Nutrient Management to Protect Water Quality
Michigan State University Cooperative Extension Service
Water Quality Extension Publications
Maurice L. Vitosh, Lee W. Jacobs, Crop and Soils Science
February 1990
6 pages

Cooperative Extension Service | Michigan State University | February 1990 (New) | Extension Bulletin WQ25

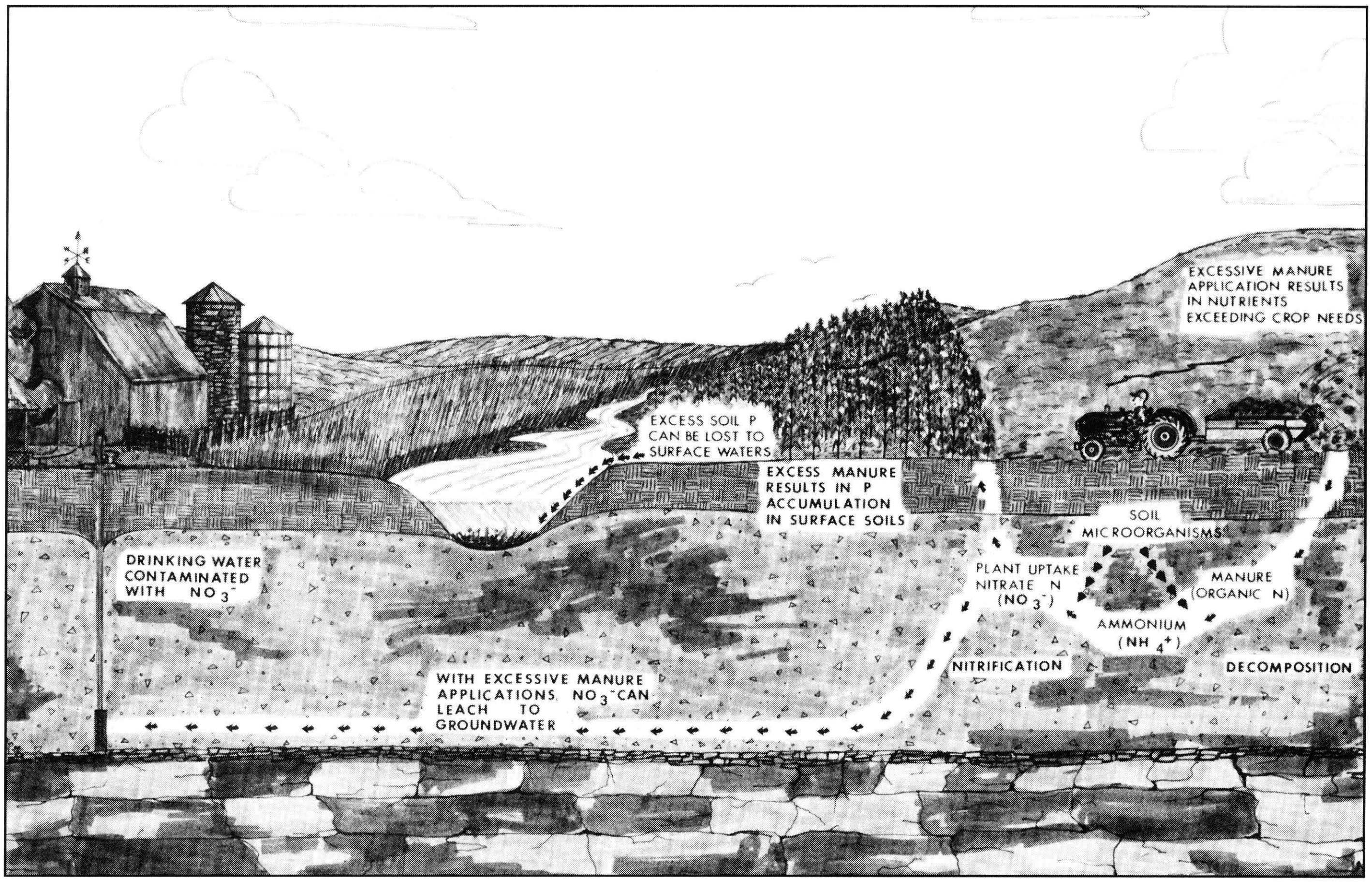
Nutrient Management to Protect Water Quality*

Maurice L. Vitosh
and **Lee W. Jacobs**
Extension Soil Specialists
Department of Crop and Soil Science
Michigan State University

Considerable national attention is being given to nitrate nitrogen (N) contamination of groundwater and phosphorus (P) contamination of surface water. The source of this contamination is non-point in nature, meaning that it cannot be specifically identified. Agricultural practices, however, have been implicated as causing much of the non-point source contamination.

