Synthesis of the 2005 Hypoxia Conference (cost effectiveness of BMPs/Cedar River watershed)

March 4, 2009

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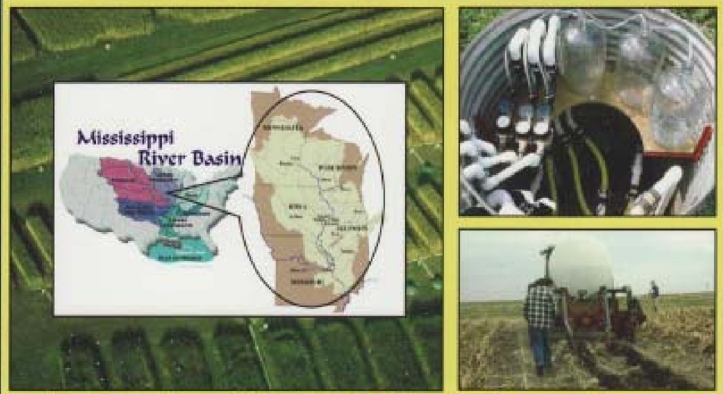
Artie; January 2, 2009

Upper Mississippi River Sub-basin Workshop

- Illinois, Iowa, Minnesota, Missouri, and Wisconsin; plus Indiana and Ohio
- 15 science panels comprised of 75 nutrient/water quality researchers
- Panelists prepared papers to offer consensus and expert opinion on the state of the science on topics and some information of cost effectiveness of practices

FINAL REPORT:

Gulf Hypoxia and Local Water Quality Concerns Workshop



September 26-28, 2005 **Ames, Iowa**

Organized by the UMRSHNC
(Upper Mississippi River Sub-basin Hypoxia Nutrient Committee)

Sponsored by Iowa State University,
the United StatesDepartment of Agriculture (USDA),
and the U.S. Environmental Protection Agency (EPA)

Link to pdf:

www.UMRSHNC.org

Hard copy available for purchase from:

ASABE

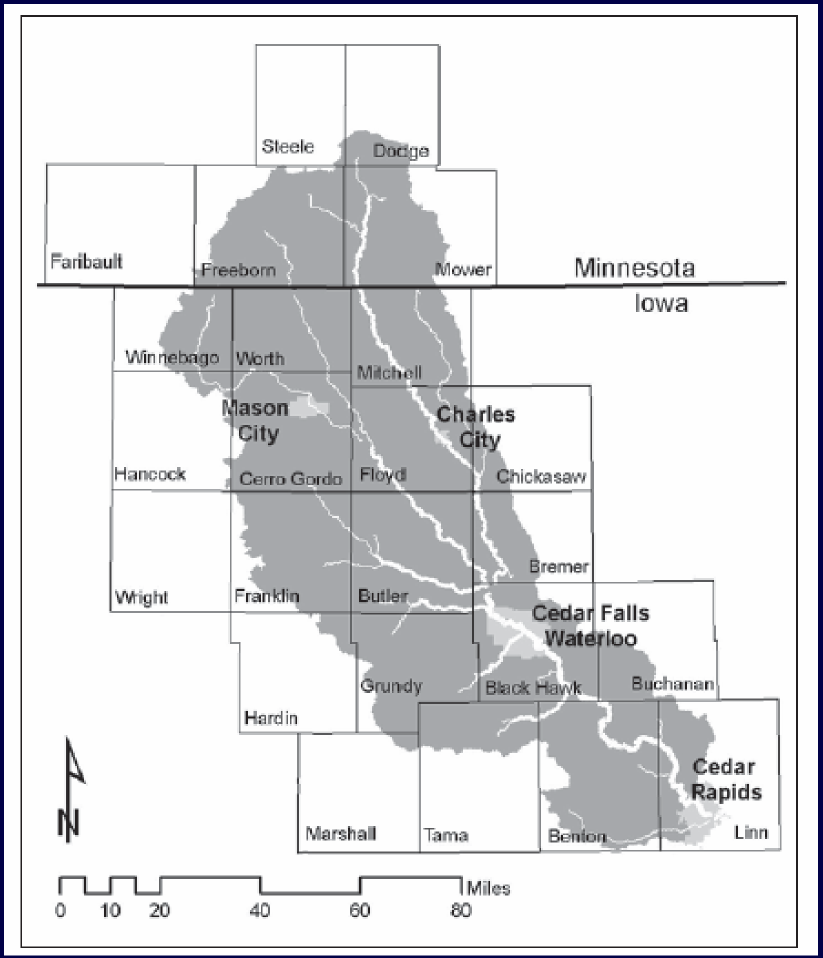
St. Joseph, MI

Reducing Nutrient Loads from Agriculture in the Upper Mississippi River Basin – A Case Study

- Cedar River Watershed; NE Iowa
- ***Preliminary*** results

Jim Baker, et al.

