Timing	Moving from Fall to Spring Pre-plant Application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to Fall Applied	5 (28)	10 (7)
		Sidedress - Compared to Pre-plant Application	7 (37)	0 (3)
		Sidedress – Soil Test Based Compared to Pre-plant	4 (20)	13 (22)
	Source	Liquid Swine Manure Compared to Spring Applied Fertilizer	4 (11)	0 (13)
		Poultry Manure Compared to Spring Applied Fertilizer	-3 (20)	-2 (14)
	Nitrogen Application Rate	Reduce to Maximum Return to Nitrogen value 149 kg N/ha (133 lb N/ac) for CS and 213 kg N/ha (190 lb N/ac) for CC	10‡	-1‡‡
	Nitrification Inhibitor	Nitrapyrin – Fall - Compared to Fall-Applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)**	-5 (1)
	Living Mulches	e.g. Kura clover - Nitrate-N reduction from one site	41 (16)	-9 (32)
Land Use	Perennial	Energy Crops Compared to Spring- Applied Fertilizer	72 (23)	-100 ɣ
		Land Retirement (CRP) Compared to Spring- Applied Fertilizer	85 (9)	-100 ɣ
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	42 (12)	7 (7)
	Grazed Pastures	No pertinent information from Iowa - Assume similar to CRP	85***	NA
Edge-of-Field	Drainage Water Mgmt.	No impact on concentration	33 (32)^	
	Shallow Drainage	No impact on concentration	32 (15)^	
	Wetlands	Targeted Water Quality	52†	
	Bioreactors		43 (21)	
	Buffers	Only for water that interacts with active zone below the buffer - a small fraction of all water that makes it to a stream.	91 (20)	

+ A positive number is nitrate concentration or load reduction and a negative number is increased nitrate.
++ A positive corn yield change is increased yield and a negative number is decreased yield. Soybean yield is not included as the practices are not expected to affect soybean yield.
* SD = standard deviation.
‡ Reduction calculated based on initial application rate for each Major Land Resource Area (MLRA).
‡‡ Calculated based on the Maximum Return to Nitrogen (MRTN) relative yield at the given rates.
** Based on 1 study with 3 years of corn and 2 years of soybean.
*** This number is based on the Land Retirement number – there are no observations to develop a SD.
^ These numbers are based on load reduction since there is no impact on concentration with these practices
† Based on one report looking at multiple wetlands in Iowa (Helmers et al., 2008a).

Table 2. Example Statewide Results for Individual Practices at Estimated Nitrate-N Reduction. Notes: Research indicates large variation in reductions not reflected in this table and some practices interact such that the reductions are not additive. (Table from Iowa Nutrient Reduction Strategy 2013)

	Name	Practice/Scenario	Nitrate-N Reduction % (from baseline)	Total Load (1,000 short ton)	N Reduced from baseline (1,000 short ton)
	BS	Baseline		307	
Nitrogen Management	CCb	Cover crops (rye) on ALL CS and CC acres	28	221	79
	RR	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	279	28
	CCa	Cover crops (rye) on all no-till acres	6	288	18
	SN	Sidedress all spring applied N	4	295	12
	NI	Using a nitrification inhibitor with all fall applied fertilizer	1	305	2
	FNb	Move all liquid swine manure and anhydrous to spring preplant	0.3	306	1
	FNa	Moving fall anhydrous fertilizer application to spring preplant	0.1	307	0
Edge-of-Field*	W	Installing wetlands to treat 45% of the rowcrop acres	22	238	69
	BR	Installing denitrification bioreactors on all tile drained acres	18	252	55
	CD	Installing Controlled Drainage on all applicable acres	2	300	7
	BF	Installing Buffers on all applicable lands	7	284	23
Land Use Changes	EC	Perennial crops (Energy crops) equal to pasture/hay acreage from 1987. Take acres proportionally from all row crop. This is in addition to current pasture.	18	253	54
	P/LR	Pasture and Land Retirement to equal acreage of Pasture/Hay and CRP from 1987 (in MLRAs where 1987 was higher than now). Take acres from row crops proportionally	7	287	20
	EXT	Doubling the amount of extended rotation acreage (removing from CS and CC proportionally)	3	297	10

