Fertilizer N Management – More than Just Rate – For Improved Crop Yields and Water Quality

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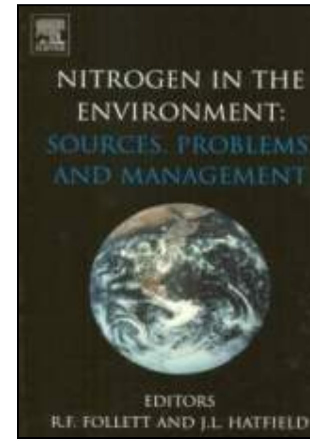
Nitrogen Recovery Efficiency by Major Cereals

- **Nitrogen use efficiency … "rarely exceeds 70% ……. often ranges from 30-60%"**
- **"conversion of N inputs to products for arable crops can be 60-70% or even more" (Kitchen and Goulding, 2001)**



Our Premise …… or Position
More in the Crop = Less in the Environment

- Improved crop yields, and greater crop nutrient recovery and soil retention, should result in less risk of nutrient loss to water and air resources
- Without detailed tracking of fertilizer N BMP implementation within watersheds, there is no definitive way of identifying the cause of water quality changes
- Increased water quality monitoring and modeling will reflect whether agriculture is improving, ….. or not
- The larger the watershed, and the larger the waterbody, the greater the potential lag time in seeing water quality improvements
- Agronomically appropriate N rates are a fundamental part of the 4Rs

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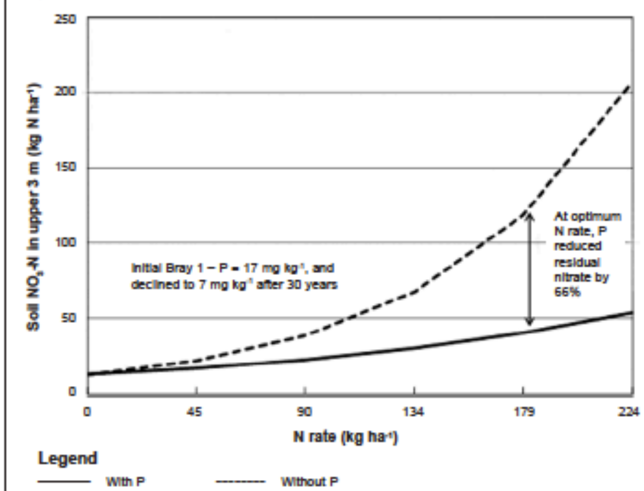
N Management and Balanced Nutrition

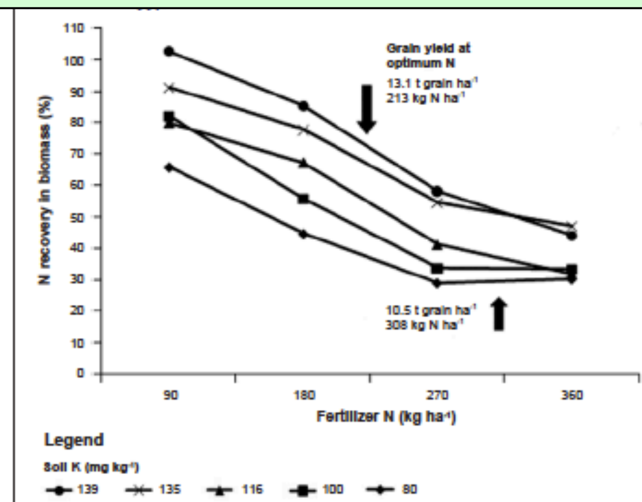
- **P and K soil fertility levels are below optimum and need improved (IPNI, 2010)**
  - 2010 median **soil P**=25 ppm: a 6 ppm <u>decline</u> since 2005; approximately 42% of samples <20 ppm agronomic optimum
  - 2010 median **soil K** =150 ppm: a 4 ppm <u>decline</u> since 2005; approximately 34% of samples <120 ppm agronomic optimum

Figure 2

Adequate phosphorus (P) fertilization of corn reduces soil profile nitrate-nitrogen (NO_3-N) and the potential for nitrate leaching (Schlegel et al. 1996).



Optimum P and K enhance crop N recovery



Snyder & Fixen. 2012. J. Soil Water Conserv.

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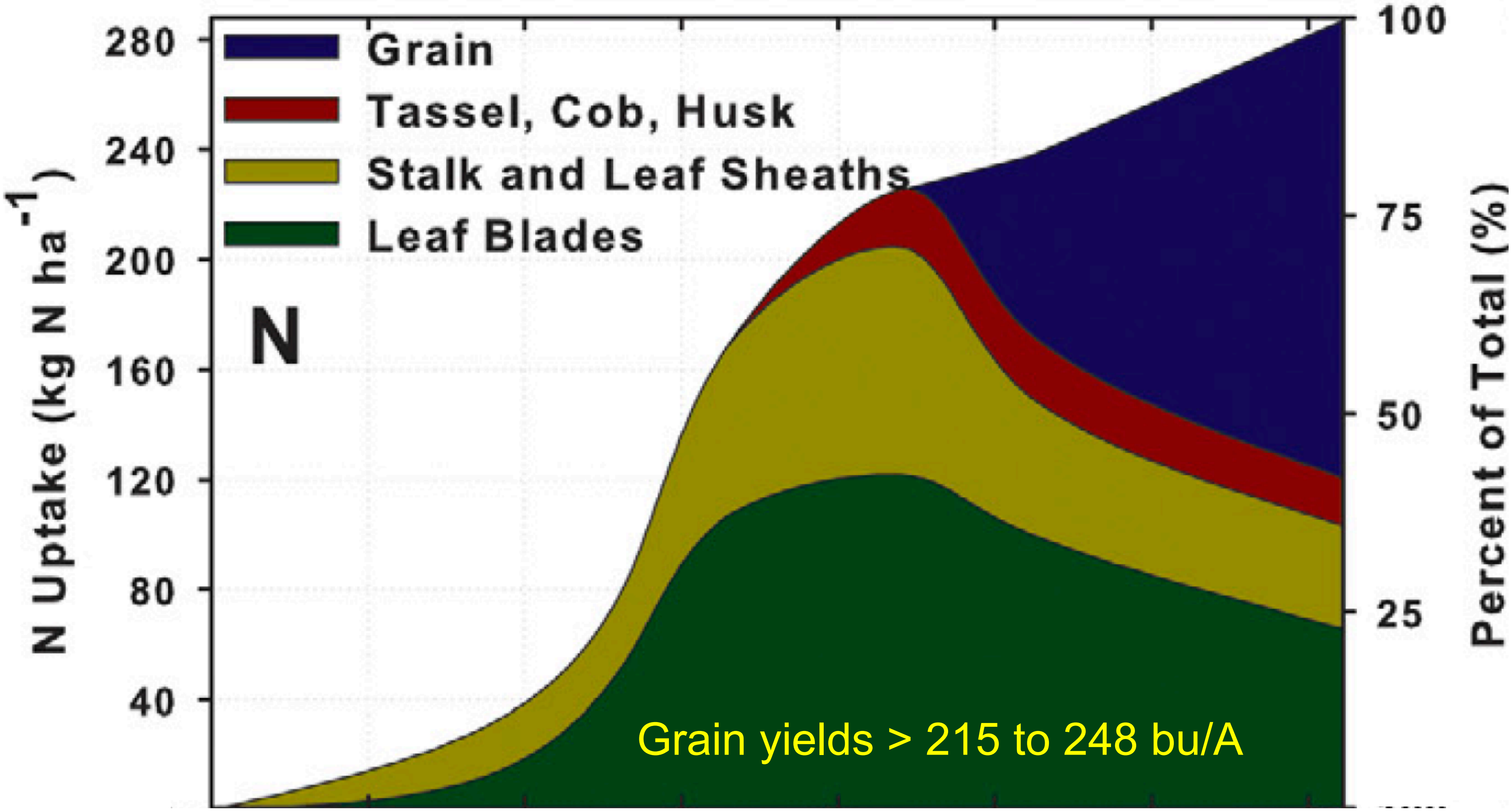
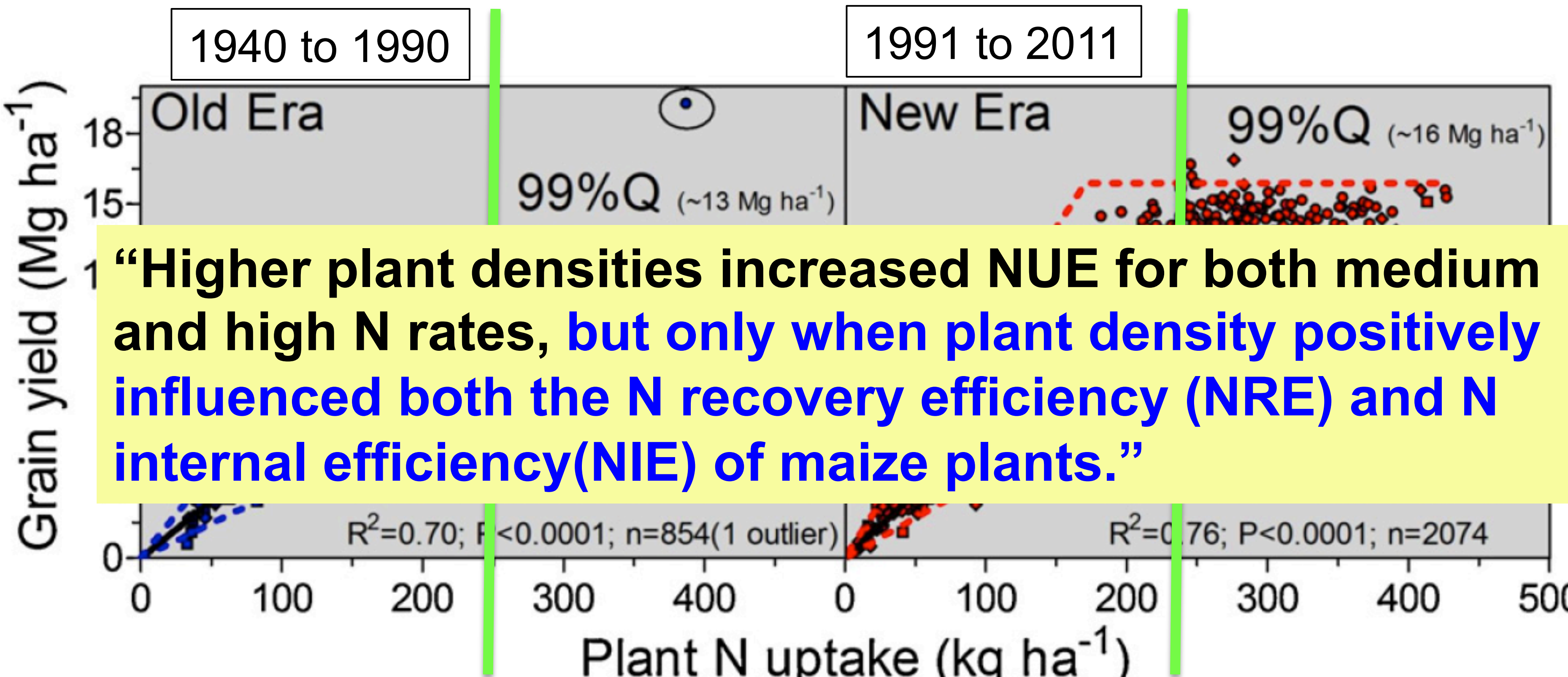
Nutrient Uptake, Partitioning, and Remobilization in Modern, Transgenic Insect-Protected Maize Hybrids



Bender et al. 2013. Agron. J. 105:161–170

New Era Corn Hybrids Yield More per Unit of N applied, …. In Association with Increased Plant Population



"Higher plant densities increased NUE for both medium and high N rates, but only when plant density positively influenced both the N recovery efficiency (NRE) and N internal efficiency(NIE) of maize plants."

