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Fertilizer BMPs to Minimize Impacts on Water Quality:

A Shared Vision

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Presented to
USDA-CSREES National Water Conference 2009

Brazil's Lula: food riots are wake-up call

Food and Agriculture Organization of the United Nations

for a world without hunger

Newsroom

UN warns of more food shortages without strong action

Madrid meeting takes on global food, nutrition and agriculture problems

Jacques Diouf (left) shakes hand with Spanish Minister of Foreign Affairs and Cooperation Miguel Angel Moratinos.

26 January 2009, Madrid - Chiefs of

Related links

- Final Statement of the Madrid High-Level Meeting on Food Security for All
- Director-General's statement
- Conference website

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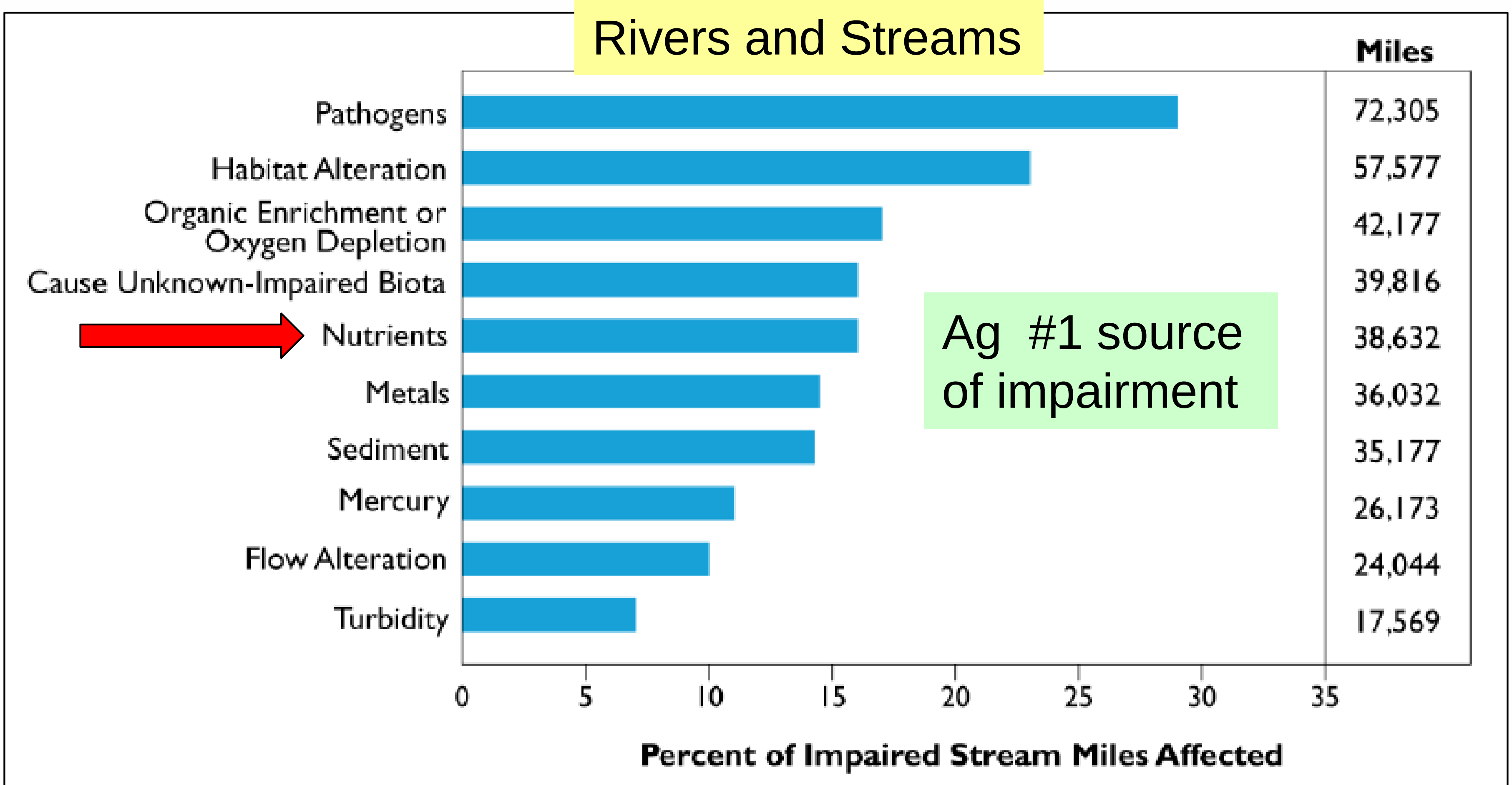
National Water Quality Inventory: Report to Congress 2004

Reporting Cycle January 2009



Rivers and Streams

Ag #1 source of impairment

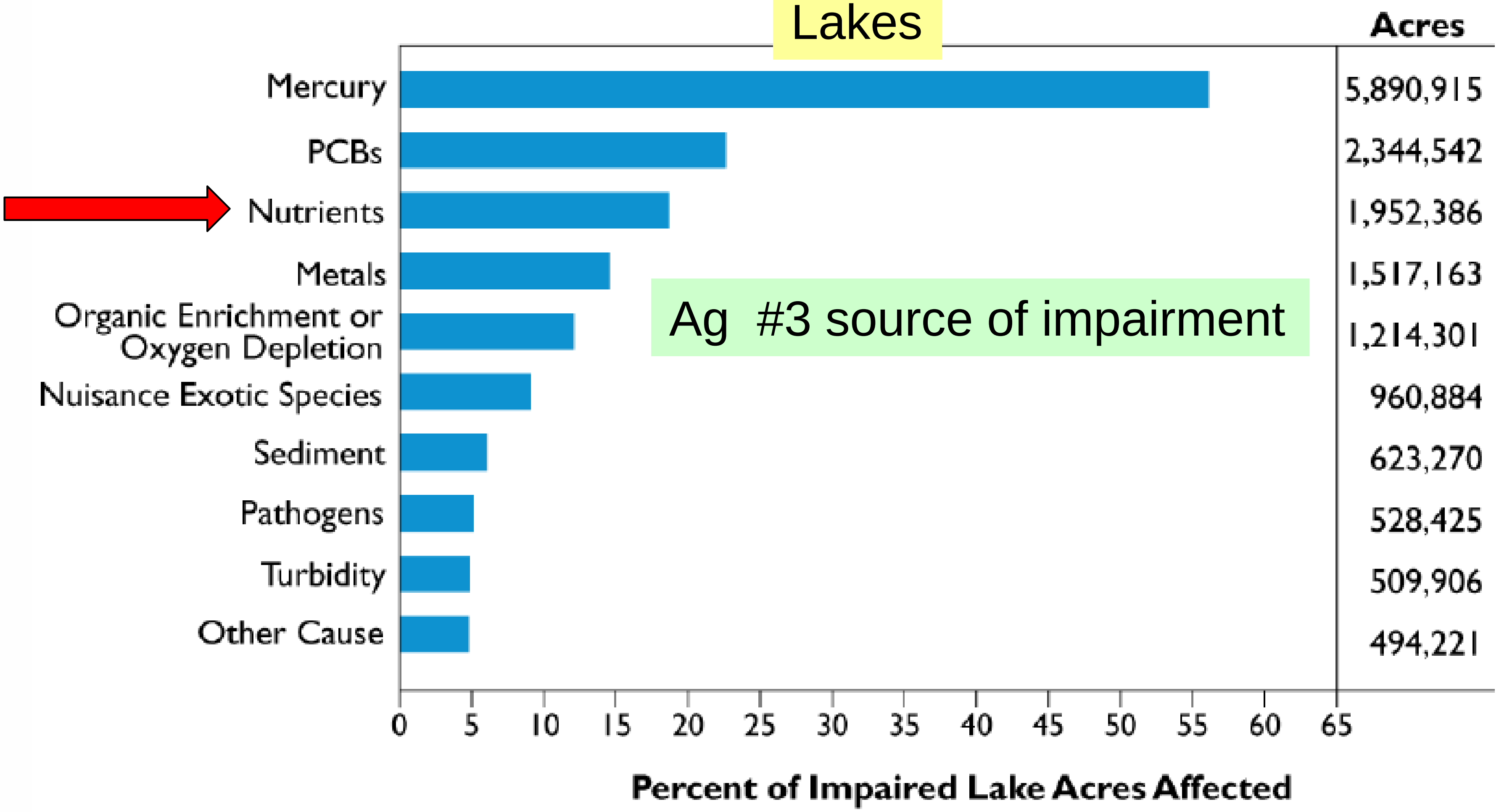
Note: Percents do not add up to 100% because more than one cause may impair a waterbody.

Figure 2. Top 10 causes of impairment in assessed rivers and streams.

http://www.epa.gov/owow/305b/2004report/

National Water Quality Inventory: Report to Congress 2004

Reporting Cycle January 2009



Lakes

Ag #3 source of impairment

Note: Percents do not add up to 100% because more than one cause may impair a waterbody.