Table 3. Example Statewide Combination Scenarios that Achieve the Targeted Nitrate-N Reductions and Estimated Equal Annualized Costs based on 21.009 Million Acres of Corn-Corn and Corn-Soybean Rotation. Notes: Research indicates large variation in reductions from practices that is not reflected in this table. Additional costs could be incurred for some of these scenarios due to industry costs or market impacts. (Table from Iowa Nutrient Reduction Strategy 2013)

		Nitrate-N	Phosphorus	Cost of N Reduction from baseline ($/lb)	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
Name	Practice/Scenario**	% Reduction from baseline					
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	2.95	3,218	756	36
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	2.61	2,357	631	30
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	4.67	1,222	1,214	58
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	0.88	4,810	225	11

* EAC stands for Equal Annualized Cost (50 year life and 4% discount rate) and factors in the cost of any corn yield impact as well as the cost of physically implementing the practice. Average cost based on 21.009 million acres, costs will differ by region, farm and field.

** Scenarios that include wetlands, bioreactors, controlled drainage and buffers have substantial initial investment costs.

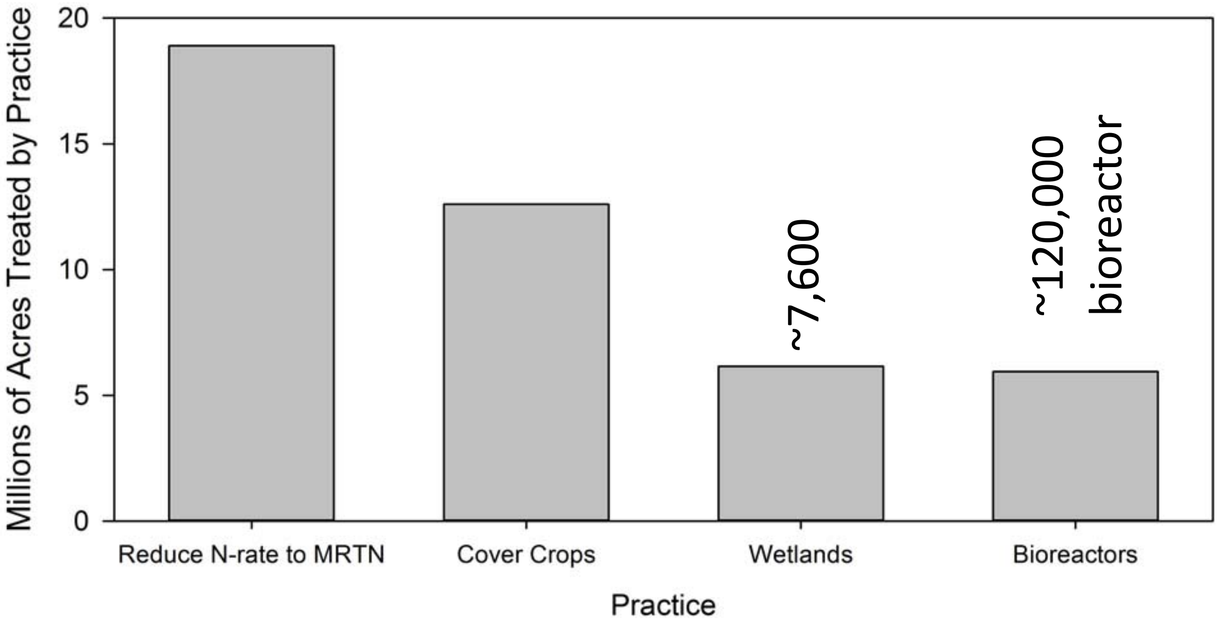

Figure 1. Acres treated by each practice in a scenario NCS1 that reaches nitrate-N reduction goal

REFERENCES

Iowa Nutrient Reduction Strategy. 2013. Section 2. Nonpoint Sources Nutrient Reduction Science Assessment. Accessed September 23, 2016 at http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2-130529.pdf

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