Ciampitti & Vyn. 2012. Field Crops Research 133: 48–67
Ciampitti and Vyn. 2011. Field Crops Research 121: 2–18

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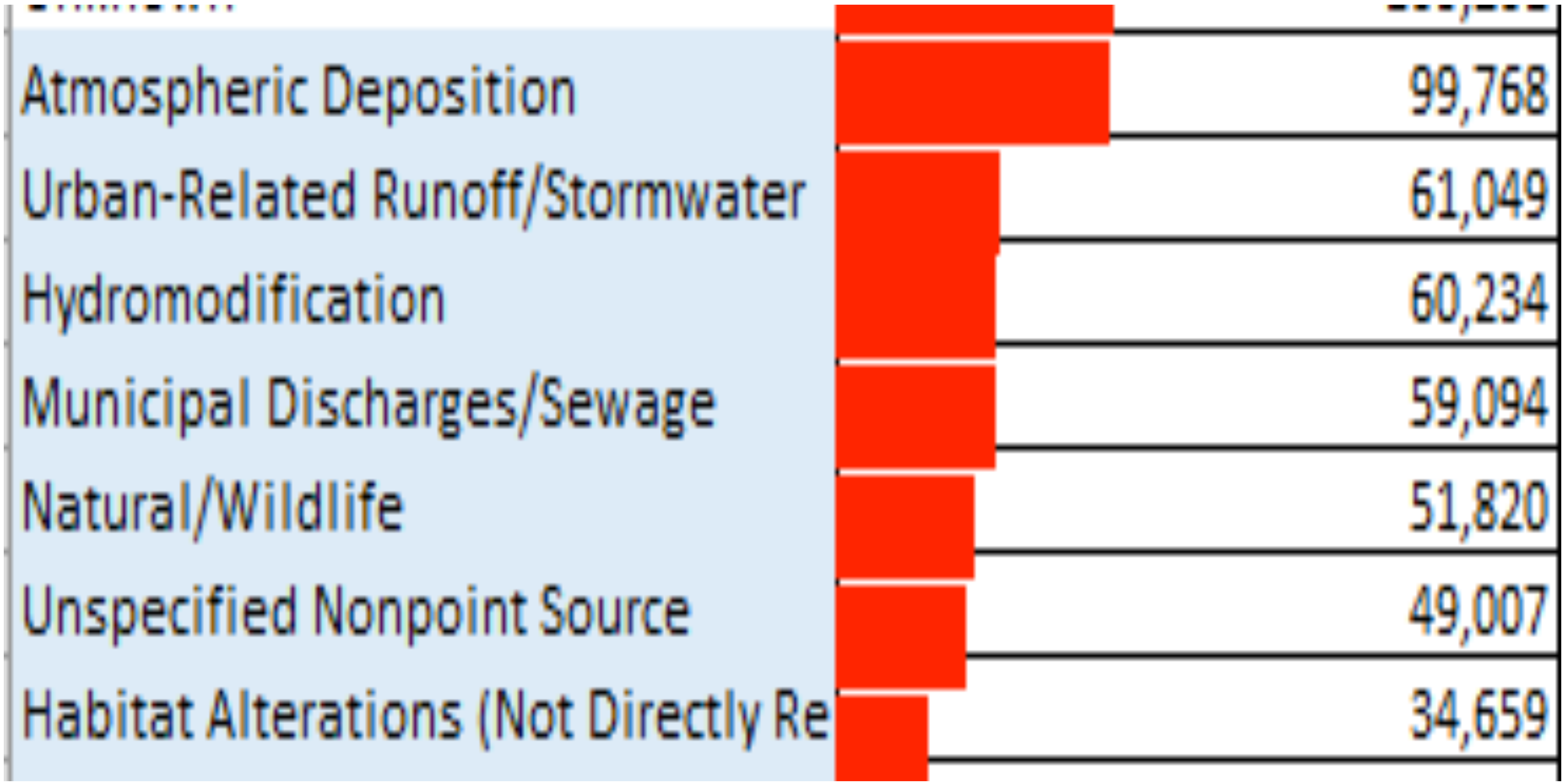
Probable Sources of Impairments in Assessed Rivers and Streams (top ten)



*NPS estimate includes those sources shaded in blue

(Source: Draft CWA 305(b) National Water Quality Inventory: http://www.epa.gov/waters/ir/)

Source: Dr. Ellen Gilinsky, EPA. Presented at Nutrient Management and Edge of Field Monitoring Conference. Memphis, TN. Dec. 2, 2015

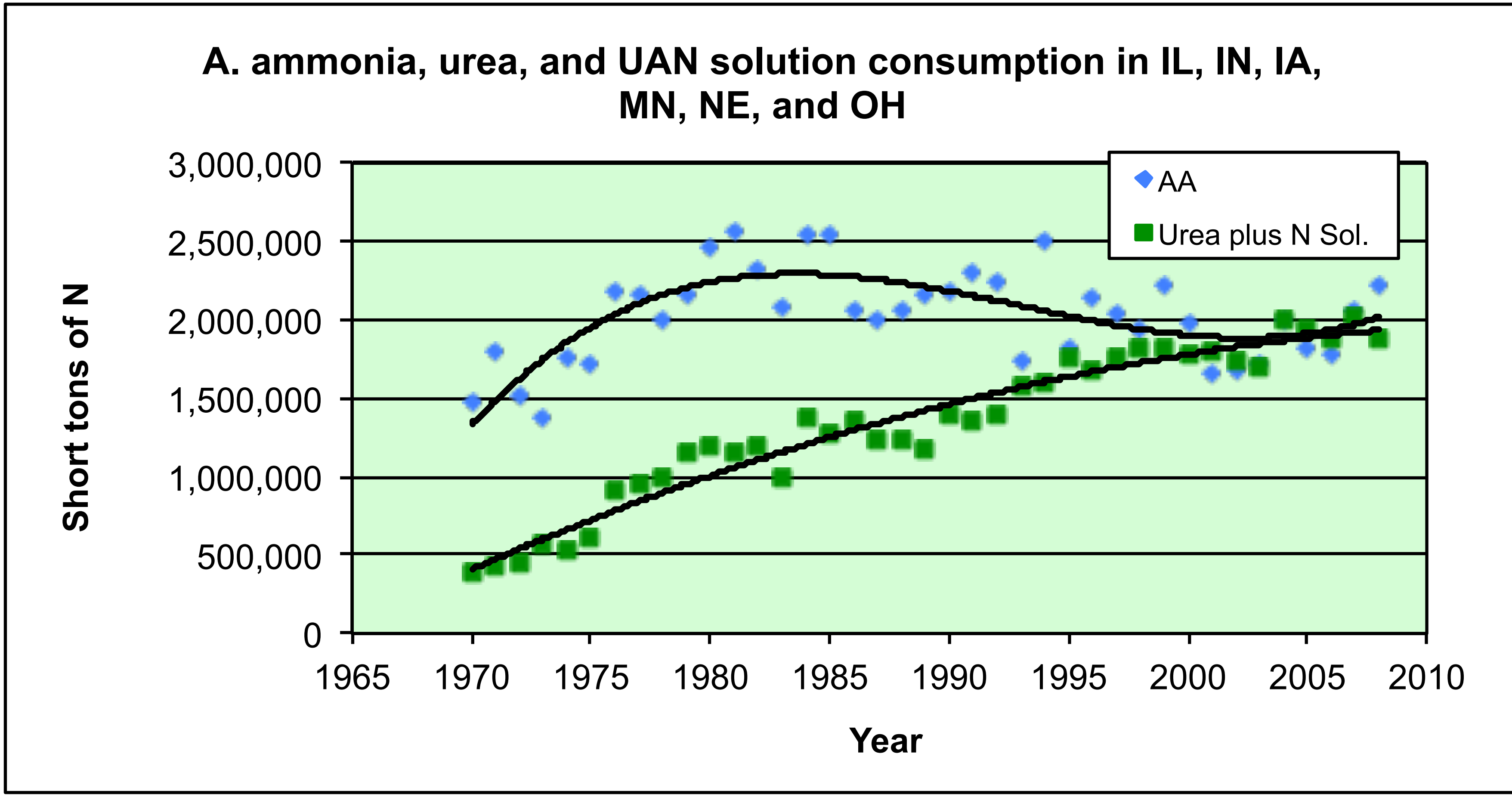
Keys to Success

Developed Jan 15, 2015

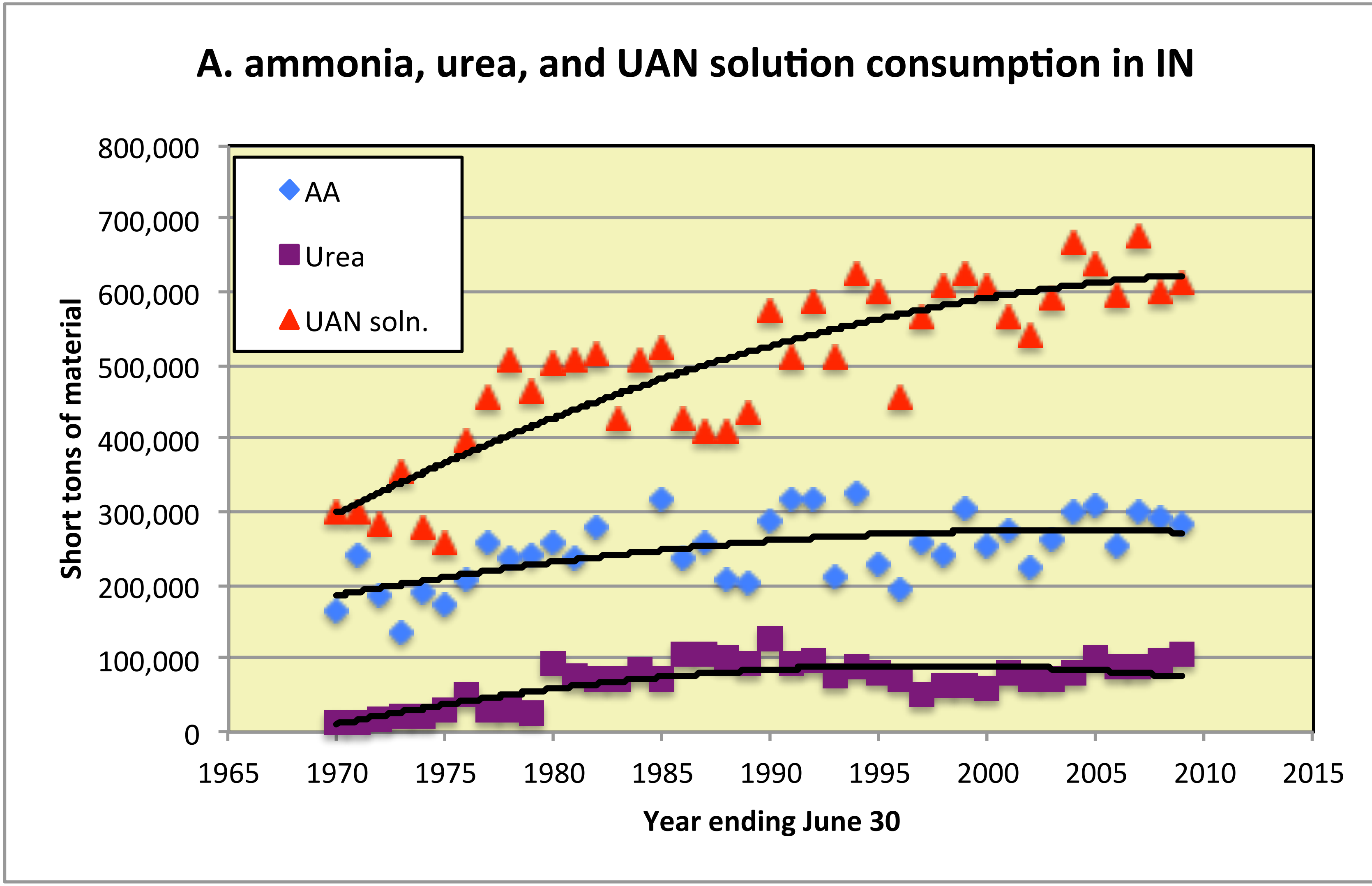
- To achieve a 45 percent reduction in N and P, HTF must engage with and seek reductions from all source sectors: *partnerships and collaboration are key to strong progress.*
- Each HTF state developed a nutrient reduction strategy with stakeholder participation.
- Strategies are the key road map and cornerstone for reaching the HTF goal.
- Focus is now on implementation on the ground in state priority watersheds.
- Federal HTF Members have a unified strategy to guide technical and financial assistance to states and continued science support.