(ISU, ARS, NRCS, IDALS, IDNR, IFB)



Background

- Nitrate issues
  - TMDL for drinking water impairment
  - Gulf of Mexico hypoxia area reduction
- Phosphorus issues
  - Pending criteria for local flowing and standing waters
  - Gulf of Mexico hypoxia area reduction

Loss reduction goals

- TMDL nitrate
  - Maximum concentration 9.5 mg/L
  - Reduce losses 35%
  - Reduce losses 10,000 tons/year (equals 5.5 lb N/acre/year)
  - Load allocation: 92% nonpoint source; 8% point source
- Hypoxia area
  - Reduce N losses 45%
  - Reduce P losses 45%

Current understanding:

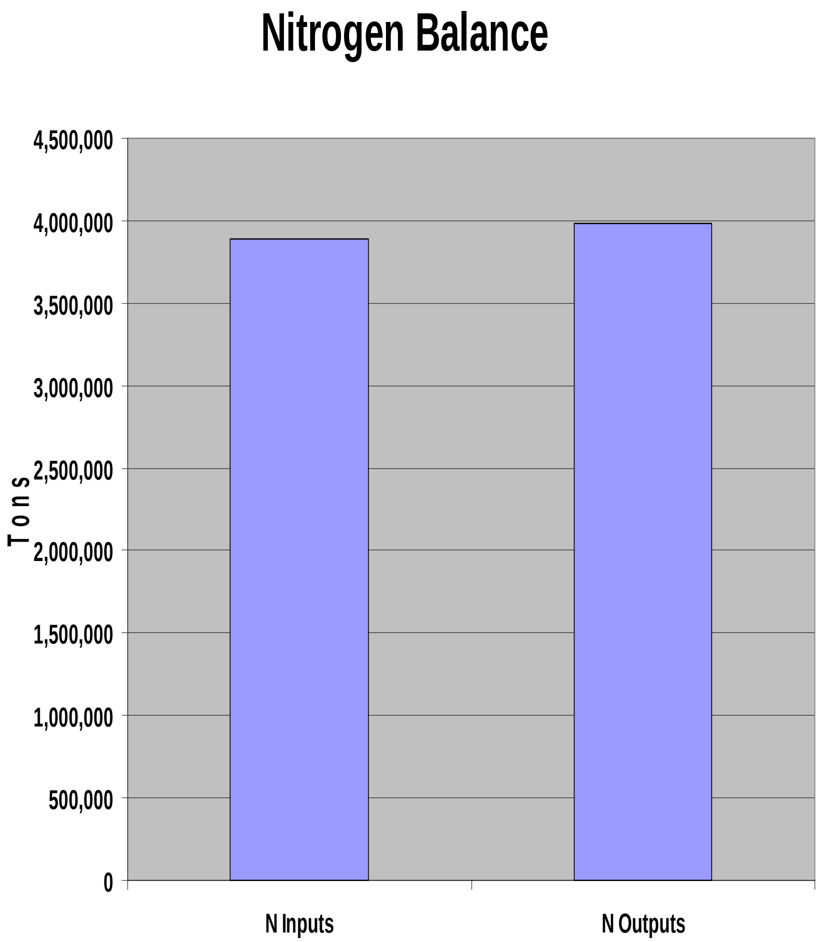
- In tile-drained landscapes:
  - N losses greater
  - Carrier, subsurface drainage water
  - Dominated by NO_3 form
  - Occur with sustained flows
  - Usually in spring at time with little ET/nutrient uptake
- In “rolling” landscapes with good surface drainage:
  - P losses greater
  - Carriers, runoff water and sediment
  - Usually dominated by P in sediment
  - Occur with “flashy” rainfall-runoff events
  - Year around, worse in spring with less vegetative cover