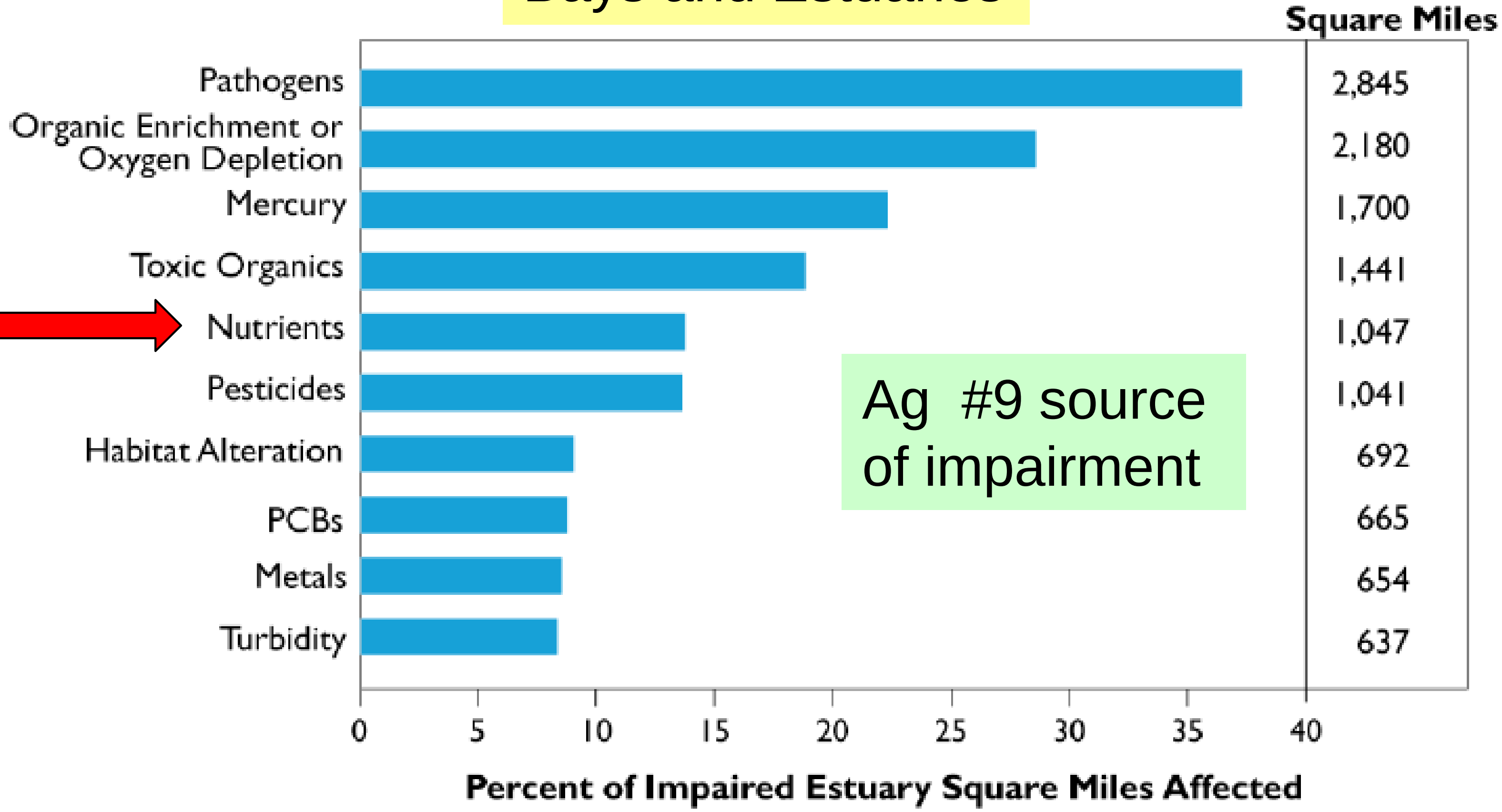
Figure 5. Top 10 causes of impairment in assessed lakes, ponds, and reservoirs.

http://www.epa.gov/owow/305b/2004report/

National Water Quality Inventory: Report to Congress 2004

Reporting Cycle January 2009

Bays and Estuaries



Ag #9 source of impairment

Note: Percents do not add up to 100% because more than one cause may affect a waterbody.

Figure 8. Top 10 causes of impairment in assessed bays and estuaries.

http://www.epa.gov/owow/305b/2004report/

The proportion of crop yields attributed to fertilizer ranges from 40 to 60%.

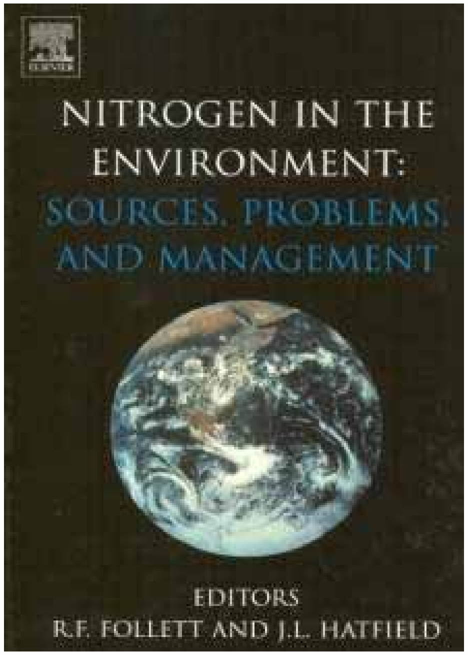
Stewart et al. Agron. J. 2005. 97:1-6.

Partial P and K budgets 1998-2000 average, except manure, which is 1997

						Removal to use ratio	
Nutrient	Region	Crop removal	Applied fertilizer	Recoverable manure	Balance	w/o manure	w/manure
		--------------- Metric tons ---------------					
P	USA	2.26	1.74	0.65	0.13	1.30	0.95
	6 lead corn states	1.02	0.60	0.17	-0.25	1.71	1.33
K	USA	7.28	3.81	1.43	-2.04	1.91	1.39
	6 lead corn states	2.49	1.55	0.38	-0.57	1.62	1.30

Kitchen and Goulding (2001) *in* Nitrogen in the Environment: Sources, Problems and Management

- **“ 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”**



NITROGEN IN THE ENVIRONMENT:
SOURCES, PROBLEMS, AND MANAGEMENT

EDITORS
R.F. FOLLETT AND J.L. HATFIELD

We can improve Nutrient Use Efficiency & Effectiveness

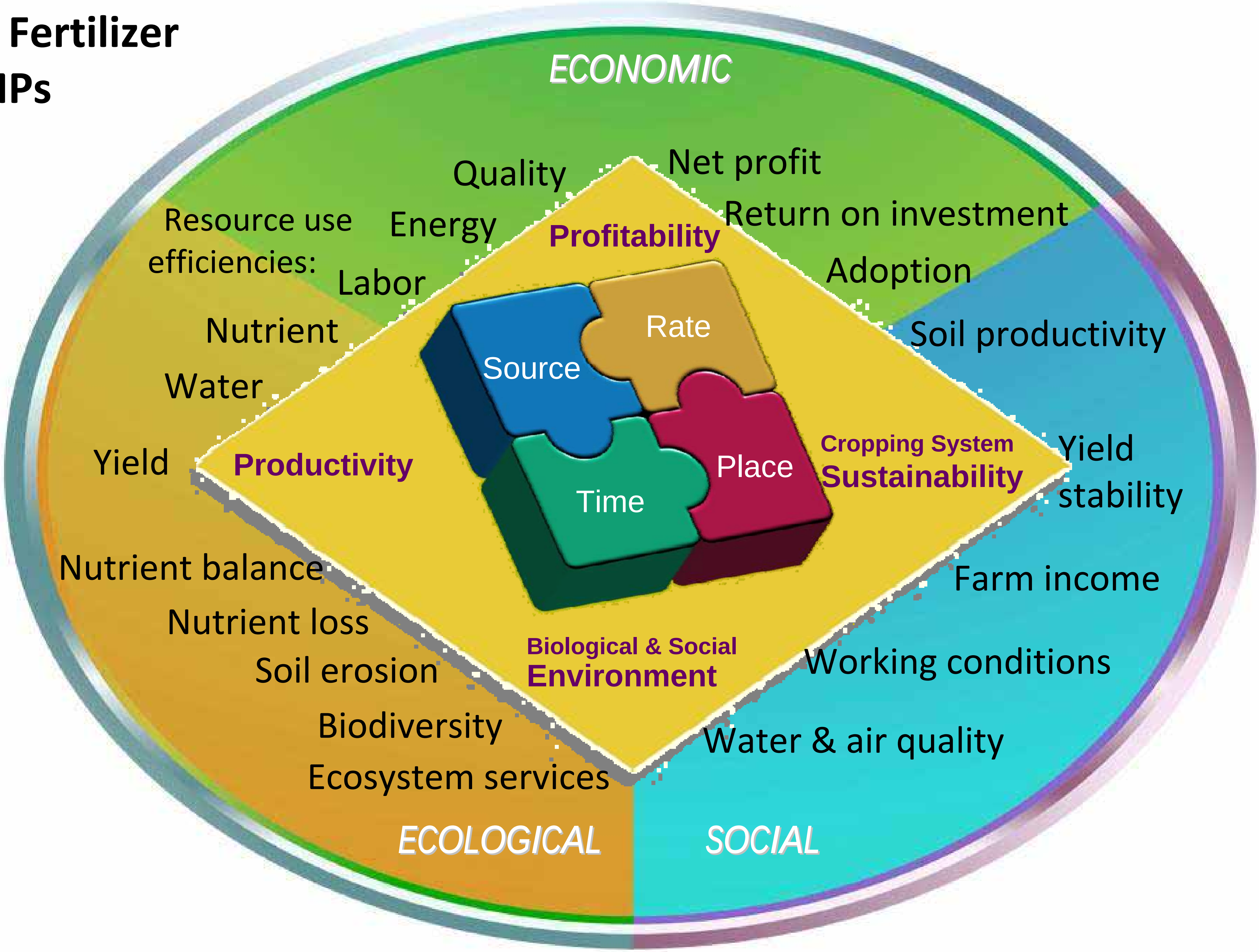
by implementing
Fertilizer BMPs …..

right source @ right rate @right time
& right placement

↓

4R Stewardship

Global Framework for Fertilizer BMPs



ECONOMIC

Quality

Net profit

Resource use efficiencies:

Energy

Return on investment

Labor

Adoption

Nutrient

Water

Soil productivity

Profitability

Rate

Source

Place

Time

Yield

Productivity

Cropping System

Sustainability

Yield stability

Farm income

Nutrient balance

Nutrient loss

Soil erosion

Biological & Social

Environment

Working conditions

Biodiversity

Water & air quality

Ecosystem services

ECOLOGICAL

SOCIAL

How Do You Define and Rate NUE?

Nutrient Use Efficiency and Effectiveness in North America:

Indices of Agronomic and Environmental Benefit

By C.S. Snyder and T.W. Bruulsema, International Plant Nutrition Institute

MINERAL FERTILIZERS have made it possible to sustain the world's growing population, sparing millions of acres of natural and ecologically-sensitive systems that otherwise would have been converted to agriculture[1]. Today, economic and environmental challenges are driving increased interest in nutrient use efficiency. Higher prices for both crops and fertilizers have heightened interest in efficiency-improving technologies and practices that also improve productivity. In addition, nutrient losses that harm air and water quality can be reduced by improving use efficiencies of nutrients, particularly for nitrogen (N) and phosphorus (P).