Source: Dr. Ellen Gilinsky, EPA. Presented at Nutrient Management and Edge of Field Monitoring Conference. Memphis, TN. Dec. 2, 2015

Shifts in N Source Consumption – May Reflect Management "Opportunities"



Data source: H. Vroomen, TFI and AAPFCO



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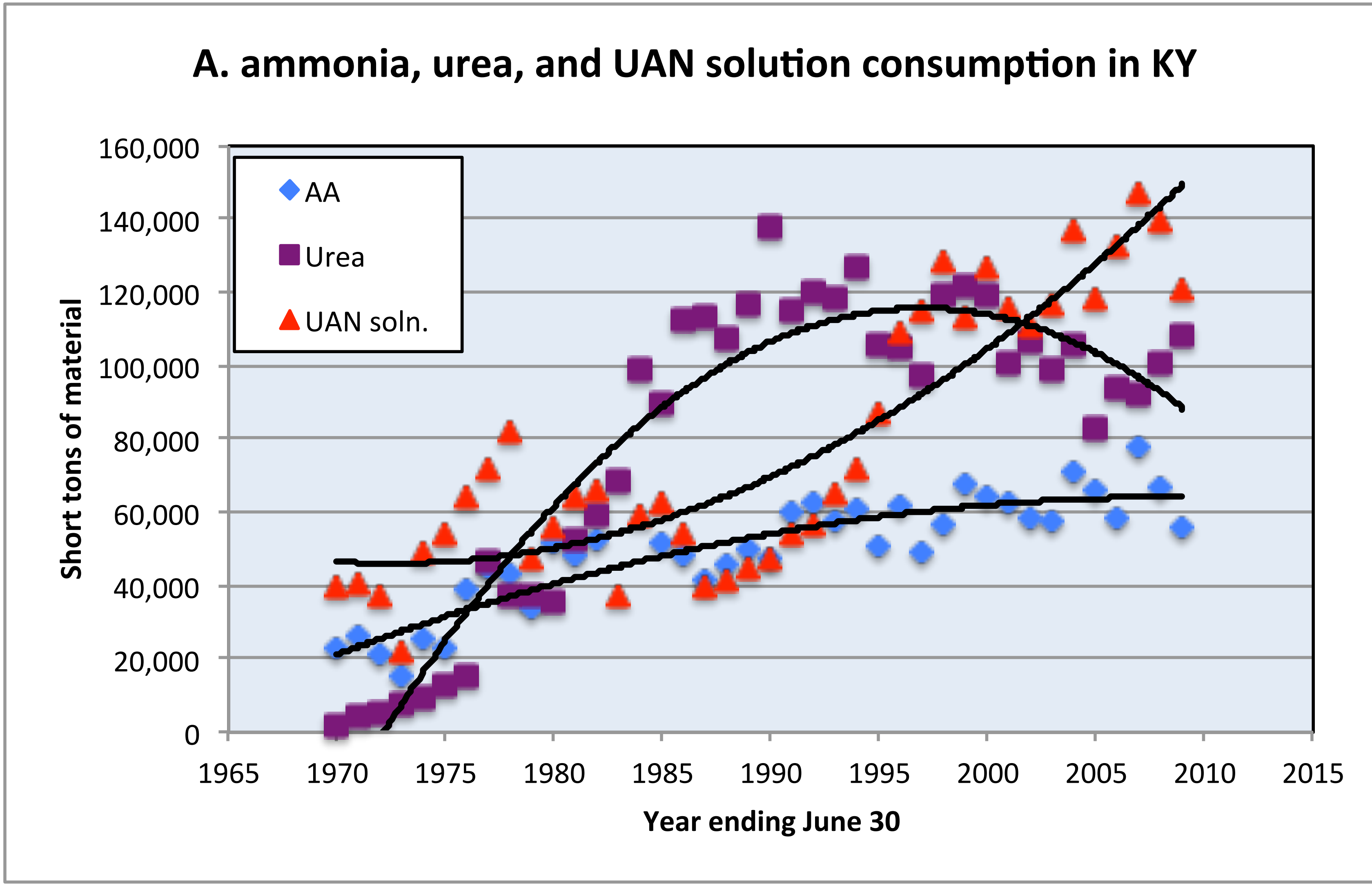

Data source: H. Vroomen, TFI and AAPFCO

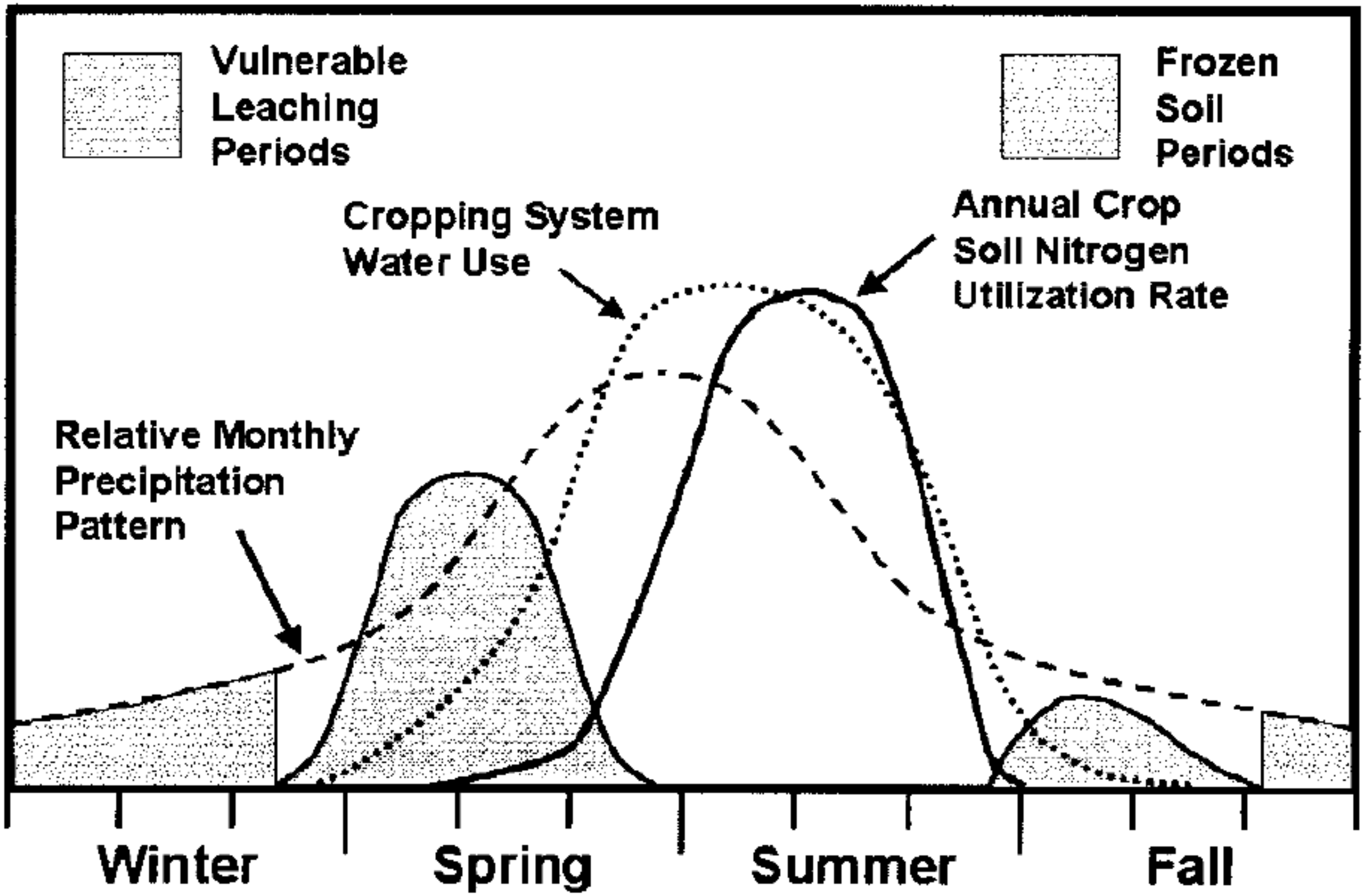

Fig. 3. General seasonal patterns for precipitation, N uptake rate by a corn crop, cropping system water use, and periods potentially favorable for NO_3 leaching from midwestern corn production (adapted from Fig. 4 of Power et al., 1998).

Dinnes et al. 2002. Agron. J.

- **“ ……. Fertilizer N management, particularly rate and time of application, plays a dominant role in the loss of nitrate to surface waters.”**

Source: Randall, G.W. 1997. Nitrate-N in surface waters as influenced by climatic conditions and agricultural practices. In Proc. Agric. and Hypoxia in the Mississippi Watershed Conf., St. Louis, MO. 14–15 July 1997. Am. Farm Bureau Federation, Park Ridge, IL. (and cited by Dinnes et al. 2002. Agron. J. 94:153–171)

N Rate and Time Affect Corn Yield and Nitrate Drainage Loss (MN)

Table 6-1. Effect of N rate and time of application on nitrate-N losses to subsurface drainage and corn yield in Minnesota (adapted from Randall and Mulla, 2001).

N[a]		Annual Loss of Nitrate-N in Drainage	Five-Year Yield Average	
Rate (lb ac^{-1})	Time	(lb N ac^{-1} $year^{-1}$)	Yield (bu ac^{-1})	Net Return (\$ ac^{-1})
0	0	7	66	--
120	Fall	27	131	100
120	Spring	19	150	135
180	Fall	34	160	143
180	Spring	26	168	154

[a] Ammonium sulfate applied to continuous corn about 1 November or 1 May.

Compared to fall application of N:
Higher corn grain yield with spring applic. and lower nitrate loss

Randall and Sawyer. 2008. Pp. 73-85 in UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). 2008. Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. St. Joseph, Michigan: ASABE.

N Rate, Time, and Nitrification Inhibitor Affect Corn Yield and Nitrate Drainage Concentration (IA)

Table 6-4. Average annual flow-weighted NO_3-N concentration in subsurface drainage from a corn-soybean rotation in Iowa as affected by time of N application, N-Serve, and N rate (2000-2003) (adapted from Lawlor et al., 2004).

Nitrogen Treatment			Four-Year Average Flow-Weighted NO_3-N (mg L^{-1})
Time	Rate (lb N ac^{-1})	N-Serve	
Fall	150	No	14.2
Fall	150	Yes	16.2
Fall	225	No	18.1
Spring	150	No	15.4
Spring	150	Yes	17.7
Spring	225	No	24.4
		LSD (0.05):	3.0

- Higher N rate in spring had highest nitrate concentration
- At 150 lbs of N/A: no advantage to spring application, and no signif. effect of nitrif. inhibitor on nitrate drainage concentration

Randall and Sawyer. 2008. Pp. 73-85 in UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). 2008. Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. St. Joseph, Michigan: ASABE.

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N Time and Nitrification Inhibitor Affect Corn Yield and Nitrate Drainage Concentration (MN)

Table 6-5. Corn production and nitrate loss as affected by time of anhydrous application and N-Serve at Waseca, 1987-1993 (adapted from Randall et al., 2003a, 2003b).

Nitrogen Treatment		Seven-Year Average			Flow-Weighted
Time	N-Serve	Corn Yield (bu ac^{-1})	N Recovery[a] (%)	Economic Return to N[b] ($ ac^{-1})	NO_3-N Concentration in Tile Drainage[c] (mg L^{-1})
Fall	No	131	31	34	16.8
Fall	Yes	139	37	43	13.7
Spring	No	139	40	47	13.7
Split	No	145	44	56	14.6
LSD (0.10):		4			

[a] N recovery = (N content in grain - N content in grain from 0 lb check) / fertilizer N rate.

[b] Based on corn = $2.00 bu^{-1}, fall N = $0.25 lb^{-1}, spring N = $0.275 lb^{-1}, N-Serve = $7.50 ac^{-1}, and application cost = $4.00 ac^{-1} $time^{-1}$.

[c] Across the four-cycle corn (1990-1993) - soybean (1991-1994) rotation.

- 150 lbs N/A as anhydrous in all treatments
- Only modest reductions in nitrate concentration in drainage with nitrification inhibitor use in the fall
- Best yield with spring split applic.,… with modest nitrate conc. reduction

Randall and Sawyer. 2008. Pp. 73-85 in UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). 2008. Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. St. Joseph, Michigan: ASABE.