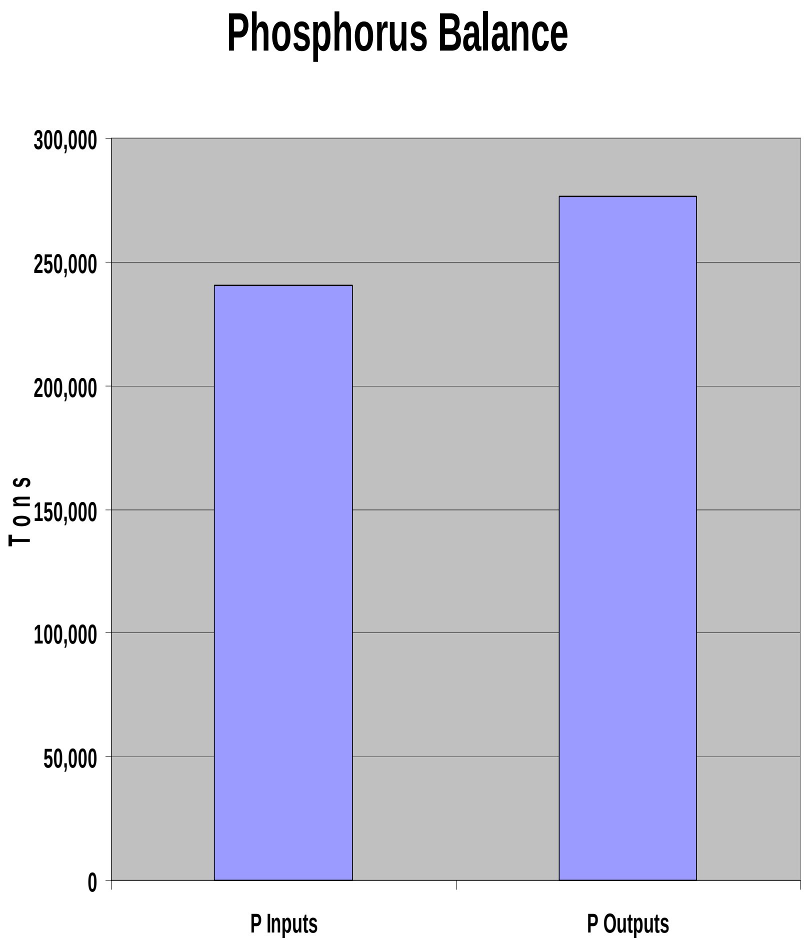
“Excess nutrients”

- Often it is written that nutrients in water resources are the result of the loss of “excess nutrients” present in the soil (implying if there were no “excess nutrients,” losses would not occur).

- BUT:
  - For optimum crop production, significant amounts of N and P must be present in the soil.
  - Precipitation that results in excess water (thus surface runoff and/or subsurface drainage) can and does come at any time.
  - When that happens some nutrients are certain to be lost.

N and P Budgets for Iowa and Iowa Watersheds





Importance of hydrology and land-use:

- Emerging science suggests that current nutrient impairment problems are not mainly due to mismanagement of fertilizers and manures, but more to historic changes in land use and hydrology that came with the conversion of prairie and wetlands to cropland.

Main Points of Panels (application to Cedar River)

Drainage Water Management

- Practice of managing the outlet of water from the drainage system to reduce volume of subsurface drainage
- Drainage reductions of 30-50% reported
- Maintaining a wetter soil profile has potential to increase surface runoff
- Most applicable to lands with <1% and likely less than 0.5% slope

Nitrate reduction (Cedar River)

- Drainage water management
  - Modeling predicts a ~50% nitrate loss reduction with installation of drainage water management (USDA Tilth Lab)
- Costs
  - Installation: $1000/structure (for 12 acres on average; 20 year life; 4% interest)
  - Operation: $10/acre/year
- Applicable to about 6.7% of the row crops
- Nitrate reduction costs of $1.56/lb

Constructed Wetlands

- Remove nitrate through denitrification (little long-term effect on P transport)
- In Iowa, 0.5 to 2% wetland area expected to remove average of 50% nitrate input
- Establishment costs of about $250/ac of “treated field” (Iowa CREP program data)
- Assuming 50-yr life and 4% interest, this would be about $1.45/lb N removed

