PROBABILITY OF SUCCESS FOR PRACTICES TO MINIMIZE WATER QUALITY PROBLEMS

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Introduction

I would like to spend my time this morning reviewing with you some of the practices and approaches research has suggested as being useful in controlling quality of both surface water and groundwater. Given the limited time available, I will highlight only a few of the study findings, and confine my remarks primarily to the problems of nitrogen pollution of groundwater and phosphorus contamination of surface waters. This limited review is prompted more by what I perceive to be the major interests of this audience and limitations of time than by any judgment about lesser importance of such pollution problems as pesticide and sediments.

Environmental Accountability

Before presenting specific management recommendations to protect water quality, I must emphasize that agriculture increasingly will be held accountable for its environmental impacts. We can argue about the need for practical rules and fair standards, we can demand demonstration of effectiveness, we can fight for realistic implementation schedules, and we can blow a little smoke. But we can't hide from the fact that agriculture's impacts on the environment will be monitored and controlled as never before.

Farmers traditionally have based their production input decisions on costs and returns. These decisions generally were not tempered by externalities, especially the societal costs of agricultural pollution. In some instances, those societal costs may exceed the production costs. "Thus, regulation is seen by many as a way to forge the link that will protect the environment from the damaging levels of agricultural input use that may result from private decision making (Crowder, et al. 1988)."

U.S. Department of Agriculture's Economic Research Service recently issued a report on costs of groundwater pollution, which concluded that the drinking water for an estimated 50 million people in the United States comes from groundwater that is potentially contaminated by agricultural chemicals. About 19 million of these

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people get their water from private wells, which are most vulnerable. Most of the people who rely on groundwater in potentially contaminated areas live where groundwater may contain pesticides or a combination of pesticides and nitrate. The researchers put first time monitoring costs at $900 million to $2.2 billion for private wells, and $14 million for community groundwater systems (Nielsen and Lee, 1987).

These and many other estimates of mounting societal costs of agriculturally related water pollution are causing state and federal governments to implement ever stronger "carrot and stick" approaches. My assessment maybe wrong, but I see the stick growing faster than the carrot. At the federal level, environmental interest groups played critical roles in shaping the 1985 farm bill. Their support for or lack of opposition to the farm bill came only after conservation reserve, cross compliance and sodbuster provisions were included. The impact of environmental organizations on future farm legislation may be similar to impact the food stamp coalition has had in the past on farm legislation.

In Wisconsin, we passed a groundwater protection law (Chapter 160 Wis. STATS) in 1984 that will lead to a set of strict enforcement standards for various pesticides in groundwater. Different cropping regions in the state will have best management practices prescribed to meet the established standards, and some pesticides in certain cropping areas will likely be banned or highly restricted in their use. It is unfortunate that the solid research base needed to implement the Wisconsin regulatory program is not in place. Even more unfortunate is the fact that no research money was provided in the bill.

In Nebraska, formerly voluntary efforts have been replaced by a tough regulatory approach to deal with nitrate in groundwater. The three phase program is based on nitrate nitrogen levels in groundwater, with Phase I areas having less than 12.5 ppm, Phase II areas have from 12.6 to 20 ppm, and Phase III areas having greater than 20 ppm. In Phase I area, the Nebraska law bans fall and winter applications of N on sandy soils. Phase II limitations are more severe. Restrictions on application practices are increased, annual residual nitrogen and irrigation well water sampling is mandated, and attendance at nitrogen management schools is required. These costs are borne by the farmer. If Phase II steps fail, then Phase III kicks in -- bringing even tougher management controls and restrictions on amount of nitrogen that can be applied (Fee, 1988).