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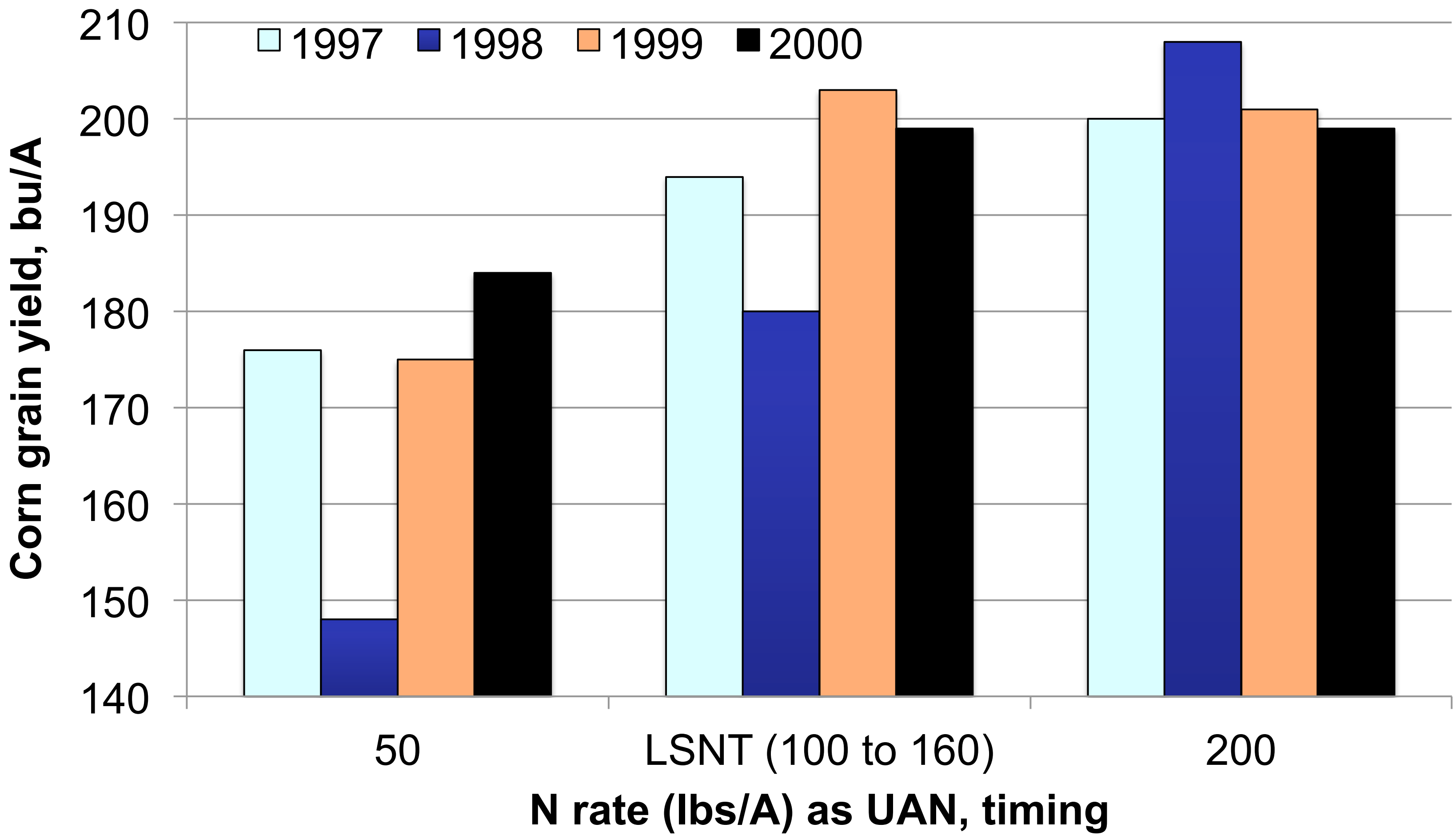
Corn Response to Late-Spring Nitrogen Management in the Walnut Creek Watershed (IA)



*50 as spring preplant; other as sidedress. 200 considered "non-limiting)

Karlen et al. 2005. Agron. J. 97:1054-1061

Corn Response to Late-Spring Nitrogen Management in the Walnut Creek Watershed (IA)

- "….. Watershed-scale implementation of the LSNT can reduce nitrate loss through drainage water, it may also increase producer risk, especially when above-normal rainfall occurs shortly after the sidedress N fertilizer is applied"
- "To encourage adoption of the LSNT program for its water quality benefits, we suggest that federal, state, or private agencies develop affordable risk insurance to help producers minimize the potential crop risk associated with this program"

Karlen et al. 2005. Agron. J. 97:1054-1061

Iowa Nutrient Science Assessment - 2012

Nitrogen Reduction Scenarios

	Practice/Scenario	Nitrate-N Reduction % (from baseline)
Nitrogen Management	Baseline	
	Cover crops (rye) on ALL CS and CC acres	28
	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
	Cover crops (rye) on all no-till acres	6
	Sidedress all spring applied N	4
	Using a nitrification inhibitor with all fall applied fertilizer	1
	Moving fall anhydrous fertilizer application to spring preplant	0.1

Target Load Reduction from NPS for Hypoxia Goal ~41%

Source: M Helmers, Iowa State U.

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Iowa Nutrient Science Assessment - 2012

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)
	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

Source: M Helmers, Iowa State U.

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Iowa Nutrient Science Assessment - 2012

Combined Nitrogen Reduction Scenarios - EXAMPLES

	Scenario	Practice/Scenario	Nitrate-N Reduction	Phosphorus Reduction
			% (from baseline)	% (from baseline)
Combination Scenarios	BS	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
	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
	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 a wetland, and 70% of all agricultural streams have a buffer)	42	20

Target Load Reduction from NPS for Hypoxia Goal ~41%

Source: M Helmers, Iowa State U.

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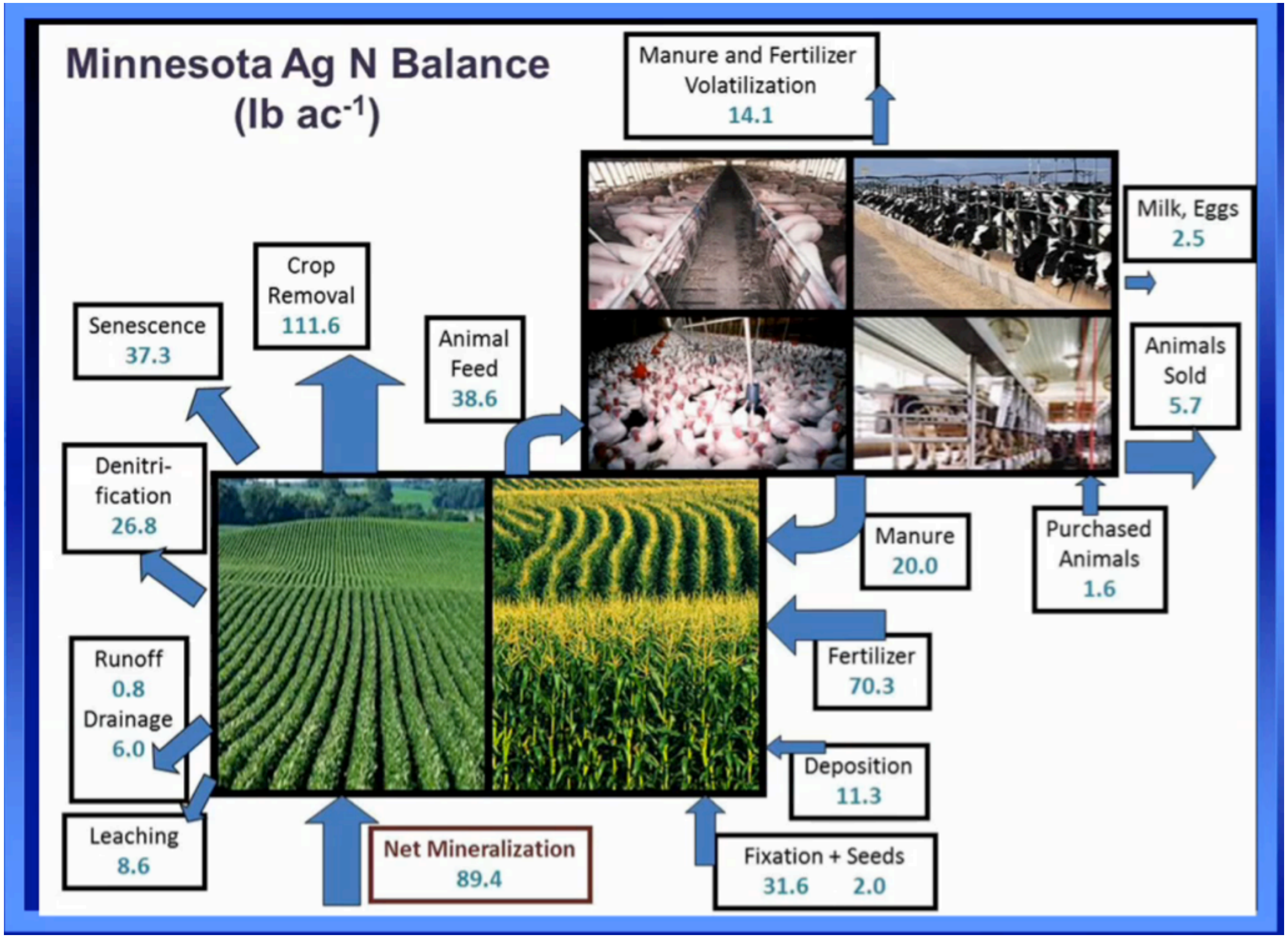
A Nonpoint Source Nitrogen Reduction Plan for Minnesota Surface Waters



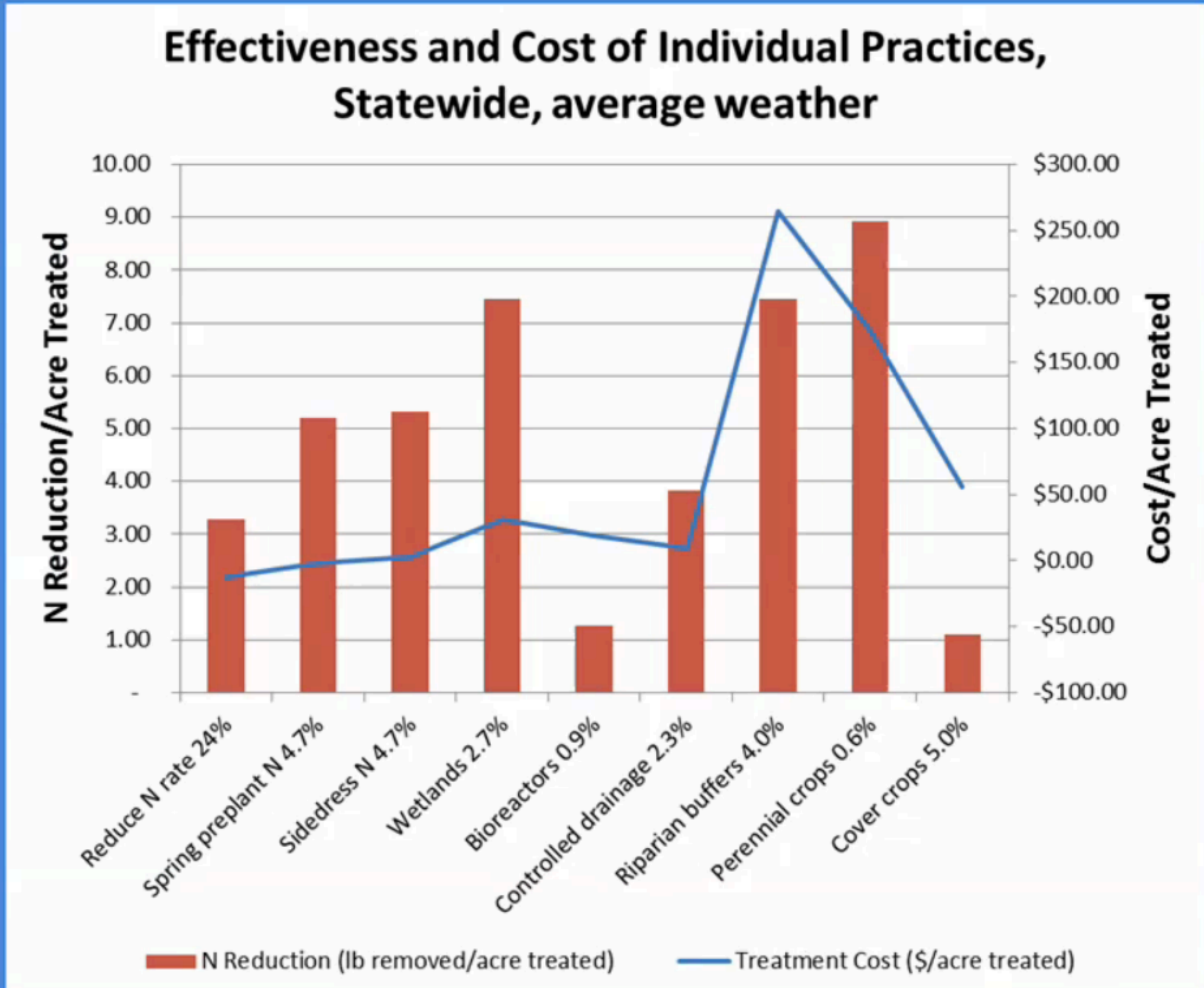
Dave Mulla. 2014. ASA-CSSA-SSSA meetings. Long Beach, CA
https://scisoc.confex.com/scisoc/2014am/videogateway.cgi/id/22143?recordingid=22143