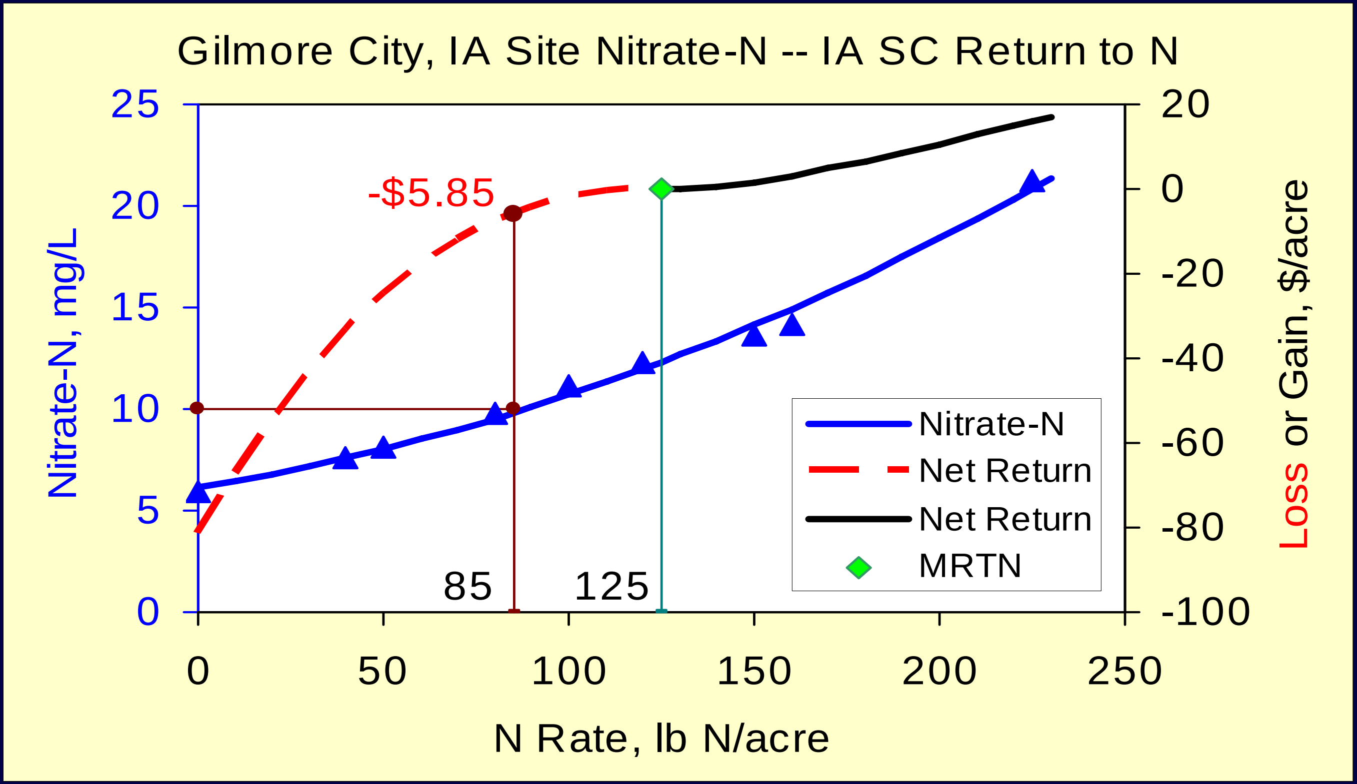
Buffers and Vegetative Filters

- Buffers most effective in trapping particulate pollutants
- Properly designed and maintained buffers may be expected to trap about 50% of incoming sediment, somewhat less for sediment-bound nutrients, and much less for dissolved nutrients
- Impact will be lower if the systems are not maintained
- Costs are mainly land out of production
- Need studies that document in-field performance under non-ideal flow conditions

Practices (Cedar River/nitrate)

- Buffer strips
  - Tile drainage “short-circuits” subsurface flow through buffer strips, eliminating any chance they would have in reducing concentrations and/or flow volumes and thus nitrate losses.