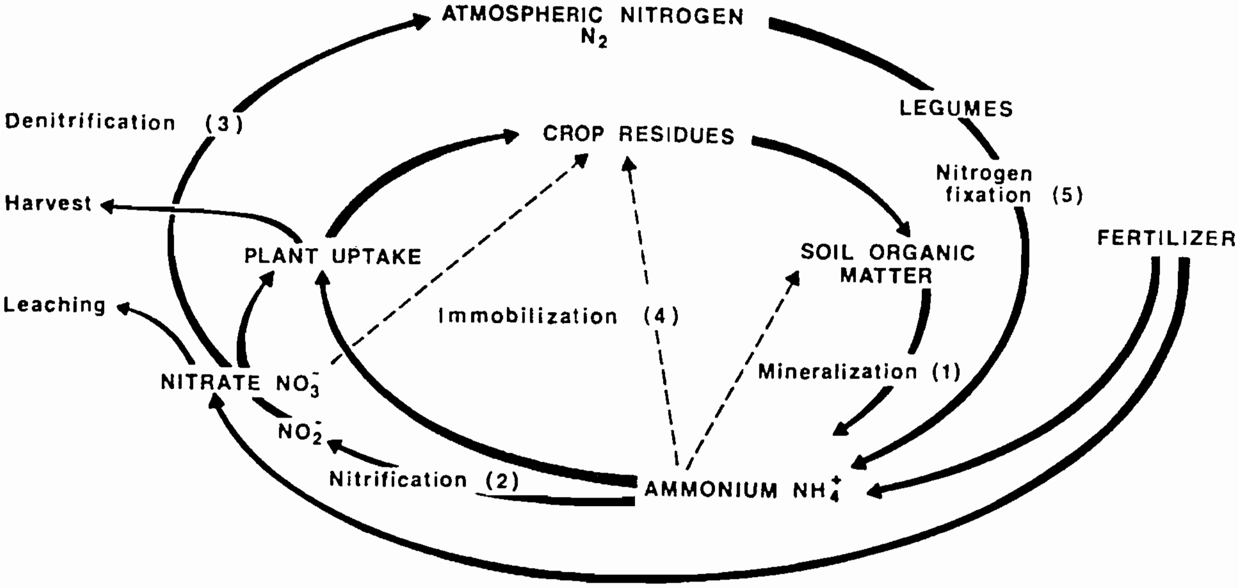
In the recent past, I believe some business and university leaders have resisted environmental considerations too vigorously, believing that farmers themselves found such environmental demands unreasonable. I question whether this assumption was ever true, and know that it does not reflect reality today. Farmers and their families are among groups most dependent upon groundwater for personal use. They also appreciate wildlife, enjoy quality fishing, boating and swimming, and they don't want to do things that cause water quality problems. They want to help remedy the problem, are willing to work toward an improved environment, and are looking to us -- those of us in agribusiness, universities and government -- for realistic and effective answers.

Nitrogen Management to Protect Groundwater

Background

Nitrogen can be and is a problem in surface water quality, but it receives most attention because of the health threat it poses when nitrate leaches into groundwater. It is on this latter problem that I will confine my remarks today. At the outset of this discussion we must recognize that nitrogen is one of the most difficult elements to trace through the environment because of the many chemical pathways and transformations it can follow. Figure 1 illustrates the complex nitrogen cycle. It also explains in large part why nitrogen is such a difficult element to manage.

Figure 1. The Nitrogen Cycle in Agriculture



(Keeney et al., 1986)

Wisconsin farmers applied 246,000 tons of nitrogen fertilizer in 1984. Much of this fertilizer went on 4.1 million acres of corn land (Keeney et al., 1986). In Wisconsin, a major dairy and livestock producing state, manure is an important source of nitrogen to agriculture, as are legume residues.

Improved management of nitrogen from fertilizer and non-fertilizer sources is the only realistic approach to minimizing nitrate additions to groundwater from cropland. Available nitrogen that is not recovered by crops is subject to loss from soil through several processes, with leaching contributing to nitrate contamination of groundwater. Increased crop recovery of available nitrogen through improved nitrogen management reduces the amount of nitrogen subject to loss to groundwater (Bundy, 1987).

Here, then, are some management practices that can reduce nitrogen threat to groundwater.

Proper Application Rate

The amount of nitrogen the farmer applies is often the most important factor affecting efficiency of crop use and nitrogen loss to groundwater. Today, economic considerations are of most importance to the farmer in determining optimum application rates. The economic optimum nitrogen rate is achieved when the cost of the last increment of fertilizer added is equal to the value of the yield increase produced by that nitrogen addition.