A Nonpoint Source Nitrogen Reduction Plan for Minnesota Surface Waters

Suitable Acres for BMPs

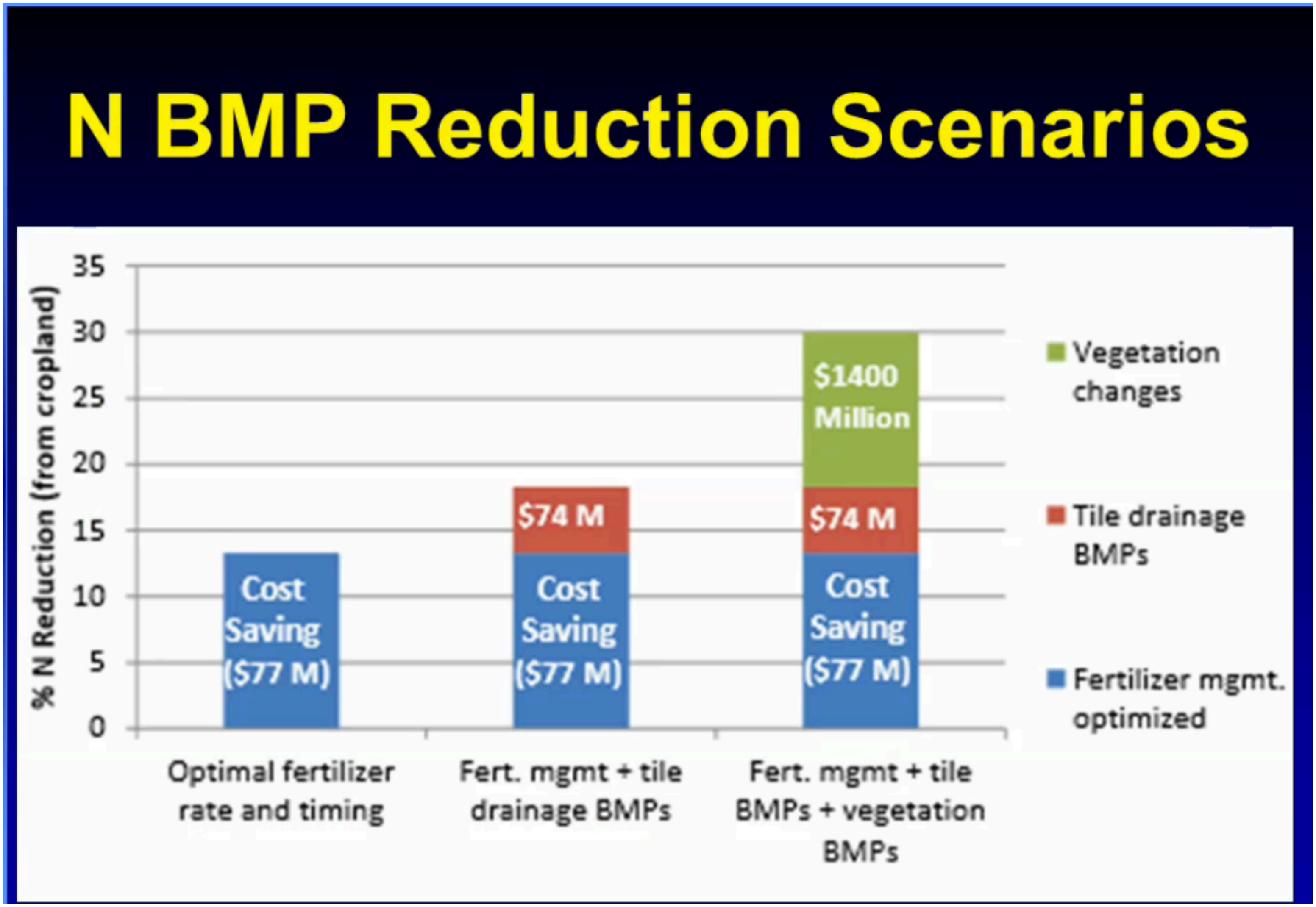
- Fertilizer rate reductions are only possible in areas where existing application rates exceed University recommendations
- Controlled drainage and bioreactors can be installed on tile drained land with slopes of 0.5%, 1% or 2%
- Perennial grass can be planted on ag land with crop productivity ratings of 60% or less (marginal land)
- Riparian buffers can be installed on ag land within 30 m of waterways
- Wetlands can be restored on tile drained land with hydric soils and high Compound Topographic Index values

A Nonpoint Source Nitrogen Reduction Plan for Minnesota Surface Waters.



"Effectiveness" is expressed as the area normalized N load reduction. "Normalized Cost" is expressed per acre.

A Nonpoint Source Nitrogen Reduction Plan for Minnesota Surface Waters.



A Nonpoint Source Nitrogen Reduction Plan for Minnesota Surface Waters

Science Assessment to Support an Illinois Nutrient Loss Reduction Strategy

	Practice/Scenario	Nitrate-N reduction per acre (%)	Nitrate-N reduced (million lb N)	Nitrate-N Reduction % (from baseline)	Cost ($/lb N removed)
	Baseline		410		
In-field	Reducing N rate from background to the MRTN (10% of acres)	10	2.3	0.6	-4.25
	Nitrification inhibitor with all fall applied fertilizer on tile-drained corn acres	10	4.3	1.0	2.33
	Split (50%) fall and spring (50%) on tile-drained corn acres	7.5 to 10	13	3.1	6.22
	Fall to spring on tile-drained corn acres	15 to 20	26	6.4	3.17
	Cover crops on all corn/soybean tile-drained acres	30	84	20.5	3.21
	Cover crops on all corn/soybean non-tiled acres	30	33	7.9	11.02
Edge-of-field	Bioreactors on 50% of tile-drained land	40	56	13.6	1.38
	Wetlands on 25% of tile-drained land	40	28	6.8	5.06
	Buffers on all applicable crop land (reduction only for water that interacts with active area)	90	36	8.7	1.63

Mark David. 2014. ASA-CSSA-SSSA meetings. Long Beach, CA
https://scisoc.confex.com/scisoc/2014am/videogateway.cgi/id/20740?recordingid=20740

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Science Assessment to Support an Illinois Nutrient Loss Reduction Strategy

	Practice/Scenario	Nitrate-N reduction per acre (%)	Nitrate-N reduced (million lb N)	Nitrate-N Reduction % (from baseline)	Cost ($/lb N removed)
	Baseline		410		
Land use change	Perennial/energy crops equal to pasture/hay acreage from 1987	90	10	2.6	9.34
	Perennial/energy crops on 10% of tile-drained land	90	25	6.1	3.18
Point source	Point source reduction to 10 mg nitrate-N/L		14	3.4	3.30
	Point source reduction in N due to biological nutrient removal for P		8	1.8	

Mark David. 2014. ASA-CSSA-SSSA meetings. Long Beach, CA
https://scisoc.confex.com/scisoc/2014am/videogateway.cgi/id/20740?recordingid=20740

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Name	Combined Practices and/or Scenarios	Nitrate-N (% reduction)	Total P (% reduction)	Cost of Reduction ($/lb)	Annualized Costs (million $/year)
NP1	MRTN, fall to spring, bioreactors 50%, wetlands 25%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding > T, buffers on all applicable lands, point source to 1.0 mg TP/L and 10 mg nitrate-N/L	35	45	**	383
NP2	MRTN, fall to spring, bioreactors 50%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding > T, cover crops on all CS, point source to 1.0 mg TP/L and 10 mg nitrate-N/L	45	45	**	810
NP3	MRTN, fall to spring, bioreactors 15%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding > T, cover crops on 87.5% of CS, buffers on all applicable lands, perennial crops on 1.6 million ac >T, and 0.9 million additional ac.	45	45	**	791
NP4	MRTN, fall to spring N, bioreactors 35%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding > T, buffers on 80% of all applicable land	20	20	**	48
NP5	MRTN, fall to spring N, bioreactors 30%, wetlands 15%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding > T, point source to 1.0 mg TP/L and 10 mg nitrate-N/L on 45% of discharge	20	20	**	66
NP6	MRTN, fall to spring N, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding > T, cover crops on 1.6 million ac eroding >T and 40% of all other CS	24	20	**	244

Mark David. 2014. ASA-CSSA-SSSA meetings. Long Beach, CA
https://scisoc.confex.com/scisoc/2014am/videogateway.cgi/id/20740?recordingid=20740

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Mark David's Conclusions for Illinois

- no simple solution, or one method to achieve goals
- will take a range of point and non point source reductions to meet targets
- initial focus could be:
  - point source P reductions ($114 million per year)
  - tile-drained nitrate reductions by agriculture (range of costs)
- strategy will get us started

Mark David. 2014. ASA-CSSA-SSSA meetings. Long Beach, CA
https://scisoc.confex.com/scisoc/2014am/videogateway.cgi/id/20740?recordingid=20740

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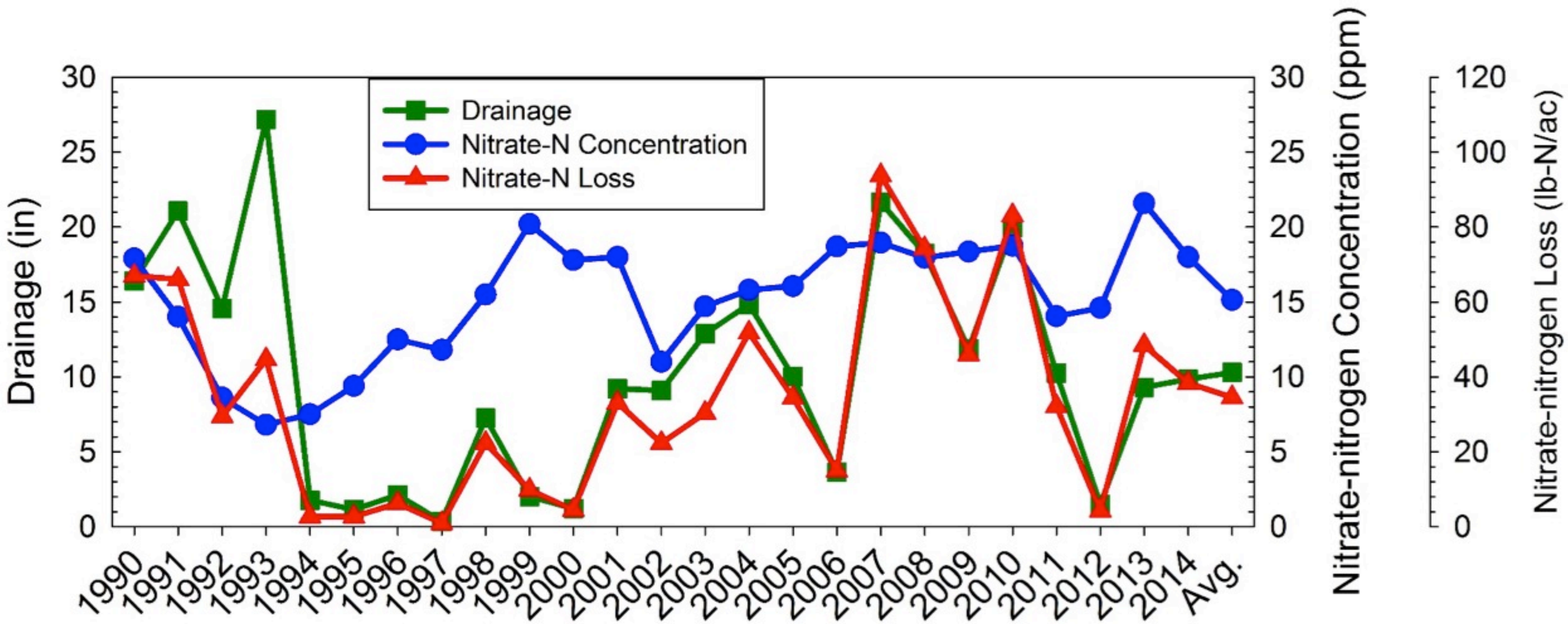
Variability in Drainage, Nitrate Concentration and Nitrate Loss – Weather a Major Driver



Corn-Soybean Rotation 150/160 lb-N/acre Application Rate

Corn Yield and Nitrate Loss in Subsurface Drainage Affected by Timing of Anhydrous Ammonia Application

Table 3. Flow-weighted annual nitrate concentration in tile drainage for each treatment for 2010–2013 and averaged for all 4 yr.