The world's population, growing in both numbers and purchasing power, is projected to consume more food, feed, fiber, and fuel—increasing global demand for fertilizer nutrients[2]. Since fertilizers are made from non-renewable resources, pressure to increase their use efficiencies will continue. At the same time, efforts should increase to enhance fertilizer use effectiveness for improved productivity and profitability of cropping systems.

System Efficiency

Efficiencies are generally calculated as ratios of outputs to inputs in a system. The "system" can be defined in many ways, depending on the interest of the observer.

Agricultural cropping systems contain complex combinations of components, including: soils, soil microbes, roots, plants, and crop rotations. Improvements in the efficiency of one component may or may not be effective in improving the efficiency of the cropping system. Efficiency gains in the short term may sometimes be at the expense of those in the long-term. Short-term reductions in application rates increase nutrient use efficiencies, even when yields decline. However, in the long-term, lower yields reduce production of crop residues, leading to increased erosion risks, decreased soil organic matter, and diminished soil productivity. Sustainable system efficiency demands attention to the long-term impacts.

Best management practices (BMPs) focus on the effectiveness of fertilizers and keeping them in the field for use by the intended crop in adapting cropping systems to the economic and environmental challenges noted above. Effectiveness is maximized when the most appropriate nutrient sources are applied at the right rate, time, and place in combination with conservation practices such as buffer strips, continuous no-till, cover crops, and riparian buffers within intensively managed cropping systems that achieve both increasing yields and diminishing nutrient losses[3]. This approach ensures that improvements to the nutrient use efficiency of the components contribute toward improving the efficiency of the entire system.

Many components contribute to the efficiency of a cropping system.

Because a cropping system includes multiple inputs and outputs, its overall efficiency depends on the science of economics. To maximize profit is to obtain the maximum value of outputs per unit value of all inputs. At the rate where the net return to the use of one input peaks, the input is making its maximum contribution to increasing the efficiency of all other inputs involved. Rates of nutrient application optimal for economic yields often minimize nutrient losses[4].

Component Efficiencies

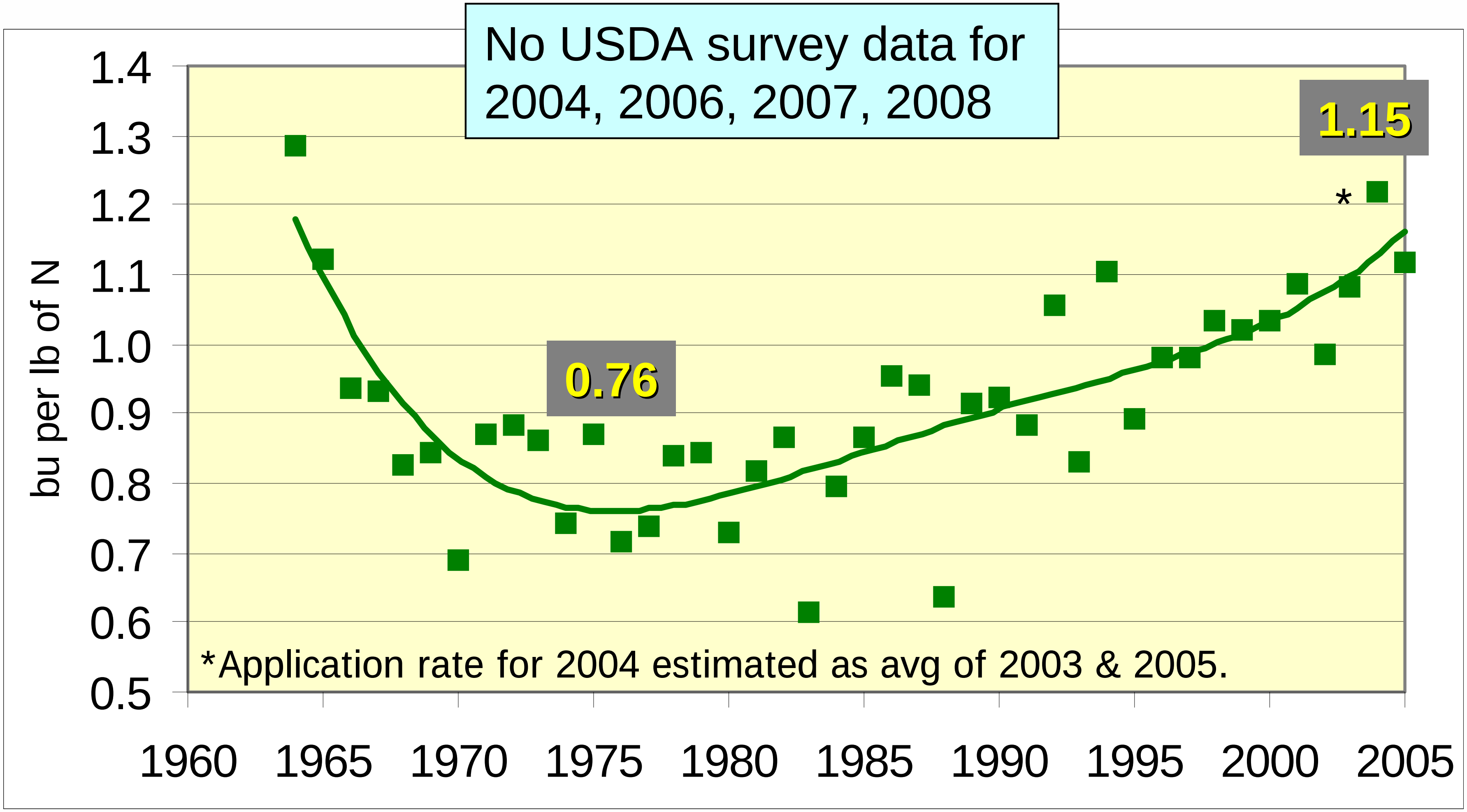
A recent review identified no fewer than 18 different definitions and calculations of nutrient use efficiency[5]. Even the most useful component efficiencies require careful interpretation if they are to contribute to effective nutrient use in cropping systems. In **Table 1**, we

http://www.ipni.net/ipniweb/portal.nsf/0/d58a3c2deca9d7378525731e006066d5/$FILE/Revised%20NUE%20update.pdf

NUE Term	Calculation	Reported Examples
PFP - Partial factor productivity	Y/F	**40 to 80** units of cereal grain per unit of N
AE - Agronomic Efficiency	$(Y-Y_0)/F$	**10 to 30** units of cereal grain per unit of N
PNB - Partial nutrient balance (removal to use ratio)	U_H/F	**0 to > 1.0** - depends on native soil fertility and fertility maintenance objectives **<1** in nutrient deficient systems (fertility improvement) **>1** in nutrient surplus systems (under replacement) **Slightly less than 1 to 1** (system sustainability)
RE – Recovery efficiency of applied nutrient	$(U-U_0)/F$	**0.1 to 0.3 -** proportion of P input recovered first year **0.5 to 0.9 -** proportion of P input recovered by crops in long-term cropping systems **0.3 to 0.5 -** N recovery in cereals-typical **0.5 to 0.8 -** N recovery in cereals- best management

F-amt. nutrient applied, Y- yield of harvested portion with applied nutrient, Y_0- yield of harvested portion with no applied nutrient, U_H –nutrient content of harvested portion of crop, U –total nutrient uptake in aboveground biomass with nutrient applied, U_0 –total nutrient uptake in aboveground biomass with no nutrient applied

Corn grain produced in the U.S. per unit of fertilizer N used, 1964 to 2005.



Since 1975: **51% increase in N efficiency**
12% increase in N fertilizer use

Data sources: USDA Ag Chem Use Survey & Annual Crop Production.

- Progress in protecting water quality and improving water use efficiency is most likely to occur through **system level changes which include fertilizer BMP implementation**, rather than through a focus on specific nutrient criteria or any one environmental indicator

- **Fertilizer N BMPs can help minimize the potential for residual NO_3-N accumulation & losses**

- **N source, rate, timing, and placement …. which may include**
  - **Urease inhibitors**
  - **Nitrification inhibitors**
  - **Slow-release materials**
  - **Controlled-release materials**
- **In combination with appropriate, site-specific cropping system and conservation practices**
  - **(e.g. conservation tillage, cover crops, vegetative buffers, managed drainage, wetlands, bioreactors, etc.)**

New Tools, Technologies, Opportunities ??

- John Deere - hi-speed (10 mph) anhydrous ammonia applicator
- Agrotain & Lange-Stegmann - $20 million Urea and Stabilized Nitrogen Center in St. Louis, MO
- Corn hybrids with improved N uptake/redistribution characteristics ???

2008 Joint Annual Meeting

Celebrating the International Year of Planet Earth

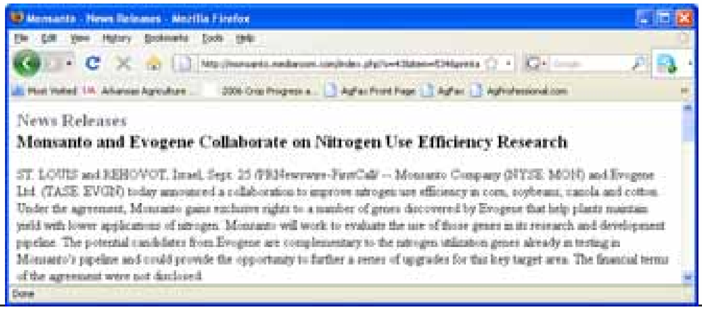
October 5-9 2008 Houston Texas

George R. Brown Convention Center

Wednesday, 8 October 2008

699-3

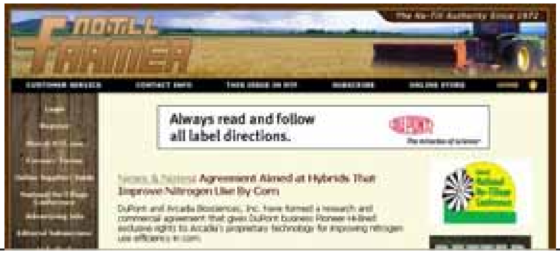
Enhancing Nitrogen Use Efficiency in Corn through Introgression of Low N Tolerance from Eastern Gamagrass.