Table 1 illustrates this relationship for continuous corn grown in Wisconsin trials.

Table 1. Yield, economic return, and recovery of applied N in grain with 40-lb/a increments of fertilizer N applied to continuous corn. Janesville, Wis. 1983-85. 1/

N rate	Yield	Value of yield increase	Cost of N	Return	N recovery
lb/a	bu/a		$/a		%
0	93	--	--	--	--
40	115	44	6	38	45
80	131	32	6	26	45
120	138	14	6	8	20
160	144	12	6	6	17
200	145	2	6	-4	0

1/ Assumes $0.15/lb for N and $2.00/bu for corn. (Bundy, 1987)

These data, typical of normal response rates, indicate that the economic optimum nitrogen rate for this production situation is 160 lb N/a, although only 6 bu/a of additional yield were obtained for the last 40 lb/a of nitrogen applied. Important to our discussion here is that recovery of nitrogen in corn grain decreased from 45% for the first 40 lb applied to 17% for the final 40-lb increment applied at the 160 lb N/a rate.

Farmers, attempting to maximize returns, understandably tend toward the economic optimum. Society, attempting to protect against environmental degradation, understandably tends toward higher nitrogen recovery rates. If nitrogen regulations become more broadly applied, hopefully those regulations will find an acceptable compromise between the two extremes.

Table 1 also clearly indicates why environmental interests tend to retreat in the face of commodity scarcity and rising prices. On the other hand, farmers must also consider what happens in the "aggregate" if most producers fertilize to achieve maximum economic return. If individual decisions on maximum economic return result in surplus "aggregate" production, the price of the commodity will fall, and maximum economic return will occur at a lower fertilization rate.

Realistic Yield Goals

Since nitrogen fertilizer recommendations are based on yield goals, unrealistic goals result in inappropriate nitrogen applications. Yield goals should not be more than 10%-20% above the recent average yield experience in a particular field (Bundy, 1987). A recent survey of corn producers in Nebraska suggests that farmers tend to be overly optimistic in setting yield goal estimates. In the four year survey of 158 producers, only 10% consistently reached their yield goal. Fifty percent attained 80% of their yield goal, and the remaining farmers fell more than 20% below their estimated yield goal (Schepers, et al., 1986). Farmers are naturally optimistic, but their optimism here is costing them money and threatening groundwater quality.

Soil Organic Matter Estimates

Wisconsin nitrogen fertilizer recommendations are based on soil organic matter content in combination with yield goals. Adjustment of nitrogen rates for soil organic matter reflects nitrogen contributions from organic matter mineralization. Wisconsin corn studies showed that yield goals of 141-160 bu/a could be achieved with 190 lb N/a in fields with less than 20 tons of organic matter per acre, and with 130 lb N/a when fields had 76-100 tons of organic matter per acre. Thumb rules such as the one that recommends 1.2 lb of N/a for each bushel of yield may not predict accurately optimum nitrogen application rates (Bundy, 1987). Organic matter content must be taken into account if accurate recommendations are to be made.

Credits for Legumes and Manure

Legumes and manure can supply substantial amounts of available nitrogen for crop production, and can contribute substantially to nitrogen leaching if not accounted for in plant recovery rates discussed earlier. Table 2 provides estimates of nitrogen credits that should be applied when manure and legume crops are present.

It is worth noting here that one of the sustainable agriculture goals of increasing use of manures and legumes as an organic nitrogen source may not have entirely beneficial results. Certainly, increasing soil organic matter will increase infiltration rates and reduce runoff. But legume residues and manure may also release nitrogen during periods when crops are not actively feeding, thus increasing the likelihood of higher nitrate leaching. These relationships and many others being suggested by sustainable agriculture approaches need further study.

Table 2. Nitrogen credits for manure applications and previous legume crops.