Nitrogen Rate
($0.22/lb N:$2.20/bu corn)



Based on Iowa yield and water quality data; corn at $5.00/bu and N at $0.50/lb

	Corn soybeans	Continuous corn
assumed initial rate (lb N/ac)	140	190
nitrate loss	19.5 lb/ac	23.2 lb/ac
loss reduction with **40 lb/ac** N rate reduction	20.1%	16.2%
nitrate-N loss reduction	3.9 lb/ac	3.8 lb/ac
corn yield reduction	4.8 bu/ac	5.0 bu/ac
cost of N loss reduction	$1.03/lb	$1.32/lb

Based on Iowa yield and water quality data; corn at $5.00/bu and N at $0.50/lb

	Corn soybeans	Continuous corn
assumed initial rate (lb N/ac)	140	190
nitrate loss	19.5 lb/ac	23.2 lb/ac
loss reduction with **80 lb/ac** N rate reduction	32.7%	30.3%
nitrate-N loss reduction	6.4 lb/ac	7.0 lb/ac
corn yield reduction	16.1 bu/ac	15.2 bu/ac
cost of N loss reduction	$6.33/lb	$5.12/lb

Nitrogen Timing, Forms, and Additives

- Nitrate leaching losses 0-15% less for spring- vs. fall-applied.
- In Iowa, 25 to 33% of N fertilizer applied in fall (mostly ammonia)
- Additional infrastructure needed if all applied in spring might add 5 cents/lb N
- Would equate to about $6.00/lb N saved
- Nitrification inhibitors have some potential; inconsistent results.
- More data needed on side-dressing/split applications

Agronomic and Environmental Implications of Phosphorus Management Practices

- Apply P at rates that optimize crop yields based on soil testing and crop removal
- Subsurface P placement reduces loss potential, particularly on sites with high risk of erosion and surface runoff
- Use P index as tool to avoid excessive P build-up and risk of P loss

Using Manure as a Fertilizer for Crop Production

- Efficient use limited by variability caused by amounts and availability of nutrients in and accuracy of manure applications.
- Incorrect applications greatly increase the potential for nutrient losses
- There is ample crop capacity to utilize manure nutrients to replace fertilizer (equal to $<15\%$ of purchased N and P)

Effects of Erosion Control Practices on Nutrient Losses

Practice	Runoff (in)	Sediment Yield (t/ac/yr)	Total Water and Soil Losses (lb/ac)	
			N	P
Typical Tillage	4.8	7.8	35.8	13.1
No-till	4.2	1.0	9.7	3.1
Contour Farming	4.4	3.9	15.9	5.3
Terraces (surface drained)	4.4	2.3	11.0	3.4
Water and Sediment Control Basins	3.9	0.4	6.5	1.6

Estimates for central Iowa, average of 10 Iowa soils, and common slope conditions

Effects of Erosion Control Practices on Nutrient Losses

- Most immediate research needs relative to effectiveness of erosion control practices in reducing nutrient losses
  - Accounting for ultimate fate of various form of phosphorus leaving the field edge
  - Quantifying the environmental significance of these forms within surface waters

Practices (Cedar River/nitrate)

- Tillage
  - There are some indications that reduced tillage, and particularly no-till, could reduce nitrate concentrations in tile drainage, possibly because of reduced mineralization with reduced soil disturbance.
  - Also water flow through more macropores with reduced tillage could allow water to “by-pass” nitrate within soil aggregates.
  - However, usually any reductions in concentrations are off-set by increased flow volumes with reduced tillage.
  - Thus, without more conclusive results, tillage is not currently being considered as a practice to reduce nitrate leaching losses.

Potential and Limitations of Cover Crops, Living Mulches, and Perennials

- Cover crops may be less effective in northern parts of the Upper Mississippi River basin
- Nitrate load reductions ranged from 13% (Minnesota) to 94% (Kentucky)
- Phosphorus load reductions ranged from 54-94%
- Cover crops require time and money to establish without short-term economic returns
- Estimate that cover crops would show some nitrate reduction on 70-80% of all corn-soybean acres in the Upper Mississippi River basin

Practices (Cedar River/nitrate)

- Fall cover crops
  - Fall-planted rye or ryegrass can reduce nitrate leaching loss by 50% (USDA Tilth lab data)
- Costs
  - Incentive costs for rye: $30/acre (seed, planting, dealing with the living plants in the spring, possible corn yield reduction)
- For corn-soybeans
  - Rye loss reduction: $3.00/lb N

Sustaining Soil Resources while Managing Nutrients

- Nutrient management needs to be evaluated against soil quality as well as crop yields and water quality
- Soil organic matter is strongly influences properties that affect productivity and tilth
- Negative N mass balances over the long term can significantly reduce SOM
- These changes, while important, are hard to measure

For the soil quality/sustainability issue, like "global warming," there is not agreement about its degree, importance, and solution