News Releases

Monsanto and Evogene Collaborate on Nitrogen Use Efficiency Research

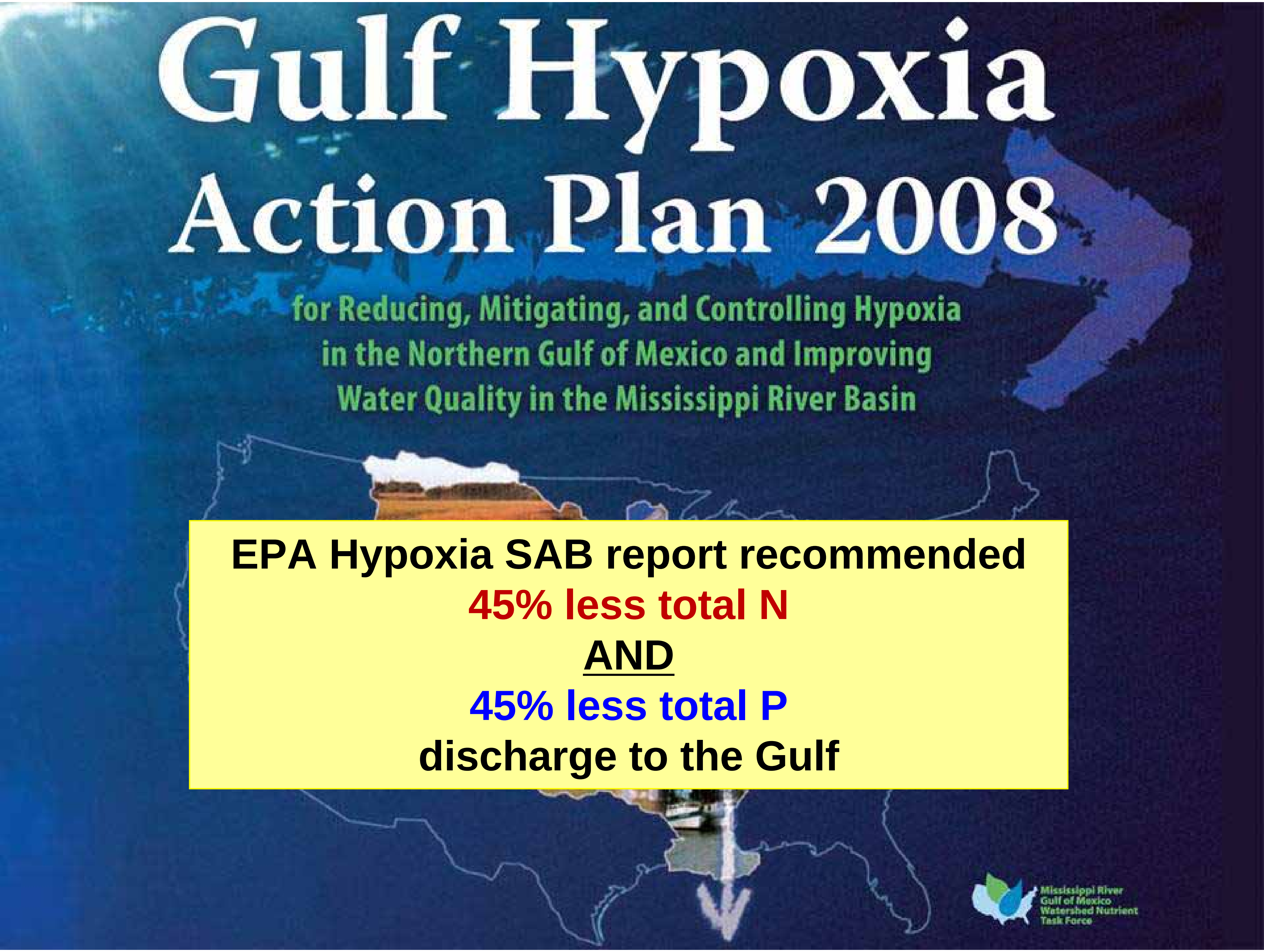
ST. LOUIS and REHOVOT, Israel, Sept. 25 /PRNewswire-FirstCall/ -- Monsanto Company (NYSE: MON) and Evogene Ltd. (TASE: EVGN) today announced a collaboration to improve nitrogen use efficiency in corn, soybeans, canola and cotton. Under the agreement, Monsanto gains exclusive rights to a number of genes discovered by Evogene that help plants maintain yield with lower applications of nitrogen. Monsanto will work to evaluate the use of those genes in its research and development pipeline. The potential candidates from Evogene are complementary to the nitrogen utilization genes already in testing in Monsanto's pipeline and could provide the opportunity to further a series of upgrades for this key target area. The financial terms of the agreement were not disclosed.



Always read and follow all label directions.

News & Notes: Agreement Aimed at Hybrids That Improve Nitrogen Use By Corn

DuPont and Arcadia Biosciences, Inc. have formed a research and commercial agreement that gives DuPont business Pioneer Hi-Bred exclusive rights to Arcadia's proprietary technology for improving nitrogen use efficiency in corn.



Gulf Hypoxia Action Plan 2008

for Reducing, Mitigating, and Controlling Hypoxia
in the Northern Gulf of Mexico and Improving
Water Quality in the Mississippi River Basin

Mississippi River
Gulf of Mexico
Watershed Nutrient
Task Force

EPA Hypoxia SAB report recommended
45% less total N
AND
45% less total P
discharge to the Gulf

Nutrients and Hypoxia in the Gulf of Mexico — An Update on Progress, 2008

By C.S. Snyder

Based on data presented here and in the U.S. Environmental Protection Agency's Science Advisory Board (EPA SAB) 2008 report, there is reason to believe that declines in discharge of N and P to the Gulf of Mexico are proceeding through voluntary actions by farmers, their advisers, and their suppliers. Driven by global economic pressures, local and personal profitability goals and objectives, and a greater environmental consciousness and stewardship ethic, farmers and practitioners are increasingly implementing fertilizer BMPs. These accomplishments are noteworthy and herald progress toward improved fertilizer nutrient use efficiency, which may lead to reductions in N and P loss from farm fields and agricultural watersheds.

Since 1985, the areal extent of hypoxia (≤2 mg/L of dissolved oxygen) in the shallow coastal waters (< 30 m or 100 ft.) of the northern Gulf of Mexico has been estimated annually in late July by scientists with the Louisiana Universities Marine Consortium (LUMCON). **Figure 1** shows the extent of hypoxia beginning in 1985 and through 2007. Historic evidence suggests hypoxia is a natural event, but current science indicates hypoxia in the Gulf has occurred more frequently and extensively in the last half century. These contemporary changes in the size and duration of the hypoxic zone are thought to be most related to nutrient discharges, specifically N and P discharges from the Mississippi and Atchafalaya River Basin (MARB).

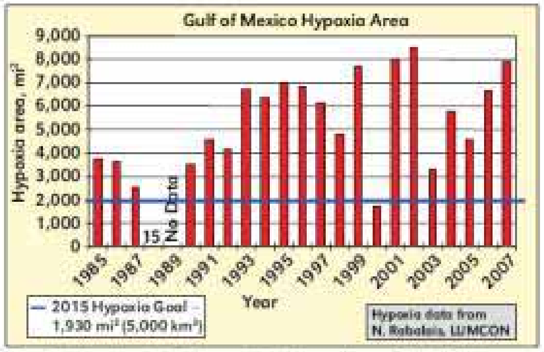


Figure 1. Areal extent of hypoxia in the northern Gulf of Mexico, as determined by annual cruises conducted in late July. Data source: N. Rabalais, LUMCON.

Federal, state, and tribal authorities developed an Action Plan and defined within-Basin goals and the goal of reducing the hypoxic zone in the Gulf of Mexico to a 5-year running average of 5,000 km² (1,930 mi²) by 2015 (MR/GMWNTF, 2001). Since 2001, knowledge has expanded on the complexity of factors (e.g. climate, weather, basin morphology, coastal water circulation patterns, water retention times, freshwater inflows, stratification of freshwater over saltwater, mixing, nutrient loadings, and loss of processing marsh lands along the Louisiana coast) that contribute to the development of hypoxia in the Gulf. For example, a recent report by Hetland and DiMarco (2008) has exposed some of the complexities associated with coastal physical processes, and factors that interact with the biology of the ecosystem, which affect hypoxia development and persistence east and west of the shelf region south of Terrebone Bay in Louisiana. These two authors suggest that a water stratification envelope may be the dominant factor affecting the areal extent of hypoxia along the Louisiana-Texas shelf, as opposed to nutrients delivered by the Mississippi and Atchafalaya discharges.

Location of nine large sub-basins comprising the MARB that are used for estimating nutrient fluxes (from Aulenbach et al., 2007)

At the request of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (MR/GMWNTF), EPA impaneled a team of leading scientists to form a hypoxia Science Advisory Board to reassess nutrient load reductions achieved, the responses of the hypoxic zone and associated water quality and habitat conditions, and economic and social effects since the 2001 Action Plan (MR/GMWNTF, 2001) was released. The SAB reported: "*Hypoxia can occur naturally in deep basins, fjords, and oxygen minimal coastal zones associated with upwelling. However, nutrient-induced hypoxia in shallow coastal and estuarine systems is increasing worldwide*" (EPA SAB, 2008). The SAB report also stated that "*recent science has affirmed the basic conclusion that contemporary changes in the hypoxic area in the northern Gulf of Mexico are primarily related to nutrient fluxes from the MARB.*" A new Action Plan is in development and a draft has been released to the public (MR/GMWNTF, 2008).

Former N discharge reduction goals (MR/GMWNTF, 2001) were aimed principally at NO_3-N discharge reduction (actually, reported as the combined measure of NO_3^- and NO_2^- forms of N), but the 2008 EPA SAB report recommended reductions in

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; BMPs = best management practices; NO_3^- = nitrate; NO_2^- = nitrite; NH_4^+ = ammonium; UAN = urea ammonium nitrate; NO_y = reactive N oxides plus the compounds produced from their oxidation.