Source	Nitrogen Credit
Manure	
Stacked or daily hauled	4 lb N/ton
Liquid manure	3 lb N/ton
Analyzed manure	40% of N content
Legume crops	
Alfalfa	40 lb N/a plus 1 lb N/a for each percent legume in stand For second year corn following good legume sod (over 50% stand) credit 30 lb N/a.
Soybeans	1 lb N/a for each bu/a of beans harvested up to maximum credit of 40 lb N/a.

(Bundy, 1987)

Nitrate Soil Tests

Recent Wisconsin research (Bundy and Malone, 1988; and Malone, 1986) shows that adjustment of nitrogen fertilizer recommendations for the amount of residual nitrate in soil profiles has potential for improving crop use efficiency and reducing nitrate loss to groundwater. These studies have shown that substantial amounts of nitrate may remain in soil profiles (0-3 ft) at the end of the growing season if nitrogen application rates exceed crop nitrogen requirements. While research to evaluate nitrate soil testing is currently incomplete, available data indicate that use of nitrate soil tests could improve nitrogen fertilizer efficiency and reduce environmental dangers (Bundy, 1987).

In addition, data are accumulating that indicate early growing season nitrogen testing may have value in predicting crop nitrogen needs (Bundy, 1988). Both plant tissue analysis and nitrate soil tests show promise in providing guidance to farmers on possible need to side dress crops to meet nitrogen requirements while avoiding costly and environmentally damaging overloads.

Timing and Placement of Nitrogen Applications

Timing and application of nitrogen applications can be important factors affecting efficiency of crop use and potential loss to environment. Literature review shows that fall applications are usually 10%--15% less effective in Wisconsin than the same amount of nitrogen applied in the spring as preplant (Bundy, 1986). Therefore greater crop nitrogen recovery and lower risk of nitrogen loss to groundwater will usually be obtained with spring applications than with fall applications. Sidedress applications are likely to increase crop recovery of applied nitrogen and reduce nitrogen loss relative to preplant applications on sandy soils where leaching is high. Sidedress applications on medium and fine textured soils usually does not increase corn yield or recovery of applied nitrogen when compared to spring preplant applications (Bundy, 1986; Randall, 1986).

Foliar and Irrigation Applications of Nitrogen

While plant leaves can absorb nitrogen in liquid solution, foliar application is prohibitively expensive, and would damage plant leaves if applied at levels great enough to meet plant needs. Application of nitrogen with irrigation water may be feasible for many irrigated crops, but the practice generally increases leaching losses, particularly if applied to shallow rooted crops, or on crops grown in hills or ridges (Jackson et al., 1987). However, residual nitrate occurring in irrigation water can sometimes be a significant source of nitrogen and should be credited. For example, water containing 10 ppm nitrate nitrogen provides 27 pounds of nitrogen with each acre-foot of water applied (Olson, 1986).

Crop and Variety Selection

Research shows that under some conditions careful selection of corn hybrids for specific fields and yield goals has potential for improving nitrogen use. Purdue University research has demonstrated that yield potential of different hybrids is directly related to the nitrogen response characteristics of the hybrid. Low fertility hybrids, for example, were found to require little nitrogen fertilizer and take up most of what they needed earlier in the season (Tsai, et al., 1984). Another study suggested that low fertility hybrids could be managed for optimum nitrogen use efficiency on droughty, low organic matter (sandy) soils (Huffman. 1986). Wisconsin research has not demonstrated these suggested advantages of hybrid selection (Bundy and Carter, 1988).

Nitrification Inhibitors and Slow Release Forms

Nitrification inhibitors when used with ammonium forms of nitrogen can improve nitrogen efficiency and limit losses in soils where leaching or denitrification potentials are high. Nitrification inhibitors function by slowing the conversion of ammonium nitrogen to nitrate, thereby reducing losses of nitrogen that occur through the nitrate form (Bundy, 1987). Present research shows that improved timing of nitrogen applications is more cost effective than the use of slow-release forms of nitrogen, due to high costs and problems of matching release rates to crop needs during the growing season (Jackson, et al., 1987).