- 170 lb N/ac/yr for continuous corn is about the "tipping point" at which soil organic matter should not decrease
- However, for the corn-soybean rotation, at 120 lb N/ac in the corn year, the N mass balance is at least 80 lb N/ac negative over the two-year period of rotation
- Thus, any reduction in N rates would increase the "mining" of soil organic matter
- Reduced soil organic matter not only reduces soil productivity but also increases water quality problems

Field-Scale Tools for Reducing Nutrient Losses to Water Resources

- Have potential for identifying areas that will contribute more to losses
- Help choose and focus management practices to control losses
- Consider both source and transport components
- Soil test levels and in-field and off-site practices, as well as site position in the landscape critical to Iowa P index

Using the Iowa P Index (Cedar River/P)

- It has three components:
  - erosion/soil loss
  - surface runoff
  - subsurface drainage (if any)
- It considers location and soil and weather characteristics
  - distance to water course
  - soil slope/type
  - annual precipitation
- It considers management
  - current P soil test level
  - amount of P additions
  - method of P additions
  - crop rotation
- It considers sediment transport control practices
  - vegetated buffer stripes
- It considers erosion control practices (using RUSLE2)
  - contouring
  - conservation tillage

Developing Watershed-scale Tools: A Case Study in the Wisconsin Buffer Initiative

- Goal of WBI was not to maximize number of buffers but rather install buffers that would have the greatest impact on chosen form of degradation
- Weighting of WBI watersheds based on:
  - Potential reduction in nutrient and sediment loads based on regression model related to land use and watershed loading data
  - Potential response of biological communities to conservation systems
  - Capacity of receiving water to receive additional P and sediments based on trophic status
- WBI developed a ranked list of 1598 predominantly ag watersheds based on probability of a positive water quality response to riparian buffers as part of a larger conservation system

Limitations of Evaluating the Effectiveness of Agricultural Management Practices in Reducing Nutrient Losses to Surface Waters

- Few rigorous studies of BMP effectiveness at the small watershed scale or larger – more long-term paired watershed studies are needed
- Responses to changes in management practices require long lag times
- Better tools are needed to identify critical sources areas within watersheds
- Model projections are uncertain due to limitations including:
  - Uncertainty of various parameters
  - Incomplete representation of field and watershed processes
  - Limited validation data

General Conclusions/Workshop

- Sufficiently high soil nutrient levels are necessary for good crop growth; thus some loss is inevitable.
- Historic changes in land-use and hydrology have resulted in productive agriculture, but are also mainly responsible for nutrient impairment problems.
- N and P transport and losses are affected quite differently by surface and sub-surface landscape drainage processes.
- Some improvement in in-field nutrient management is possible, but off-site practices also are needed, using targeted/site-specific designs.
- There are no easy answers, and care must be taken to avoid promoting the wrong practices.
- Improvements will be incremental, and variability in weather can dominate both short- and long-term outcomes.
- Management impacts on soil quality/sustainability bears further consideration.
- A new landscape vision has considerable potential (but an approach that likely will require public funding).
- Current and evolving resource problems continue to create demand for new solutions that only additional research can provide.

Cedar River Watershed

- 3,650,000 acres within Iowa above city of Cedar Rapids
- Nitrate losses (2001 – 2004 period)
  - 28,561 tons/year
  - 15.6 lb/acre/year
- 73% row-crop (2,400,000 acres corn/beans; 150,000 acres continuous corn)
- About 2/3 of the row-crop land has tile drainage
- Annual precipitation: about 34 inches
- Stream flow (2001 - 2004 period)
  - Total 8 inches
  - "Base flow" about 65% of total

Potential N Management Practices

- In-field
  - N rate/timing
  - Cropping
  - Tillage
  - Cover crops
  - Water management
- Off-site
  - Buffer strips
  - Constructed wetlands

Practices (nitrate)

- N rate
  - Starting point critical
  - NASS fertilizer data for 2005 for four northeast Iowa sub-regions is 124 lb N/acre/year on corn
  - IDALS state-wide fertilizer sales data for 2001 – 2005 averaged 137 lb N/acre/year on corn
  - Manure applications (?)
- ISU recommendations
  - For corn following soybeans: 100 – 150 lb N/acre
  - For continuous corn: 150 – 200 lb N/acre

One example scenario to reduce nitrate losses 35% (9,200 tons/non-point source allocation) while retaining row-crop production