Treatment†	2010-corn	2011-soybean	2012-corn	2013-soybean	Avg.
	mg N L^{-1}				
FH	24.2a‡	35.4a	32.4a	21.1a	28.3a
F	10.7b	9.0b	16.0b	11.6c	11.8b
PP	6.9c	6.0b	10.7c	11.4c	8.8d
SD	6.8c	7.6b	11.9c	13.8b	10.0c
Avg.	10.7A	12.5A	16.1A	14.1A	

† Treatments are FH– very high N rate applied in fall, F– fall-applied N, PP– N applied preplant, and SD– N applied as sidedress.

‡ Numbers within a column followed by the same lowercase letter and numbers within a row followed by the same uppercase letter are not significantly different ($P \leq 0.05$).

Dan Jaynes. USDA ARS. Iowa. 2015. Soil Sci. Soc. Am. J. 79:1131–1141

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Table 4. Annual nitrate load in tile drains by treatment for 2010–2013 and averaged for the 4 yr.

Treatment†	2010-corn	2011-soybean	2012-corn	2013-soybean	Avg.
	kg N ha^{-1}				
FH	80.9a‡	73.8a	9.8a	38.2a	50.7a
F	37.7b	15.8b	3.1b	17.1c	18.4b
PP	27.6b	12.8b	2.6b	19.6c	15.7b
SD	28.1b	19.4b	5.4ab	25.2b	19.5b
Avg.	39.3A	26.8AB	5.0C	24.6B	

† Treatments are FH– very high N rate applied in fall, F– fall-applied N, PP– N applied preplant, and SD– N applied as sidedress.

‡ Numbers within a column followed by the same lowercase letter and numbers within a row followed by the same uppercase letter are not significantly different ($P \leq 0.05$).

F and PP yields (~234 bu/A) not significantly different, but lower than FH and SD yields (>260 bu/A)

Dan Jaynes. USDA ARS. Iowa. 2015. Soil Sci. Soc. Am. J. 79:1131–1141

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Impacts of 4R Nitrogen Management on Crop Production and Nitrate-Nitrogen Loss in Tile Drainage

Table 1. Treatments at the Northwest Iowa Tile Drain Water Quality Study Site.

Treatment Number	Tillage	Nitrogen Application Time	Nitrogen Application Rate (lb N/acre)*
1	Conventional tillage**	Fall (Anhydrous Ammonia with nitrapyrin)	135
2	Conventional tillage	Spring (Anhydrous Ammonia)	135
3	Conventional tillage	Split with variable N at sidedress (40 lb/acre of UAN at planting plus in-season adjusted rate no later than mid-vegetative growth stage)	Yearly variable based on in-season adjusted rate
4	Conventional tillage	None	0

* For corn plots only. The 135 lb N/acre rate is based on the Corn Nitrogen Rate Calculator output for corn following soybean in Iowa at a 0.10 price ratio (http://extension.agron.iastate.edu/soilfertility/nrate.aspx).

** Fall chisel corn stalks with spring disk/field cultivate, and spring disk/field cultivate soybean stubble.

IPNI-2014-USA-4RN16. http://research.ipni.net/page/RNAP-6408

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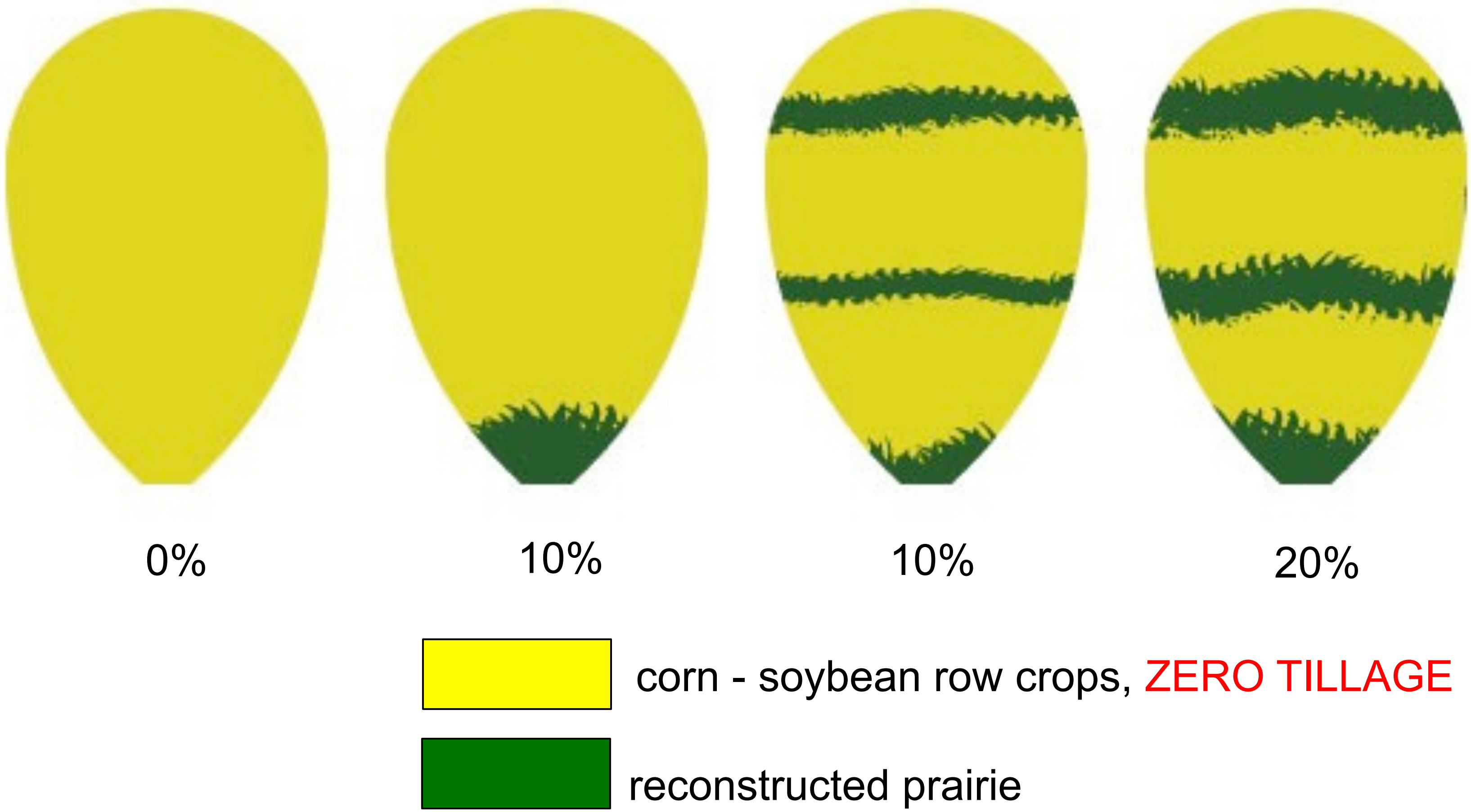
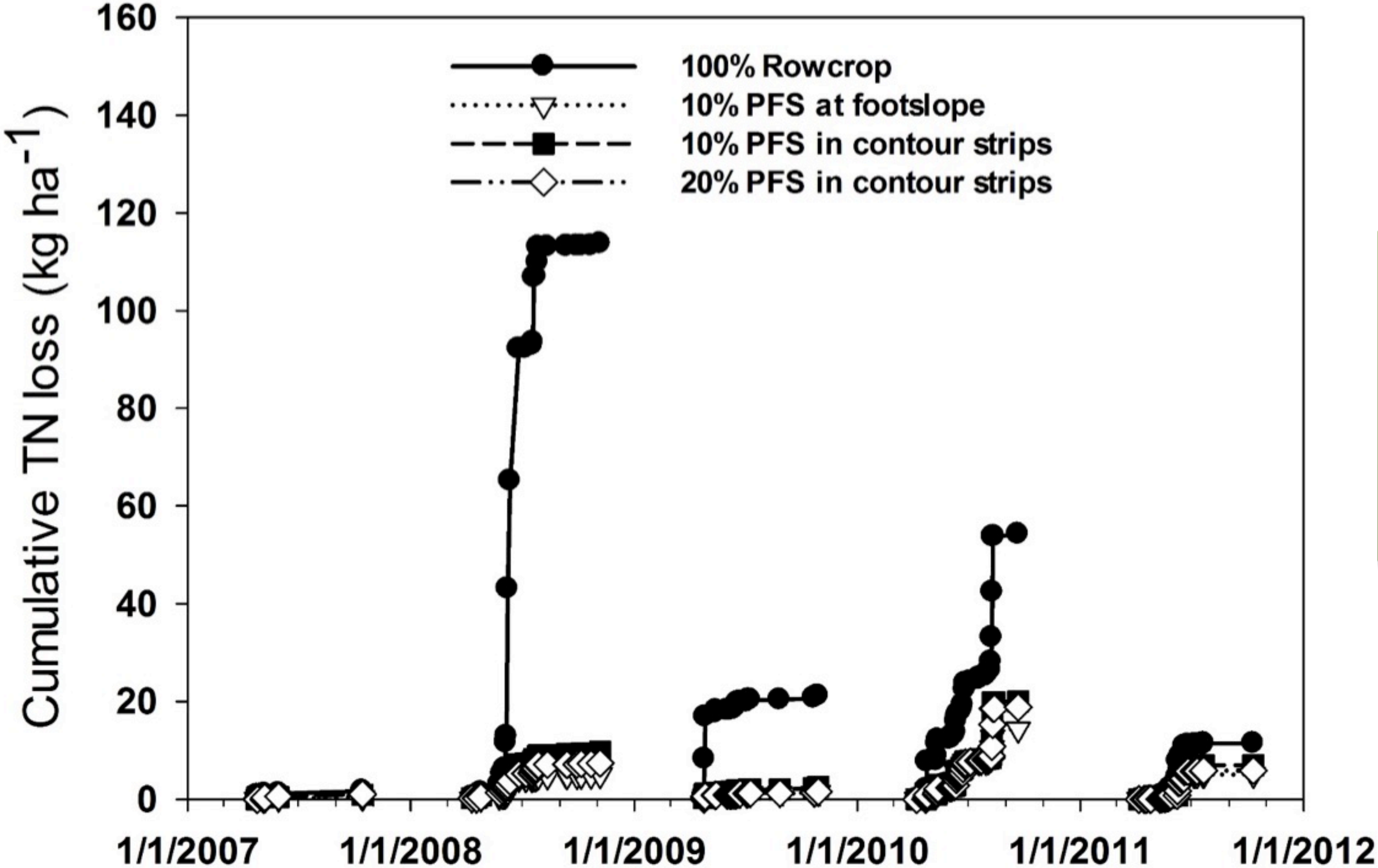
Experimental Watershed Treatments