Improved Overall Management

Improved calibration of equipment, more even distribution of fertilizer, and adjusting application rates within fields are low-cost, existing technologies that can be used to improve nitrogen use efficiency and lessen environmental problems (Jackson et al., 1987). In addition, sound agronomic practices must be followed to achieve high yields, including, for example, sufficient levels of phosphorus and potassium, and other nutrients; high plant populations; adapted varieties; and weed and insect control.

Proper irrigation management can also be important in decreasing potential for nitrate leaching. Research and grower use have verified the effectiveness of the Wisconsin Irrigation Scheduling Program (WISP). Growers using WISP have maintained productivity while applying less water. Research shows that when irrigation scheduling is used, leaching occurs only after major storms (Jackson, et al., 1987).

Bottom Line Prospects for Meeting Nitrogen Standards

If the practices and technologies identified above are diligently applied, it should be possible over time to approach and meet reasonable nitrate standards in most cropping areas of the country. I will assume that the current nitrate standard of 10 ppm will continue to be used. However, even in cropping areas "generally considered safe," some nitrate leaching will likely occur when nitrogen is applied at efficient and profitable crop production levels. We can and must control gross mismanagement of nitrogen application. This will result in significant improvement, but we will have to work through a period of above standard nitrate contamination while we flush from the system the excesses of the recent past. Evaluation of improvement will determine if these practices are adequate to meet current standards.

We must also recognize that intensive agricultural practices are now taking place on some environmentally fragile soils and geologic areas where even diligent application of the best practices and technologies may result in unacceptable groundwater or other environmental deterioration. Sandy soils in areas of extremely high water tables, and shallow soils over badly fractured bedrock are examples of environmentally fragile cropping areas, particularly when they are adjacent to urban areas dependent upon groundwater for their water supply

In those areas, we may be faced with some complex decisions that balance rights of individual farmers to use their lands for certain types of cropping, and the rights of society to protect and manage natural resources, such as groundwater recharge, for the larger public good. In environmentally fragile cropping areas, society may have to prescribe less intense cropping practices. For example, it may be necessary to restrict intensive row cropping to every third or fourth year. Or drastic restrictions on pesticide and fertilizer use may be mandated. In these situations, it is also reasonable to expect society to "cost-share" on practices that significantly reduce the farmer's net returns.

In other instances, society may place a sufficiently high value on a natural resource, such as groundwater recharge, that all threats to that resource will be eliminated or held to absolute minimum. This could be done through land use zoning, hopefully with fair compensation to existing land owners for the restricted use. In other instances, governmental units may buy outright the critical land areas. This is an extreme alternative, but one that is not without precedent. In New York and Arizona, governmental units have bought or are buying land areas for the sole purpose of managing them to ensure adequate quality and quantity of surface water and groundwater to meet water supply needs.

Phosphorus Management to Protect Surface Waters

Background

While nitrogen commands most attention as a groundwater pollutant, it is phosphorus that commands most attention in surface waters. Certainly, nitrogen loading in surface waters also is of concern, but normally it is not the limiting factor in excessive weed growth. Excessive weed and algae growth harms water recreational use for fishing, swimming and boating, and creates headline-generating stinks of both the physical and political variety.

Soil phosphorus is a complex mix of both organic and mineral materials that vary greatly in solubility. Plant roots absorb phosphorus from the soil only if present in the soil solution as an ion. Soluble mineral phosphorus may be precipitated as calcium, iron or aluminum phosphates. Some phosphorus is absorbed on the surface of carbonates, hydroxides, oxides and clay particles. In these forms, phosphorus is relatively insoluble, and moves primarily in the erosion process. Phosphorus is also released from decaying organic materials such as crop residues, manures and municipal sewage. Research has shown that the concentration of phosphorus in soil solution is frequently less than 0.1 ppm. Such a dilute solution is the basis for widespread use of fertilizer phosphorus and the great increase in crop yields associated with use of phosphorus on deficient soils (Robertson and Christenson, 1985).