Sub-basin Contributions of **N** & **P**

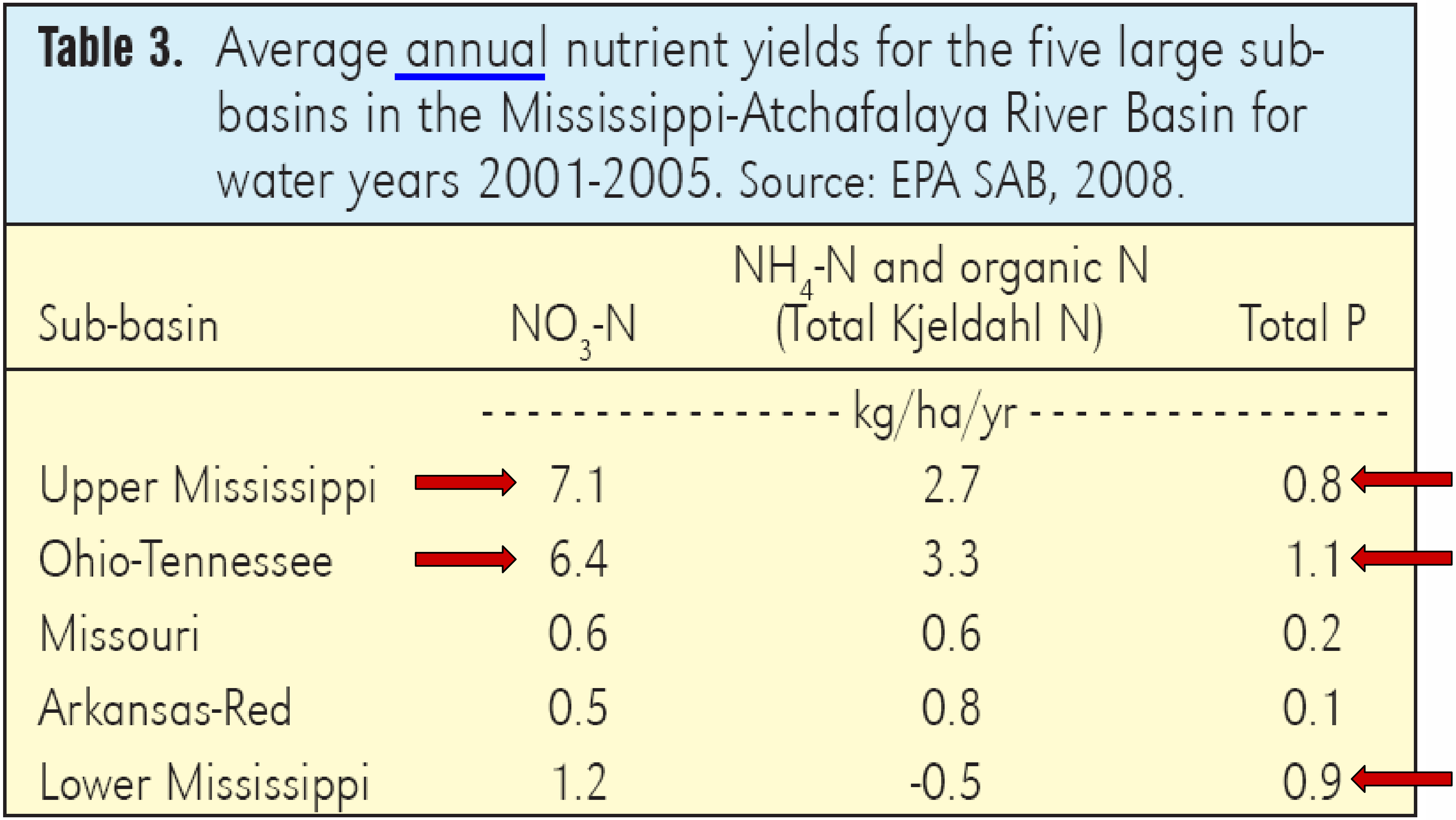


Table 3. Average annual nutrient yields for the five large sub-basins in the Mississippi-Atchafalaya River Basin for water years 2001-2005. Source: EPA SAB, 2008.

Sub-basin	NO_3-N	NH_4-N and organic N (Total Kjeldahl N)	Total P
	----------------	kg/ha/yr	----------------
Upper Mississippi	7.1	2.7	0.8
Ohio-Tennessee	6.4	3.3	1.1
Missouri	0.6	0.6	0.2
Arkansas-Red	0.5	0.8	0.1
Lower Mississippi	1.2	-0.5	0.9

Has nutrient discharge increased ?

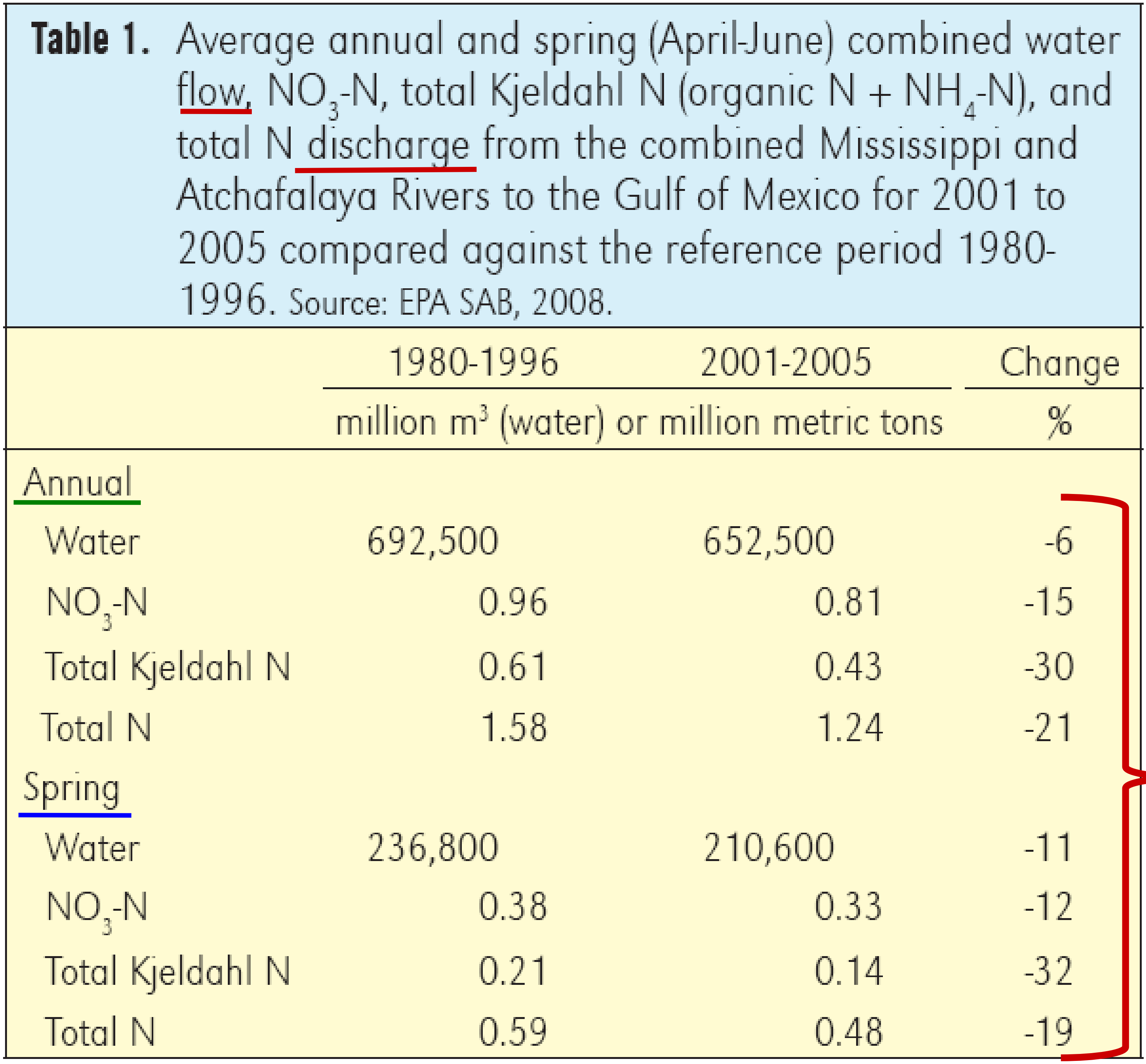


Table 1. Average annual and spring (April-June) combined water flow, NO_3-N, total Kjeldahl N (organic N + NH_4-N), and total N discharge from the combined Mississippi and Atchafalaya Rivers to the Gulf of Mexico for 2001 to 2005 compared against the reference period 1980-1996. Source: EPA SAB, 2008.

	1980-1996	2001-2005	Change
	million m^3 (water) or million metric tons		%
Annual			
Water	692,500	652,500	-6
NO_3-N	0.96	0.81	-15
Total Kjeldahl N	0.61	0.43	-30
Total N	1.58	1.24	-21
Spring			
Water	236,800	210,600	-11
NO_3-N	0.38	0.33	-12
Total Kjeldahl N	0.21	0.14	-32
Total N	0.59	0.48	-19