Practice	% reduction	Acres* treated	Tons reduced	Cost per lb	Total cost/yr
140 to 100 N rate - CB	20.1% or 3.9 lb/ac	all or 1.70 M ac	3,315	$1.03	$6.83 M
190 to 150 N rate - CC	16.2% or 3.8 lb/ac	all or 0.10 M ac	190	$1.32	$0.50 M
Avoid fall application	15% or 2.5 lb/ac	all or 300,000 ac	375	$6.00	$4.50 M
Rye cover crops	50% or 8 lb/ac	10% or 170,000 ac	680	$3.00	$4.08 M
Water mgt.	50% or 8 lb/ac	10% or 167,000 ac	670	$1.56	$2.09 M
Construct. wetlands	50% or 8 lb/ac	59% or 1.00 M ac	4,000	$1.45	$11.60 M
TOTALS		*[*2/3 of 2.55 M or 1.70 M ac]*	9,230	$1.60	$29.60 M/yr

Scaling to Iowa Statewide

- About ¼ of Iowa is tile drained: equals 9 million acres
- Cost to Cedar River watershed (1.7 million acres drained) estimated at $29.6 million/year
- Cost to Iowa would be $157 million/yr for 35% nitrate removal
- For the next 10%, to reach a 45% reduction, wetlands, cover crops, and further reductions in N applications are only options left (unless cropping changes) – all with decreased efficiencies and increased lb N/ac costs.

P loss reduction

- Based on report #3 of the “Integrated Assessment” and also the Iowa state nutrient budget, the average P loss with river flow is about 0.75 lb/ac/yr.
- A 45% reduction of the 1,560 tons of P loss per year would be 702 tons.
- Or the average, total P concentration (that in water plus sediment) would have to be reduced from 0.415 to 0.228 mg/L.

[Note that the draft P criterion for standing waters (i.e. lakes) in Iowa is being proposed at 0.035 mg/L].

P index calculations in two Cedar River subwatersheds (Chad Ingels and John Rodecap; ISU extension)

Results of P index calculations

- Coldwater-Palmer
  - 207 fields
  - 99 with P index ≥ 1.00 (lb/ac/yr)
  - 9 with P index ≥ 2.00
  - max = 6.12; average = 1.06
  - average soil test P = 34 ppm (max = 401; 54% above the optimum range)
- Lime Creek
  - 209 fields
  - 67 with P index ≥ 1.00 (lb/ac/yr)
  - 3 with P index ≥ 2.00
  - max = 3.01; average = 1.07
  - average soil test P = 36 ppm (max = 120; 57% above the optimum range)

Practice: Reducing soil test levels to the optimum level

- The break between “optimum” and “high” soil test P levels (Bray-1) for row-crops is 20 ppm.
- At 20 ppm soil test P level, soluble P in surface runoff is estimated at 0.150 mg/L.
- At 35 ppm, it is 0.225 mg/L.
- With 35% of river flow estimated to be surface runoff, that would be 2.8.”
- Over time, reduced or no P inputs to fields testing “high” would save money and reduce P levels and losses.
- The reduction in P loss associated with reducing the average soil test level from 35 to 20 ppm would meet about 1/7 of that needed for a 45% reduction.

Achieving the remaining P-reduction

- Further conversion to conservation and no tillage (currently 4% no-till).
- Additional contouring (currently 6%).
- Use of vegetated buffer strips.
- Use of water and sediment control basins.
- Use of terraces.

Summary/Concerns

- To reach the Gulf Hypoxia reduction goal of 45% for total nitrogen, of which nitrate is about 2/3, the costs will be significantly higher.
- There is the concern that reducing field P losses, and more importantly reducing P which is actually transported to streams, will not reduce in-stream P concentrations or the amount exported to the Gulf.
- At issue is how much P can be provided by recycling from the soils and sediment already present in the stream, lake, and marine systems.

Summary/Concerns

- Despite what some believe, there are few “win-win” situations, and those associated with rate of nutrient inputs will not get us to currently targeted water quality goals.

- Reaching those goals will come at considerable effort and costs, and therefore, it is imperative to be sure that the practices promoted will secure those goals; and furthermore, that reaching those goals will result in the anticipated environmental benefits.

- Producers and the public, once deceived and/or disappointed, will not readily cooperate or be supportive in the future.

"We have an opportunity/obligation to create a coordinated, integrated initiative that builds on research and addresses compelling needs"

Wendy Wintersteen, Dean, College of Agriculture, ISU
April 12, 2006