Most research has concluded that use of phosphorus fertilizers has been increasing on agricultural lands. A North Central Region publication reviewed numerous studies, and concluded that in most of the states in the region phosphorus soil test levels are increasing. The increase is most pronounced in states in the eastern part of the region that have been applying larger quantities of phosphorus fertilizer. The study suggested that fertilizer applications were greatest on sandy soils devoted to high value crops such as potatoes and vegetables, and in land areas near concentrations of animals (Ellis and Olson, 1986).

Although there has been much publicity about elevated phosphorus levels and low water quality, the relationship is not as simple and direct as many believe. Phosphorus content of surface water represents the sum that is dissolved in solution in available form and that in suspension in unavailable forms. Solution levels in lakes and streams are usually very low.

Total phosphorus levels in surface runoff vary greatly, and are likely to be highest in runoff occurring immediately after fertilizer or manure applications. Levels may also be very high where soil erosion rates are high. Soil erosion undoubtedly accounts for the greatest phosphorus loss from croplands. Suspended materials in water flowing across cultivated land may have a phosphorus content as high as 1 lb/ton of transported material. This may be a tolerable level where soil erosion rates are low -- in the range of 1-3 tons/acre. It is totally unacceptable where soil losses are in excess of 10 tons/acre (Robertson and Christenson, 1985).

Because phosphorus has low solubility and high affinity for mineral soil particles, most phosphorus in surface runoff waters is thought to be associated with eroded soil particles. Thus the common assumption has been that reducing soil erosion and sedimentation is the best way to deal with phosphorus related problems in surface waters (Illinois Environmental Protection Agency, 1986). The Illinois study makes the following recommendations for control of phosphorus from agricultural croplands.

Terraces:

Terraces can reduce sediment associated with phosphorus loads by as much as 95%, while reducing dissolved phosphorus losses from 30-70%. Water ponds behind terraces allow soil particles time to settle out of suspension, can increase water infiltration, and further reduce surface runoff.

Contouring:

The Illinois paper reports that contouring can reduce sediment losses by 50-60%. Particulate phosphorus loads can be reduced by an average of 45%. Since contouring increases infiltration and reduces runoff, it lowers dissolved phosphorus losses by 20-50%.

Sod Rotations:

Small grain or legume crops in the rotation improve soil structure, increase organic matter content and increase porosity when compared to continuous row cropping. Particulate phosphorus loads can be reduced by 65% and dissolved phosphorus loads from 30-75% when sod rotations are used.

Conservation Tillage

Conservation tillage systems require that a minimum 30% residue cover be left on the soil surface after secondary tillage operations are completed and the crops have been planted. The Illinois literature review shows that the use of conservation tillage can reduce particulate phosphorus losses by an average of 50% (ranged from 25-70%) and dissolved phosphorus losses from 24-42%. In some cases, the Illinois review found that dissolved phosphorus concentrations under conservation tillage systems can be higher than that found under conventional tillage because residues left on the soil surface can impede the attachment of applied phosphorus fertilizer to the soil. However, because runoff is reduced, a decrease in dissolved phosphorus loads will generally result.

No-Till

With the no-till method, crops are planted with no seedbed preparation and all crop residues remain on the soil surface other than those displaced when readying the soil for seed placement. No-tilled soils reduce erosion substantially and therefore reduce particulate phosphorus by an average of 55% (ranged from 33%-81%). Because of the large amounts of residue and broadcast phosphate fertilizers remain on the soil surface in no-till situations, increased dissolved phosphorus loads in surface runoff will be noticed (up to 100% increase). However, even though dissolved phosphorus loads increase, the total phosphorus loads are reduced substantially when compared to the total phosphorus lost with conventional tillage, because of dramatic reductions in both soil lost and run-off that occur under no-till conditions.

Sediment Basins and Filter Strips

These structures do not affect the amount of runoff from a watershed, but they do slow the movement of water and allow sediments to settle out. Because of variability in size, shape, and proximity to water bodies, their effect on phosphorus loading of surface waters is uncertain. However, it can be assumed that since sediment is allowed to filter out in these structures, the sediment associated phosphorus loads will also be reduced.