Notable Declines

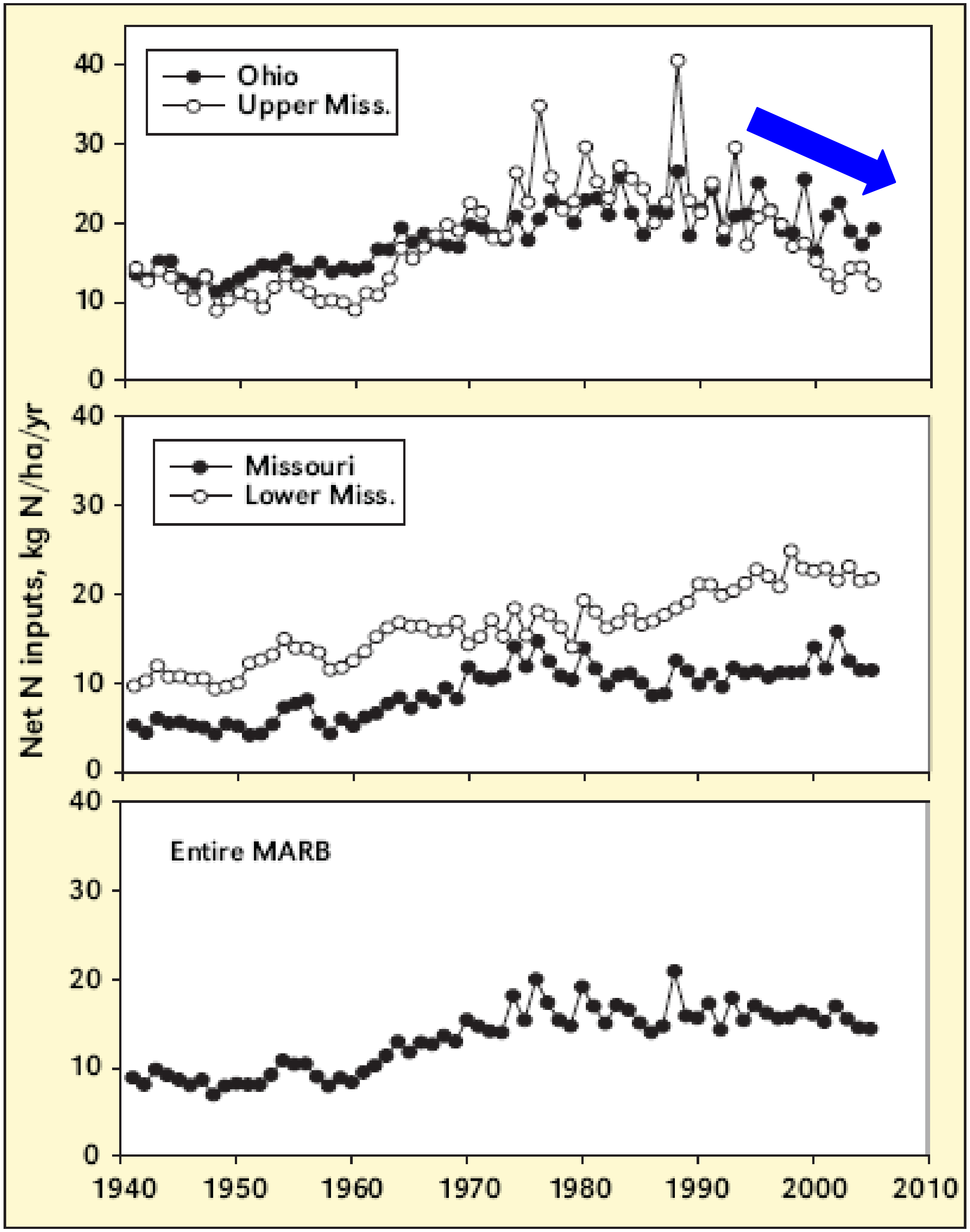


Figure 8. Nitrogen mass balance and net inputs for major regions of the Mississippi-Atchafalaya River Basin through 2005. Source: EPA SAB, 2008.

Voluntary actions are reducing the “net” Nitrogen (N) balance in the Mississippi River Basin; especially in two key upper sub-basins.

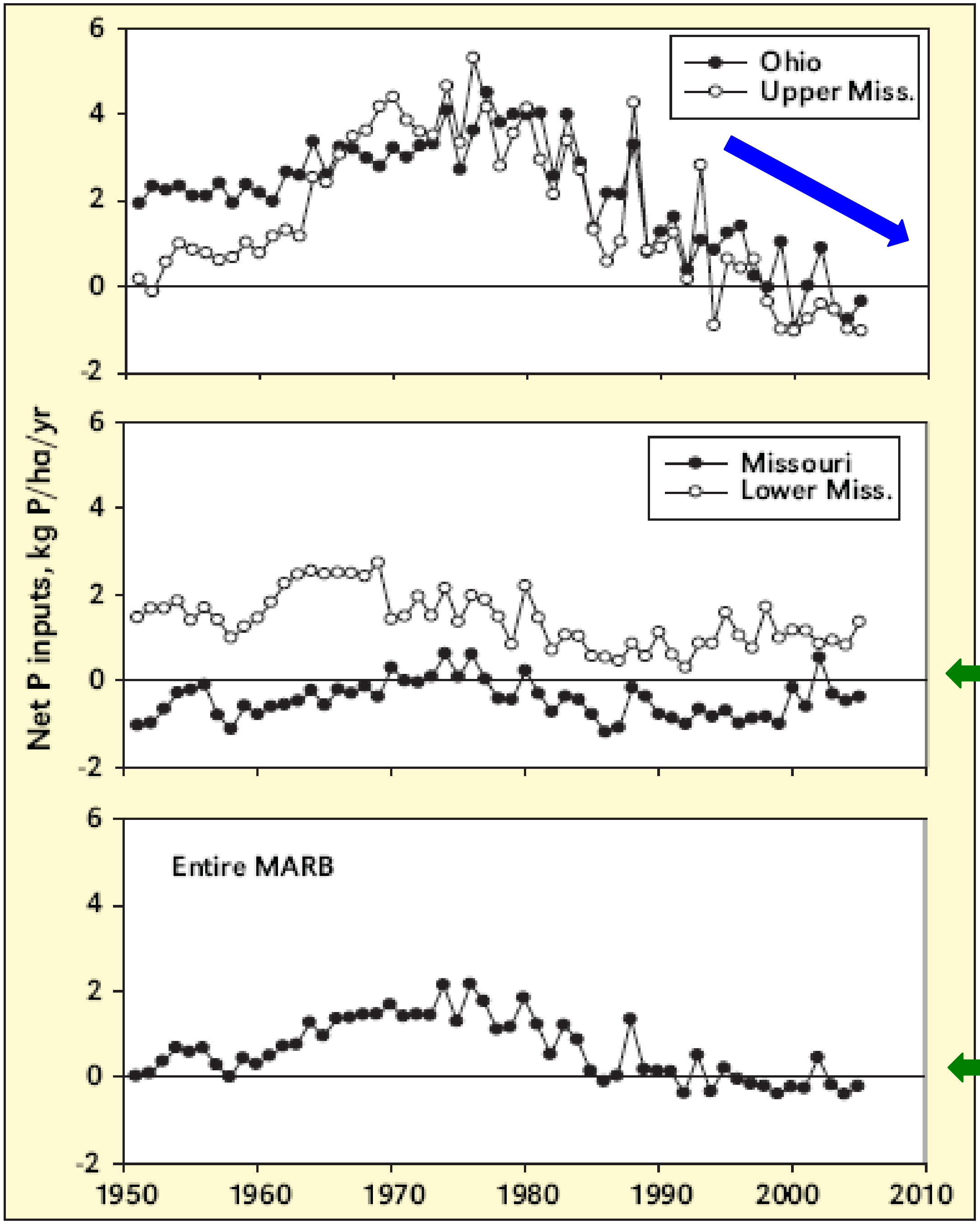


Figure 9. Phosphorus mass balance and net inputs for major regions of the Mississippi-Atchafalaya River Basin through 2005. Source: EPA SAB, 2008.

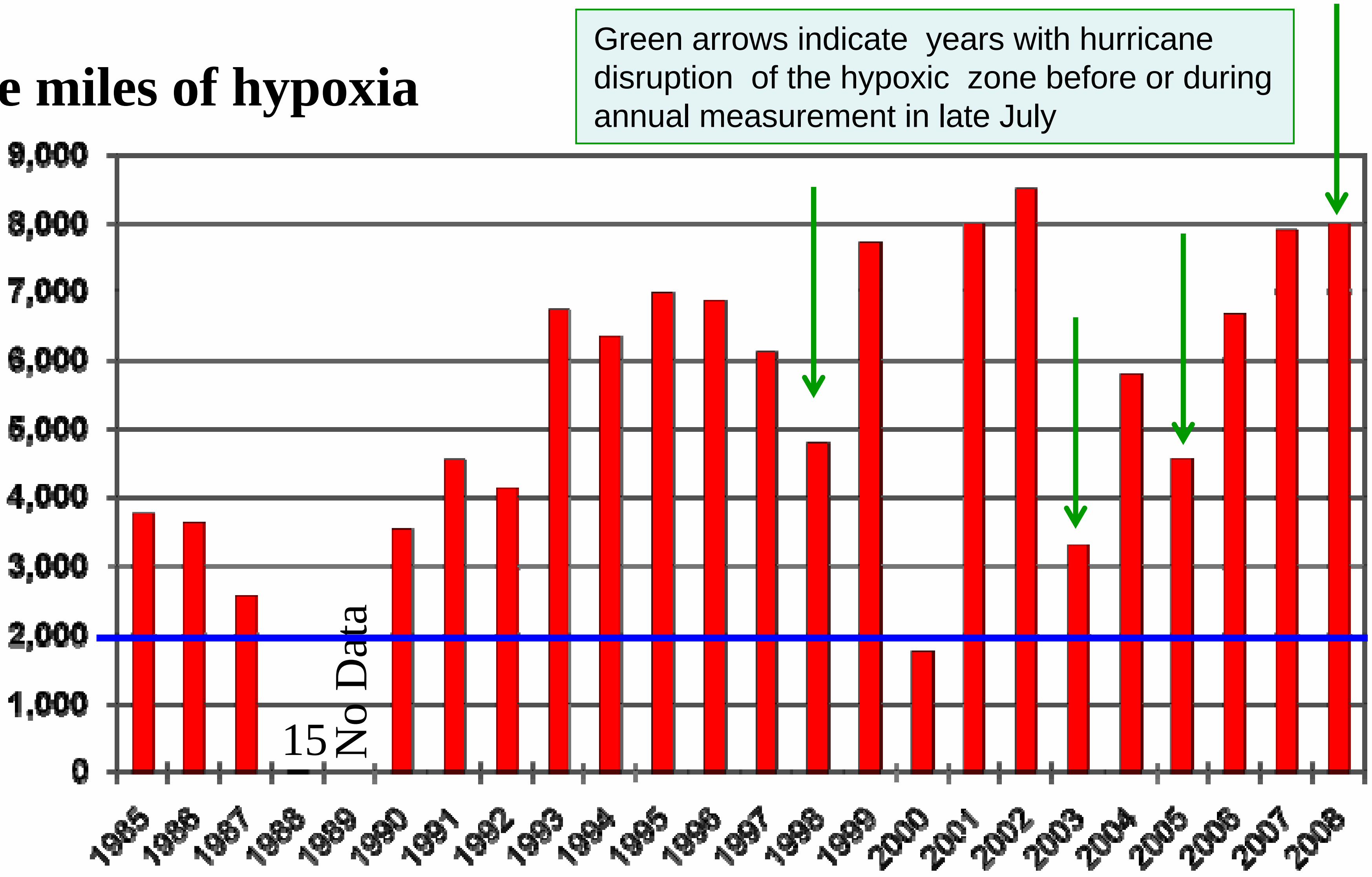
Voluntary actions are also reducing the "net" phosphorus (P) balance in the Mississippi River Basin; especially in two key upper sub-basins.