12 watersheds:



Iowa State U., M. Helmers. Edge of Field Conf. Dec. 2015

Total Nitrogen Loss in Runoff (2007-2011)

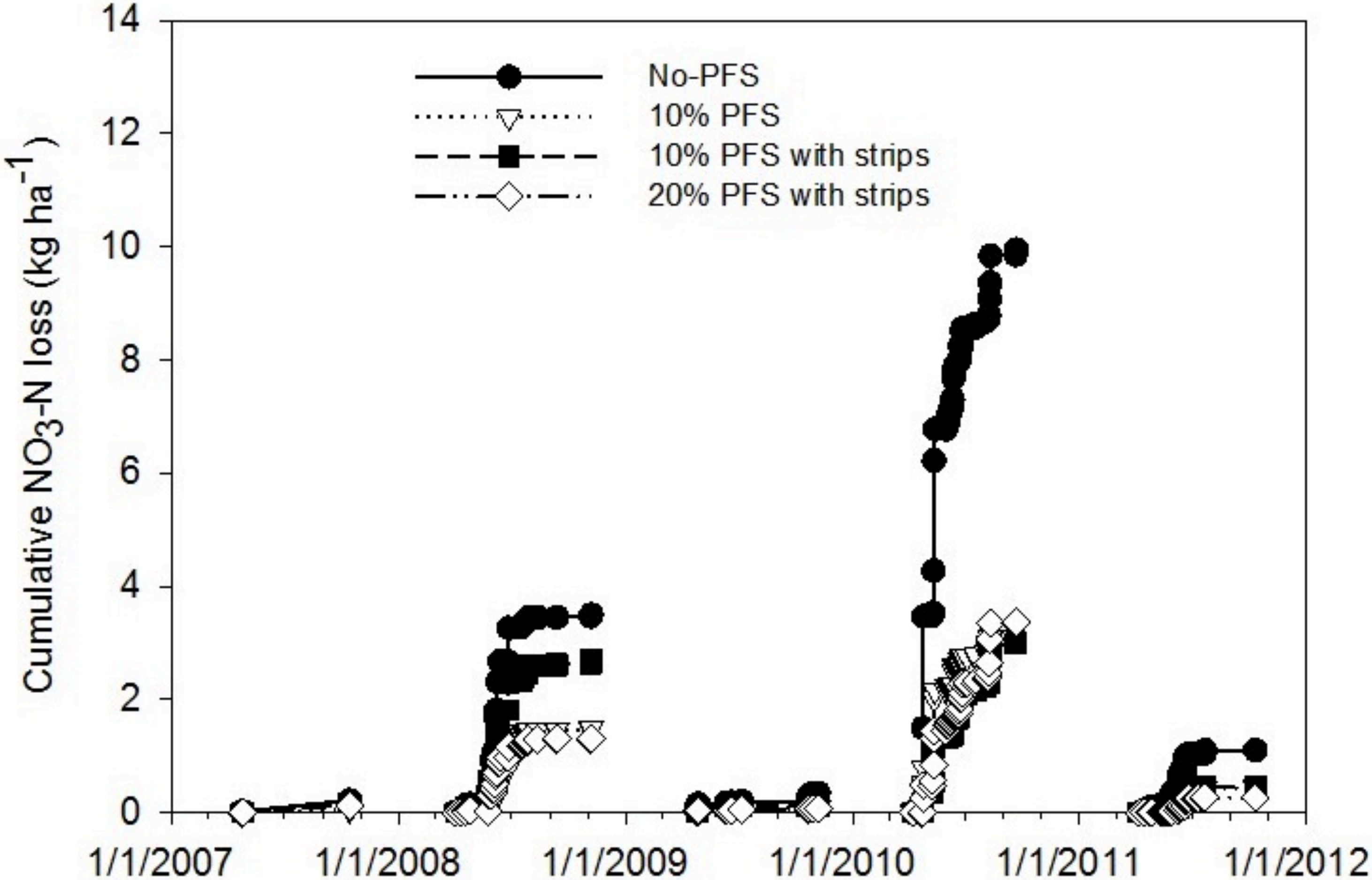


>90% Reduction in TN export from watersheds with prairie filter strips

Zhou et al., 2014

Iowa State U., M. Helmers. Edge of Field Conf. Dec. 2015

Nitrate-N Loss in Runoff (2007-2011)



Zhou et al., 2014

Iowa State U., M. Helmers. Edge of Field Conf. Dec. 2015

Summary

- In Iowa, on average the majority of drainage and nitrate-N loss occurs in April-June
- Timing of nitrogen application (fall or early season sidedress) had little impact on nitrate-N concentrations in drainage
- In north-central Iowa, winter cereal rye cover crops reduced nitrate-N concentration in subsurface drainage by ~25%
- Strategically sited prairie strips hold potential for reducing surface runoff and loss of sediment and nutrients with surface runoff

Full COSUST paper available online at:

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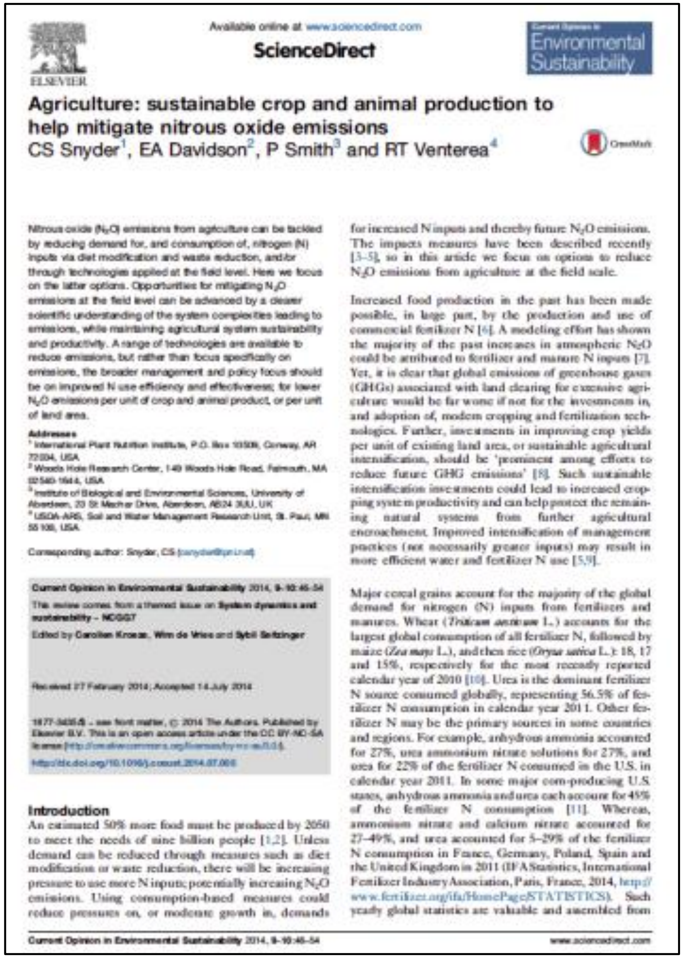

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Current Opinion in Environmental Sustainability

Agriculture: sustainable crop and animal production to help mitigate nitrous oxide emissions

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Nitrous oxide (N_2O) emissions from agriculture can be tackled by reducing demand for, and consumption of, nitrogen (N) inputs via diet modification and waste reduction, and/or through technologies applied at the field level. Here we focus on the latter options. Opportunities for mitigating N_2O emissions at the field level can be advanced by a clearer scientific understanding of the system complexities leading to emissions, while maintaining agricultural system sustainability and productivity. A range of technologies are available to reduce emissions, but rather than focus specifically on emissions, the broader management and policy focus should be on improved N use efficiency and effectiveness; for lower N_2O emissions per unit of crop and animal product, or per unit of land area.

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Introduction

An estimated 50% more food must be produced by 2050 to meet the needs of nine billion people [1,2]. Unless demand can be reduced through measures such as diet modification or waste reduction, there will be increasing pressure to use more N inputs; potentially increasing N_2O emissions. Using consumption-based measures could reduce pressures on, or moderate growth in, demands for increased N inputs and thereby future N_2O emissions. The impacts measures have been described recently [3–5], so in this article we focus on options to reduce N_2O emissions from agriculture at the field scale.

Increased food production in the past has been made possible, in large part, by the production and use of commercial fertilizer N [6]. A modeling effort has shown the majority of the past increases in atmospheric N_2O could be attributed to fertilizer and manure N inputs [7]. Yet, it is clear that global emissions of greenhouse gases (GHGs) associated with land clearing for extensive agriculture would be far worse if not for the investments in, and adoption of, modern cropping and fertilization technologies. Further, investments in improving crop yields per unit of existing land area, or sustainable agricultural intensification, should be 'prominent among efforts to reduce future GHG emissions' [8]. Such sustainable intensification investments could lead to increased cropping system productivity and can help protect the remaining natural systems from further agricultural encroachment. Improved intensification of management practices (not necessarily greater inputs) may result in more efficient water and fertilizer N use [5,9].

Major cereal grains account for the majority of the global demand for nitrogen (N) inputs from fertilizers and manures. Wheat (*Triticum aestivum* L.) accounts for the largest global consumption of all fertilizer N, followed by maize (*Zea mays* L.), and then rice (*Oryza sativa* L.): 18, 17 and 15%, respectively for the most recently reported calendar year of 2010 [10]. Urea is the dominant fertilizer N source consumed globally, representing 56.5% of fertilizer N consumption in calendar year 2011. Other fertilizer N may be the primary sources in some countries and regions. For example, anhydrous ammonia accounted for 27%, urea ammonium nitrate solutions for 27%, and urea for 22% of the fertilizer N consumed in the U.S. in calendar year 2011. In some major corn-producing U.S. states, anhydrous ammonia and urea each account for 45% of the fertilizer N consumption [11]. Whereas, ammonium nitrate and calcium nitrate accounted for 27–49%, and urea accounted for 5–29% of the fertilizer N consumption in France, Germany, Poland, Spain and the United Kingdom in 2011 (IFA Statistics, International Fertilizer Industry Association, Paris, France, 2014, http://www.fertilizer.org/ifa/HomePage/STATISTICS). Such yearly global statistics are valuable and assembled from

Recent Examples of N Management Changes on N_2O Emission Reduction (1 of 4)

Comparison technology or N practice	Reference technology or fertilizer N practice	Emission reduction (%)	Comment [COSUST paper reference]
Urea with urease inhibitor (UI)	Urea alone	Nil	Meta analysis; 35 studies [36] [1]
Nitrification inhibitor (NI) or polymer coated urea (PCU)	Conventional N, no inhibitor or polymer coating	35-38	
Urea	Anhydrous ammonia	50	15-yr.-old corn-soybean system [33] [2]
Change in time, source, place	Standard or reference N management	20-80	Summary of >20 studies [37] [1]
Urea ammonium nitrate (UAN) with NI	UAN with no inhibitor	19-67	Side-dressed UAN, subsurface colter-applied at V4-V6 [41] [2]

[1] range of agricultural crops [2] corn (maize)

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Recent Examples of N Management Changes on N_2O Emission Reduction (2 of 4)

Comparison technology or N practice	Reference technology or fertilizer N practice	Emission reduction (%)	Comment [COSUST paper reference]
Fertilizer N with UI and NI	Fertilizer N with no inhibitor	38	Meta analysis; 3 studies, 20 observations [42] [2]
Fertilizer placement >5cm deep	Fertilizer placement <5 cm deep	>30	Meta analysis; reduced tillage [26] [3]
Urea with NI	Urea with no inhibitor	81-100	Full growing season measurements (217–382 days); fertilizer banded >5 cm deep, 20 cm from plant row; clay loam soil . PSCU emissions lower than urea, first 20 days after application [43] [4]
Polymer sulfur coated urea (PSCU)	Urea with no coating	-35 to -46	

[2] corn (maize) [3] range of agricultural crops, excluding rice
[4] sugarcane, residue removed or burned

Recent Examples of N Management Changes on N_2O Emission Reduction (3 of 4)