Stripcropping

The purpose of stripcropping is to reduce erosion and improve water control. While runoff volume may not be greatly affected, states the Illinois review, slowing the downhill movement of water will reduce its capacity to pickup and transport soil particles in suspension. Because contour stripcropping reduces soil erosion, particulate phosphorus loads will be reduced. The extent of the reduction was not revealed in this review.

Other Management Practices

A host of farm management practices can contribute to lessening environmental problems caused by phosphorus loading in surface waters. These include 1) proper fertilizer application rates, 2) timing fertilizer applications, 3) storage and application of manure, and 4) liming practices.

Proper fertilizer application rates. Wise and careful use of fertilizer is one of the most important means of controlling phosphorus pollution. Soil testing will minimize the error between optimum and actual rates of fertilizer application.

Timing fertilizer applications. This is an extremely important factor in determining nutrient utilization efficiency and crop yields. Applying phosphorus and other fertilizers at the time of maximum growth and demand of the plant will reduce nutrient losses. This application timing will vary from farm to farm, depending on soil type, crops, date of planting and so forth (Illinois State Environmental Protection Agency, 1986).

Storage and application of manure. Animal, municipal and industrial wastes will all contribute to phosphorus pollution of surface waters unless properly stored and applied. This means good housekeeping in properly constructed livestock holding facilities and yards to prevent manure runoff, particularly when located near streams and lakes. It means incorporating such wastes into the soil as quickly as possible after application, and it means refraining from spreading manure on frozen, snow-covered soil adjacent to streams or with slopes greater than 6% whenever possible.

Liming practices. Proper soil pH improves plant's ability to use phosphorus fertilizers. If pH is too low, excessive phosphorus may be applied to counter low plant uptake, and this will increase phosphorus runoff in both dissolved and attached forms.

Bottom Line Prospects for Reducing Phosphorus Loadings

While no standard now exists for phosphorus content of surface runoff waters, an informal, yet poignant public standard will continue to be applied. That standard will be expressed in the thickness of the weed growth near a person's summer cottage, in the smell and clarity of the water at a another person's favorite swimming beach, and in the weed tangle in a boater's motor prop. Some states, including Wisconsin, are giving consideration to development of standards for phosphorus in runoff water. With or without a formal standard, however, agriculture's contribution to the problem will be measured, and accountability demanded.

I am less confident here than I was with nitrate contamination of making acceptable progress with existing technologies and practices. Getting highly erodible lands out of production through the Conservation Reserve Program, and requiring improved conservation plans on all farms benefiting from federal government programs will certainly help. But runoff from highly productive, highly fertile farms will always translate into some loss of phosphorus to adjacent streams and lakes. Summer algae blooms and weed growth in lakes may be an unwelcome by-product of productive soils. I am confident that we can do more with agricultural practices to reduce the surface pollution problem; I am not sure, however, that we can ever reach a quality level that is expected by some people.

Tradeoffs in Nitrate and Phosphorus Management

A funny thing happened to us while we were working to reduce surface water pollution and soil erosion. We noticed that in our efforts to hold the soil and water on the land, we were probably increasing water infiltration, and thus, the groundwater pollution that comes with leaching. As of now, this is mostly an untested hypothesis, without a great deal of data to support or refute it. Still, it is a nagging proposition that will demand more of our research attention, and will challenge our abilities to add two positive environmental programs together without getting a negative.

Among limited research data relevant to the tradeoff hypothesis is a 1988 computer modeling analysis done by the Economic Research Service of the U.S. Department of Agriculture. The study used the CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) model to estimate edge of field losses of soil, runoff losses of nitrogen, phosphorus and pesticides, and nitrate leached out of the rootzone. ERS constructed the model to compare in a consistent manner relative field losses of soil and selected chemicals among different management practices. The researchers modeled a variety of field management practices and manure applications rates using the CREAMS model. Also estimated were the effects of crop residues, current crops, fertilization, land use, and climate (precipitation, solar radiation, and temperature) on field losses of pollutants.

The results show that permanent vegetation, hay or pasture, is the most effective soil conservation practice for soil and nutrient runoff control because it reduces soil loss by 95% and nitrogen loss in surface runoff waters by 90%. However, nitrate leaching increases 26% compared with conventional corn grain manured at 20 tons per acre annually.