This is a concern, however, because soil P may be "mined", and may lead to yield reductions and lower N use efficiency

Gulf of Mexico Hypoxia Area

Square miles of hypoxia

Green arrows indicate years with hurricane disruption of the hypoxic zone before or during annual measurement in late July

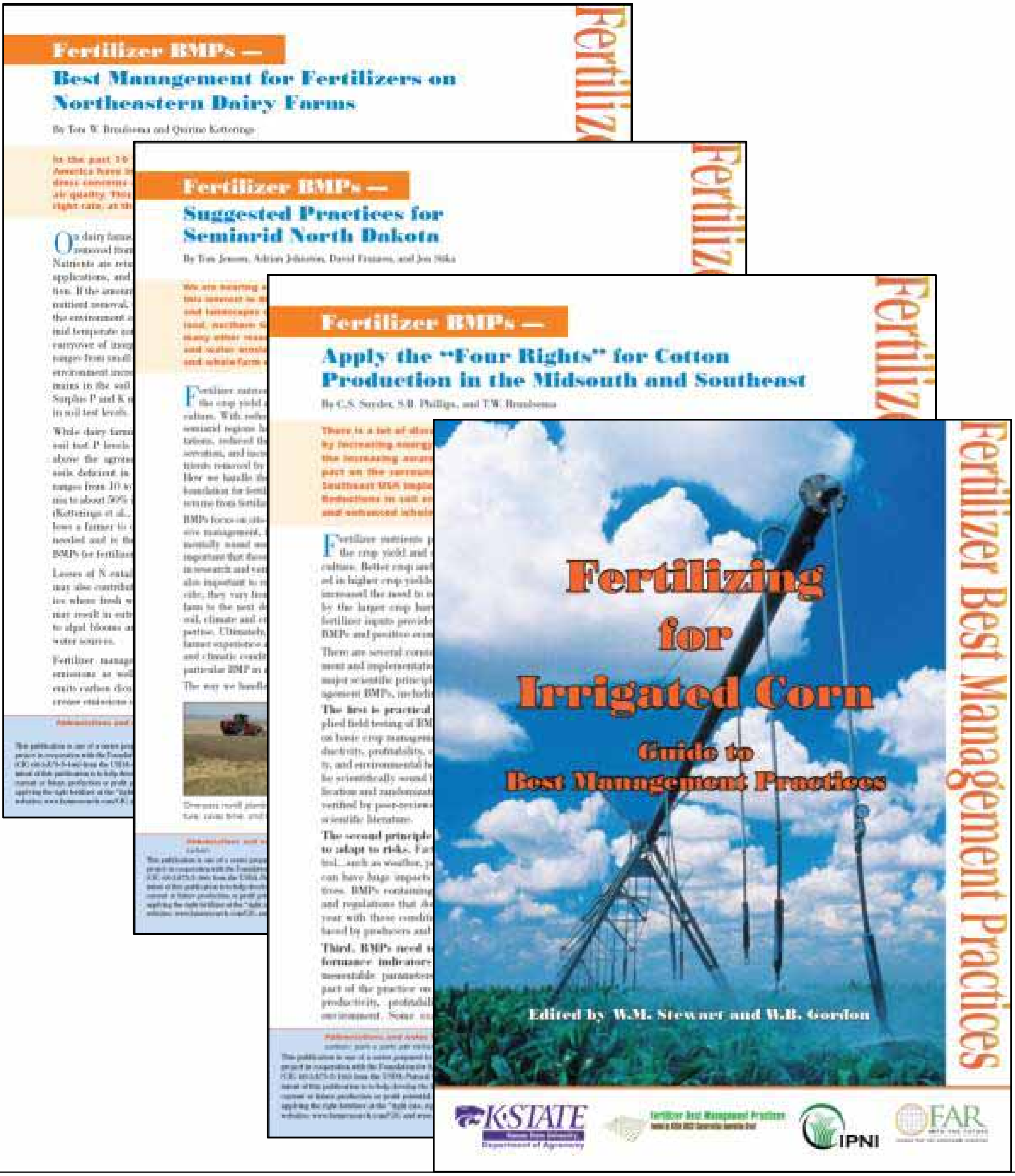


2015 Hypoxia Goal

Year

Hypoxia data from N. Rabalais, LUMCON

Fertilizer BMP Education & Outreach



Fertilizer BMPs —

Best Management for Fertilizers on Northeastern Dairy Farms

By Tom W. Bruulsema and Quirine Ketterings

Fertilizer BMPs —

Suggested Practices for Semiarid North Dakota

By Tom Jensen, Adrian Johnston, David Franzen, and Jon Stika

Fertilizer BMPs —

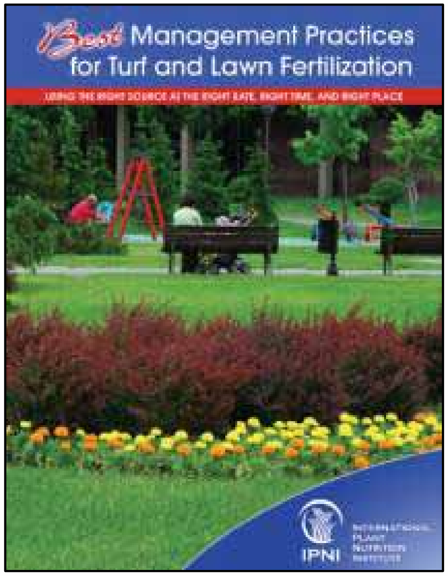
Apply the "Four Rights" for Cotton Production in the Midsouth and Southeast

By C.S. Snyder, S.B. Phillips, and T.W. Bruulsema

Fertilizing for Irrigated Corn

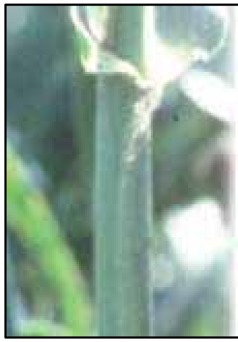
Guide to Best Management Practices

Edited by W.M. Stewart and W.B. Gordon



Best Management Practices for Turf and Lawn Fertilization

USING THE RIGHT SOURCE AT THE RIGHT RATE, RIGHT TIME, AND RIGHT PLACE



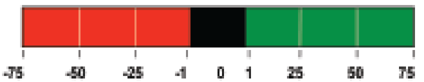
Fertilizer Nitrogen BMPs to Limit Losses that Contribute to Global Warming

By C.S. Snyder

Table 1. Relative effectiveness of management scenarios, shown as advantage of "Scenario 1" over "Scenario 2", in reducing N losses and greenhouse gas emissions. Effectiveness rating represents estimate of the relative potential N loss reduction, on-farm and within-watershed.[1]

			Indirect effects on N_2O emissions			Direct greenhouse gas emission[3] N_2O
			Water discharges as NO_3^-		NH_3 volatilization	
N Source[2]	Fertilizer N Management Practice		Leaching	Runoff		
	Right agronomic N rate					
	Scenario 1	**Scenario 2**				
All Sources	Accounting for soil N supply and other input sources (e.g. manure, irrigation water, etc.)	No such N accounting (assumes over-application)	⬜⬛🟩	⬜⬛🟩	⬜⬛🟩	⬜⬛🟩
All Sources	Site-specific N management (variable rate and/or source)	No site-specific management	⬜⬜🟩	⬜⬜🟩	⬜⬜🟩	⬜⬛🟩
	Right N timing					
	Scenario 1	**Scenario 2**				
AA	Applied in the fall after soil temp. below 50 °F for spring-planted crops	No waiting	⬜⬛🟩	⬜⬛⬜	⬜⬛⬜	🟥⬛🟩
AA, AS, PA, U, UAN	Spring application, for spring planted crops (e.g. corn)	Fall application	⬜⬛🟩	🟥⬛🟩	⬜⬛🟩	⬜⬛🟩
AA, AS, PA, U, UAN, AN, PN	Spring split or sidedress applied, for spring planted crops	All preplant applied	⬜⬛🟩	⬜⬛🟩	🟥⬛⬜	🟥⬛🟩
AA, AS, PA, U, UAN, AN, PN	Spring or split fall-spring application, for fall planted crops (e.g. wheat, canola)	All fall applied	⬜⬛🟩	⬜⬛🟩	⬜⬛🟩	⬜⬛🟩
AA, AS, PA, U, UAN, AN, PN	Nitrification inhibitor used	None used	⬜⬛🟩	⬜⬛🟩	⬜⬛⬜	🟥⬛🟩
U	Controlled release technology used	None used	⬜⬛🟩	⬜⬛🟩	⬜⬛🟩	🟥⬛🟩
	Right N placement					
	Scenario 1	**Scenario 2**				
AS, PA,U, UAN, AN	Subsurface incorporation	Surface broadcast	🟥⬛🟩	⬜⬜🟩	⬜⬛🟩	⬜⬛🟩
U, UAN	Surface banded	Surface broadcast	🟥⬛🟩	⬜⬛🟩	⬜⬛🟩	🟥⬛🟩
AS, PA, U, UAN, AN, PN	Shallow sidedress band – 1 in. (2 cm)	Sidedress band deeper than necessary – ≥ 4 in. (10 cm)	🟥⬛⬜	⬜⬛⬜	🟥⬛⬜	🟥⬛🟩
U, UAN	Surface applied with urease inhibitor; abundant crop residues	No inhibitor	⬜⬛⬜	⬜⬛⬜	⬜⬛🟩	⬜⬛🟩
U, UAN	Surface applied with urease inhibitor; minimal crop residues	No inhibitor	⬜⬛⬜	⬜⬛⬜	⬜⬛🟩	⬜⬛🟩

Legend for ratings in table:



Ratings can represent broad, multiple ranges (e.g. negative to positive), or a single quartile. The rating scheme is based to some extent on a conservation practice rating scheme in Table 17 in EPA SAB (2008).

---

[1] Relative percentage (%) advantage of "Scenario 1" over "Scenario 2," estimated from available literature and experienced observation. This rating scheme does not identify the quantity of N loss, which can be relatively small <1 to 2 lb/A (<1 to 2 kg/ha) in some conditions. Relative effects do not include emissions associated with manufacture or transport of inputs. Ratings are subject to change with research progress.