Comparison technology or N practice	**Reference technology or fertilizer N practice**	**Emission reduction (%)**	**Comment [COSUST paper reference]**
Fertilizer N (including urea with UI and NI, urea–ammonium nitrate (UAN) with UI and NI, urea, UAN, ammonium nitrate, or PCU)	Poultry litter	46-81	Humid region; surface broadcast, not incorporated [39] [2]
Commercial fertilizer	Manure	40	Meta analysis; 9 studies, 73 observations [42] [2]
Calcium ammonium nitrate	Manure (poultry, or liquid swine, or liquid dairy)	54	Surface applied N, incorporated by tillage, day of application [40] [2]

[2] corn (maize)

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Recent Examples of N Management Changes on N_2O Emission Reduction (4 of 4)

Comparison technology or N practice	Reference technology or fertilizer N practice	Emission reduction (%)	Comment [COSUST paper reference]
UAN with UI and NI	UAN with no inhibitor	41	Full growing season N_2O measurements; irrigated; no-till and tilled; surface banded N near emerged corn row [35] [2]
	Urea with no inhibitor	61	
UAN with methylene urea & urea triazone	UAN	28	
	Urea	57	
PCU	UAN	14	
PCU	Urea	42	
Urea with UI and NI	Urea with no inhibitor	37	Dairy cows excluded 2 months prior; plant N recovery: 50 to 85% [38] [5]

[2] corn (maize)
[5] using perennial ryegrass (*Lolium perenne* L.)/white clover (*Trifolium repens* L.) pasture

N_2O Emissions vs. N Use Efficiency

- Cropping system NUE (*i.e. apparent N recovery*)
  - improvements at modest fertilizer N rates correlated strongly with reduced yield-scaled N_2O emissions (from meta analyses of 19 studies, 147 observations; van Groenigen et al., 2010)

Each point: average of 3 studies, 27 observations each

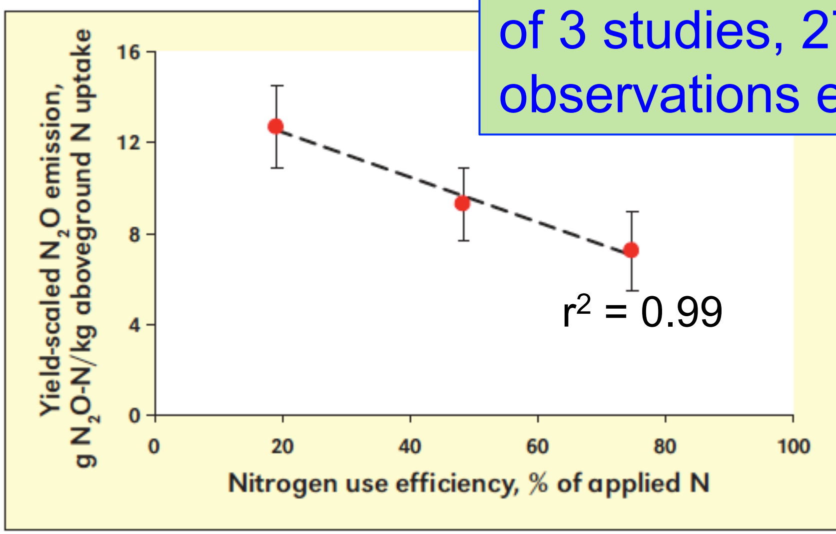


Figure 2. Meta-analysis results of the relationship between N use efficiency and yield-scaled N_2O emissions. NUE is expressed as apparent recovery efficiency (in %) of applied N.

van Groenigen, J.W., G.L. Velthof, O. Oenema, K.J. Van Groenigen, and C. Van Kessel. 2010. European Journal of Soil Science 61:903-913.

van Groenigen et al. 2011. Better Crops 95(2):16-17.

Invited Scientists Who Participated in IPNI-TFI-CFI March Nitrogen (N) Management Workshop

N Agronomists

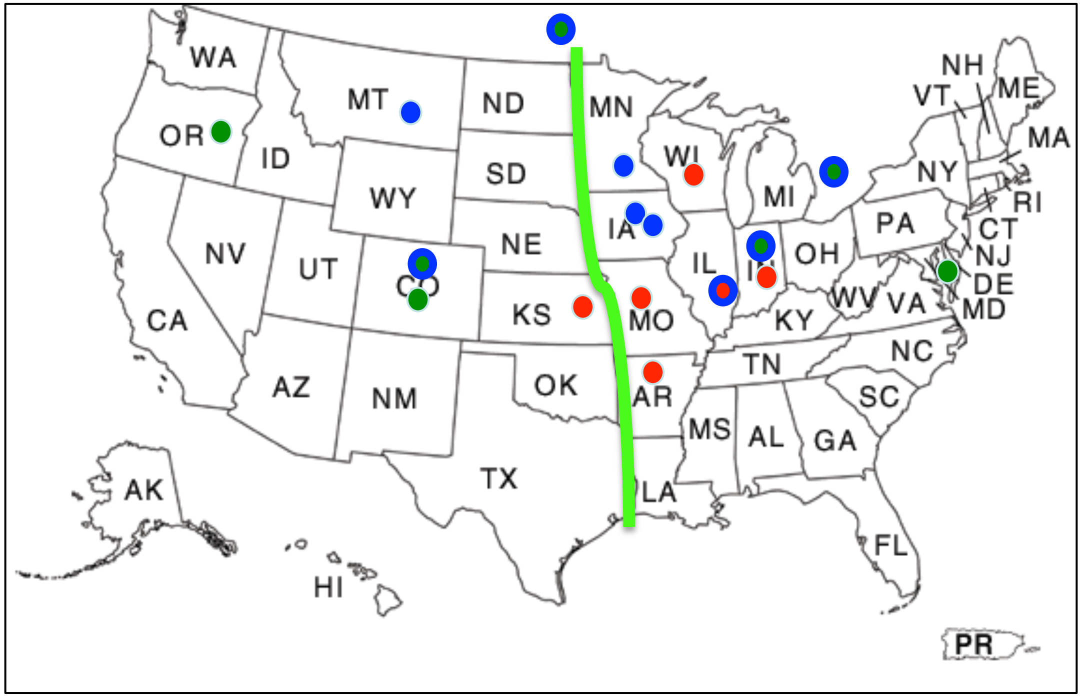
- Peter Scharf – U of MO
- Dave Franzen – ND State U
- Jim Camberato – Purdue U
- Dave Mengel – KS State U
- Carrie Laboski– U of WI
- Cameron Pittelkow – U of IL
- Trent Roberts – U of AR

N_2O Scientists

- Rick Engel – Montana State U.
- Rod Venterea – MN, USDA-ARS
- Tony Vyn- Purdue U
- Jerry Hatfield – IA, USDA-ARS
- Tim Parkin – IA, USDA ARS
- Keith Paustian/ Steve Ogle – CO State U.
- Steve Del Grosso – CO, USDA ARS
- Adam Chambers – OR, USDA NRCS
- Marlen Eve – DC, USDA Ofc. Chief Econ.

Canadian Scientists

- Claudia Wagner-Riddle - U of Guelph
- Mario Tenuta, U of MB
- David Burton, Dalhousie U (formerly Nova Scotia Ag. College
- Miles Dyck, U of Alberta



Scientific Advisory Group member

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DRAFT- 7 Corn, Soybean, Wheat Regional 3-Tiered 4R-N Management Frameworks

- Irrigated corn-soybean South
- Irrigated corn-soybean North
- Non-irrigated corn-soybean west
- Non-irrigated corn-soybean east
- Non-irrigated corn-soybean N. central upper Midwest (between east, west, and northern)
- Wheat – northern Great Plains
- Wheat – southern Great Plains

- Reviewed and modified in science breakouts; presented to March 2015 Workshop invited N scientists …. using a live "blind" voting process.
- **FRAMEWORKS (with basic, intermediate, and advanced N management for improved crop N recovery (i.e. NUE)) …… UNANIMOUSLY APPROVED**

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3-Tiers of 4R-N Management

- Below Basic BMPs (best management practices)
  - **25%** of the growers
- **Basic**
  - practices adopted by approximately **50%**
- **Intermediate**
  - practices adopted by approximately **20%**
- **Advanced**
  - practices adopted by approximately **5%**

Example: Non-irrig. corn-soybean - East

Performance Level	Right Source	Right Rate	Right Time	Right Place	N_2O Red. %
Basic	• Guaranteed or book value for all sources applied • Urea, UAN, Anhydrous Ammonia, Manure	• Rate based on evidence recognized by regional soil fertility extension • Properly accounting for legume & Manure N	• Spring; not on frozen soil • Apply manure according to a manure management plan	• Broadcast and incorporated, injected or subsurface band • If broadcasted Urea accompanied by an inhibitor • UAN w/herbicide no more than 40 Lbs	?
Intermediate	• Guaranteed or known analysis for all sources applied; with nitrification inhibitor or controlled release if preplant; with urease inhibitor for urea/UAN surface applied sidedress	• Rate based on evidence recognized by regional soil fertility extension, including results of local adaptive management research. • Manure analysis required to determine rate	• Some or all applied nitrogen in season or if pre-plant used with NI or polymer-coated	• Broadcast and incorporated, injected or subsurface band, surface application allowed only for sidedress urea with UI or dribbled UAN	?
Advanced	• Guaranteed or known analysis; with nitrification inhibitor or controlled release if preplant; with urease inhibitor for urea/UAN sidedress	• Rate based on evidence recognized by regional soil fertility extension, or results of local adaptive management research, AND, in addition, addressing within-field and weather-specific variability using tools such as crop sensors, PSNT, models that allow adjustment of in-season N rates	• Some or all N applied in-season	• Broadcast and incorporated, injected or subsurface band, surface application allowed only for sidedress urea with UI or dribbled UAN	?

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Example: Non-irrig. corn-soybean - East

Performance Level	Right Source
Basic	• Guaranteed or book value for all sources applied • Urea, UAN, Anhydrous Ammonia, Manure
Intermediate	• Guaranteed or known analysis for all sources applied; with nitrification inhibitor or controlled release if preplant; with urease inhibitor for urea/UAN surface applied sidedress
Advanced	• Guaranteed or known analysis; with nitrification inhibitor or controlled release if preplant; with urease inhibitor for urea/UAN sidedress

Example: Non-irrig. corn-soybean - East

Performance Level	Right Rate
Basic	• Rate based on evidence recognized by regional soil fertility extension • Properly accounting for legume & Manure N
Intermediate	• Rate based on evidence recognized by regional soil fertility extension, including results of local adaptive management research. • Manure analysis required to determine rate
Advanced	• Rate based on evidence recognized by regional soil fertility extension, or results of local adaptive management research, AND, in addition, addressing within-field and weather-specific variability using tools such as crop sensors, PSNT, models that allow adjustment of in-season N rates

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Example: Non-irrig. corn-soybean - East

Performance Level	Right Time
Basic	• Spring; not on frozen soil • Apply manure according to a manure management plan
Intermediate	• Some or all applied nitrogen in season or if pre-plant used with NI or polymer-coated
Advanced	• Some or all N applied in-season

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Example: Non-irrig. corn-soybean - East

Performance Level	Right Place
Basic	• Broadcast and incorporated, injected or subsurface band • If broadcasted Urea accompanied by an inhibitor • UAN w/herbicide no more than 40 Lbs
Intermediate	• Broadcast and incorporated, injected or subsurface band, surface application allowed only for sidedress urea with UI or dribbled UAN
Advanced	• Broadcast and incorporated, injected or subsurface band, surface application allowed only for sidedress urea with UI or dribbled UAN

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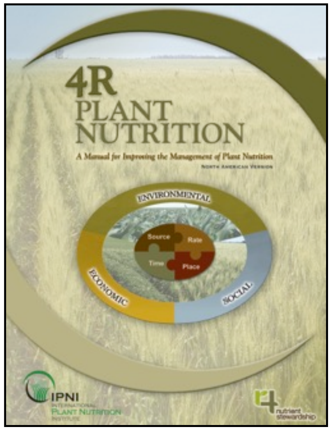
We Can Improve N Use Efficiency and Effectiveness

by implementing nutrient BMPs …

Right source @ Right rate,
Right time, and Right place

In conjunction with other proven conservation practices

4R Nutrient Stewardship



QUESTIONS ?

Better Crops, Better Environment … through Science

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IPNI 4R Research Projects and Reports
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