In the modeling parameters used in this study, contour tillage reduced soil loss by 45%, total nitrogen by 18% and total phosphorus by 37%. Nitrate leaching increased slightly, however. Conservation tillage practices -- reduced tillage (chisel plowing followed by harrowing once) and no-till -- were both efficient and cost effective for soil and nutrient loss control. No-till reduced nitrate leaching as well, thus producing reductions in all pollutant losses. The researchers found terrace systems to be highly effective in erosion control but not as effective as no-till for reducing total nitrogen losses. Terrace systems reduce total nitrogen losses by 26% compared to 37% for no-till. Terraces increase nitrate leaching.

In a concluding section of their paper, the ERS researchers say that "although reductions in surface losses of soil, nitrogen, and phosphorus can be achieved with soil conservation practices, the control of nitrate leaching is more complicated. Reducing surface runoff and its constituents increases percolation of water through the soil, potentially boosting the leaching of nitrate, pesticides, fecal coliform bacteria, and some small amount of phosphorus to groundwater.

"An effective way to reduce nitrates in field runoff is to cut back on nutrients from manure, crop residues, and fertilizers. ...

"The linkages between soil conservation practices and nutrient management are also complex and variable. Effective soil conservation on a field with excess nutrients can result in accelerated degradation of groundwater quality, while improving surface water quality. However, when timing and amount of nutrients are matched to crop needs, soil conservation practices can improve surface runoff and still maintain leachate concentrations of nitrate at levels consistent with drinking water quality standards (Crowder and Young, 1988)."

Research is underway in numerous states, including Wisconsin, to develop nitrogen management models (Oberle, et al., 1987). These computer models would improve nitrogen fertilizer recommendations by clearly displaying the options. Development of models is hampered both by lack of funds and by data on effects of management practices. Many models on nitrogen cycling in the soil and in soils-plant systems are available, but they are much too complex for use on a practical scale. However, with improved understanding of nitrogen cycling, it might now be possible to develop practical, predictive models for nitrogen fertilizer needs for any number of crops.

University of Wisconsin researchers are attempting to design such a model to run on microcomputers. County Extension faculty, crop consultants, and fertilizer dealers could produce more accurate fertilizer recommendations by considering in an orderly fashion, the many variables (soil type, manure/alfalfa credits, cropping history, past weather etc.) that affect nitrogen needs of corn, for example (Jackson, et al., 1987). This expert systems approach is based on accurate and predictive computer models Such systems will allow site-specific fertilizer recommendations to be made, and will require considerable farmer involvement. This farmer involvement may be highly beneficial in that it can encourage more implementation of recommended practices.

The key to resolving the tradeoff dilemma between groundwater and surface water pollution may lie in this fine tuning of plant nutrient testing and applications. Prophylactic fertilizer applications not only are uneconomic, they create conditions where management strategies become environmentally competitive rather than complementary. If we solve the runoff problem, we can only avoid the leachate problem by keeping plant nutrient levels at minimums needed for efficient and profitable crop growth. The dilemma may never be resolved if we continue to attack the problem along isolated disciplinary routes. Rather, we need to move to integrated systems approaches that attempt to assess numerous relevant variables in complex, whole-farm models.

If this integrated, agricultural systems approach sounds like an argument in support of sustainable agriculture, I make no apologies. In the water quality area and in many other areas important to farming success, we must do a better job of integrating knowledge, technologies and practices, and applying them at the farm level. If we don't provide research and advice on this integrative task, we leave our jobs only partially done and individual farmers with impossibly complex decisions.

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PROCEEDINGS OF THE EIGHTEENTH

NORTH CENTRAL EXTENSION - INDUSTRY SOIL FERTILITY WORKSHOP

9-10, November 1988, Holiday Inn St. Louis Airport North

Bridgeton, Missouri

Volume 4

Program Chairman:

K. A. Kelling

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CREDITS

The professionalism shown by Ms. Barbara Brown in typing portions of this document and in helping organize its preparation is acknowledged and appreciated.

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