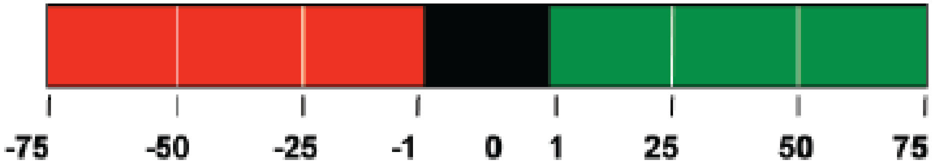
[2] N sources: AA=anhydrous ammonia, AS=ammonium sulfate, PA=predominantly ammonium containing, U=urea, UAN=urea ammonium nitrate solutions, AN=ammonium nitrate, PN=predominantly nitrate-containing.

[3] Data insufficient to allow ratings for emissions of the other two principal greenhouse gases, CH_4 and CO_2.

Table 1. Relative effectiveness of management scenarios, shown as advantage of "Scenario 1" over "Scenario 2", in reducing N losses and greenhouse gas emissions. Effectiveness rating represents estimate of the relative potential N loss reduction, on-farm and within-watershed.[1]

			Indirect effects on N_2O emissions			Direct greenhouse gas emission[3] N_2O
			Water discharges as NO_3^-		NH_3 volatilization	
N Source[2]	Fertilizer N Management Practice		Leaching	Runoff		
	Right agronomic N rate					
	Scenario 1	Scenario 2				
All Sources	Accounting for soil N supply and other input sources (e.g. manure, irrigation water, etc.)	No such N accounting (assumes over-application)	⬜⬛🟩	⬜⬛🟩	⬜⬛🟩	⬜⬛🟩
All Sources	Site-specific N management (variable rate and/or source)	No site-specific management	⬜🟩⬜	⬜🟩⬜	⬜🟩⬜	⬜⬛🟩⬜

Legend for ratings in table:

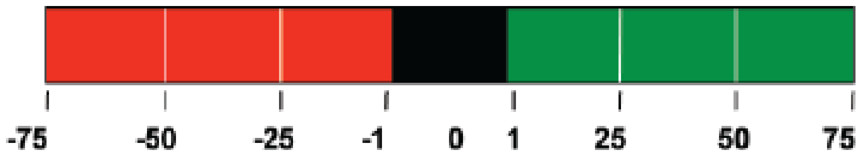


Ratings can represent broad, multiple ranges (e.g. negative to positive), or a single quartile. The rating scheme is based to some extent on a conservation practice rating scheme in Table 17 in EPA SAB (2008).

			Indirect effects on N_2O emissions			Direct greenhouse gas emission[3] N_2O
			Water discharges as NO_3^-		NH_3 volatilization	
N Source[2]	Fertilizer N Management Practice		Leaching	Runoff		
	Right N timing					
	Scenario 1	**Scenario 2**				
AA	Applied in the fall after soil temp below 50 °F (10 °C) for spring-planted crops	No waiting	⬛🟩🟩🟩	⬛	⬛	🟥⬛🟩
AA, AS, PA, U, UAN	Spring application, for spring planted crops (e.g. corn)	Fall application	⬛🟩🟩	🟥⬛🟩🟩	⬛🟩🟩🟩	⬛🟩🟩🟩
AA, AS, PA, U, UAN, AN, PN	Spring split or sidedress applied, for spring planted crops	All preplant applied	⬛🟩	⬛🟩	🟥⬛	🟥⬛🟩
AA, AS, PA, U, UAN, AN, PN	Spring or split fall-spring application, for fall planted crops (e.g. wheat, canola)	All fall applied	⬛🟩	⬛🟩	⬛🟩	⬛🟩🟩
AA, AS, PA, U, UAN, AN, PN	Nitrification inhibitor used	None used	⬛🟩🟩	⬛🟩	⬛	🟥⬛🟩🟩
U	Controlled release technology used	None used	⬛🟩🟩	⬛🟩🟩	⬛🟩🟩	🟥⬛🟩🟩

[2] N sources: AA=anhydrous ammonia, AS=ammonium sulfate, PA=predominantly ammonium containing, U=urea, UAN=urea ammonium nitrate solutions, AN=ammonium nitrate, PN=predominantly nitrate-containing.

Legend for ratings in table:



Ratings can represent broad, multiple ranges (e.g. negative to positive), or a single quartile. The rating scheme is based to some extent on a conservation practice rating scheme in Table 17 in EPA SAB (2008).

			Indirect effects on N_2O emissions			Direct greenhouse gas emission[3] N_2O
			Water discharges as NO_3^-		NH_3 volatilization	
N Source[2]	Fertilizer N Management Practice		Leaching	Runoff		
	Right N placement					
	Scenario 1	**Scenario 2**				
AS, PA,U, UAN, AN	Subsurface incorporation	Surface broadcast	⬜🟥⬛🟩⬜	⬜⬜⬜🟩⬜	⬜⬜⬛🟩⬜	⬜⬜⬛🟩⬜
U, UAN	Surface banded	Surface broadcast	⬜🟥⬛🟩⬜	⬜⬜⬛🟩⬜	⬜⬜⬛🟩⬜	⬜🟥🟥⬛🟩🟩⬜
AS, PA, U, UAN, AN, PN	Shallow sidedress band – 1 in. (2 cm)	Sidedress band deeper than necessary – ≥ 4 in. (10 cm)	⬜🟥⬛⬜⬜	⬜⬜⬛⬜⬜	⬜🟥⬛⬜⬜	⬜🟥⬛🟩⬜
U, UAN	Surface applied with urease inhibitor; abundant crop residues	No inhibitor	⬜⬜⬛⬜⬜	⬜⬜⬛⬜⬜	⬜⬜⬛🟩🟩	⬜⬜⬛🟩⬜
U, UAN	Surface applied with urease inhibitor; minimal crop residues	No inhibitor	⬜⬜⬛⬜⬜	⬜⬜⬛⬜⬜	⬜⬜⬛⬜⬜	⬜⬜⬛🟩⬜

Legend for ratings in table:

Ratings can represent broad, multiple ranges (e.g. negative to positive), or a single quartile. The rating scheme is based to some extent on a conservation practice rating scheme in Table 17 in EPA SAB (2008).

SUMMARY

- **Farmers and their crop advisers** will need to maintain their vigilance and improve their skills to achieve further gains in nutrient use efficiency and effectiveness.
- Progress is being made, more is expected, ….. good reason for optimism as knowledge expands
- Research on improved nutrient management, and education and outreach can help reduce nutrient losses from fields

SUMMARY

- Increased crop yields, improved plant genetic selection, and improved pest control may all be contributing to the lowered net anthropic N and net anthropic P inputs observed in the last decade or more.
- Benefits are reflected in lower N and P delivery to the Gulf of Mexico during the peak spring (April-June) discharge …..
- Except in epic rainfall/flood years like 1993 & 2008

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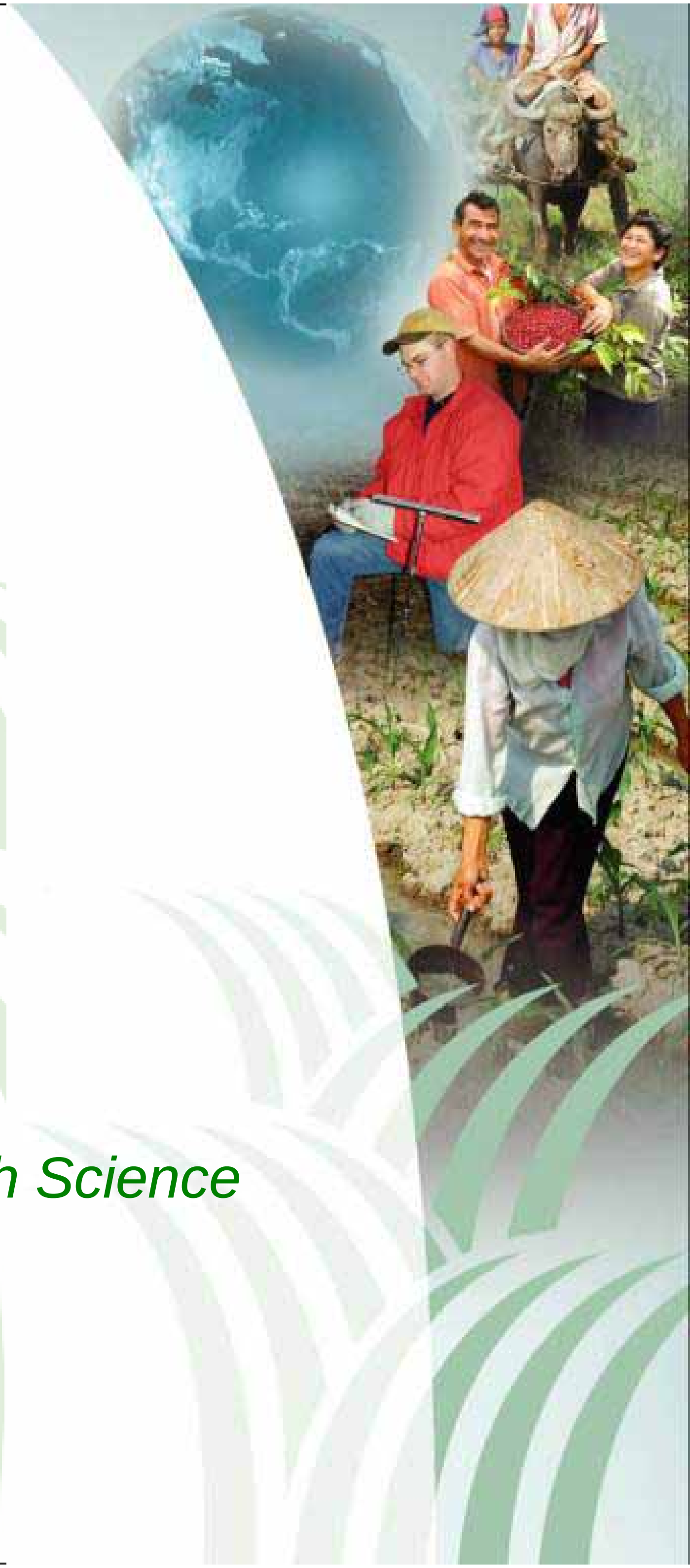

Thank You

Better Crops, Better Environment … through Science

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