Water is the most common ingredient in all natural processes and is the medium for movement of nutrients away from the land surface. It is constantly being recycled from water surfaces and through plants to the atmosphere by evapotranspiration and back again to the earth's surface as precipitation to produce stream flow and groundwater flow on and within our land surface. As water moves through this cycle, it dissolves nutrients from soil minerals, crop residues, fertilizers, manures and other materials. Thus nutrients, like water, have their own natural cycle.

The earth contains an abundant supply of plant nutrients, but not all agricultural soils contain adequate nutrients for intensive crop production, particularly N, P and potassium (K). Fertilizers, manures and other organic materials are required to supplement nutrients supplied by the soil. All nutrients, whether they are synthetic or naturally occurring, can become mixed with surface water or groundwater by natural processes such as runoff and leaching. Therefore, proper management of all nutrients is crucial to protect surface and groundwater quality.



*This material is based on work supported by the U.S. Department of Agriculture, Extension Service, under special project number 89-EWQI-1-9143.

Managing the amount, form, placement and time of nutrient application is the only realistic and practical approach to minimizing the risk of surface and groundwater contamination. Education and demonstration programs are urgently needed to help producers become more aware of potential environmental problems and to get them to adopt best management practices. Other alternatives, which are less desirable, include legislative action and enforcement. Farmers need to develop a total farm nutrient management plan for their farms. They need to look at the entire farm operation, not just one field at a time. To develop a total farm nutrient plan, they should ask a number of questions: What nutrient inputs exist on the farm? Is the farm operation utilizing these inputs to their fullest potential? Where might the operation be overloading the nutrient cycle? What practices need more attention?

The following management practices will help to assure protection of water quality. Farmers should voluntarily follow as many of these practices as possible.

Soil Testing

Soil testing is one of the best tools we have for obtaining an inventory of the nutrients that the soil can supply. One of the keys to a good soil testing program is proper soil sampling. MSU Extension bulletins E-498, Sampling Soils for Fertilizer and Lime Recommendations, and E-1616, Soil Sampling for No-till and Conservation Tillage, available from your county Extension office, give instructions for obtaining a good representative soil sample. Once we have determined what the soil can supply, we can better determine whether the crop needs supplemental nutrients. Fertilizer, manure additions and nutrient removal by crops will alter the soil test, so each field should be tested every two to three years. For high value crops or fields where large amounts of fertilizer are added, retesting every year is desirable. Fertilizer recommendations based on soil tests frequently vary between soil testing laboratories. Though many commercial laboratories recommend more fertilizer than Michigan State University does, numerous studies have shown that MSU recommendations are adequate and economical.

Realistic Yield Goals

Recent surveys have shown that many farmers are overly optimistic in assessing their yield goals. Because fertilizer recommendations are normally based on yield goal, selecting an unrealistically high yield goal leads to overfertilization and loss of farm income, and potentially threatens water quality. The key is to select a yield goal that is both realistic and achievable, based on soil potential and level of crop management utilized. The farmer should achieve the yield goal at least two out of five years or nearly 50 percent of the time. If the goal is seldom achieved, you need to reassess the entire crop management system to identify what factors other than soil fertility are limiting yield.

Soil Organic Matter, Legume and Manure Credits

The contribution of soil organic matter to plant nutrition should be taken into account to make accurate N recommendations. High organic matter soils will need less fertilizer N to obtain the same crop yield because they are capable of mineralizing more N than low organic matter soils. Michigan State University N fertilizer recommendations are based on soils with 0 to 4 percent organic matter. See Table I for suggested N credits for soil organic matter.

Legumes have long been used in crop production systems to improve the fertility and tilth of soils. The N supplied by legumes, which is due to a nitrogen fixation process in root nodules, needs to be credited to subsequent crops as a part of the nutrient management plan. A good stand of alfalfa will release more than 100 pounds of N per acre in the first year after being plowed or renovated. Other legumes, such as soybeans, red clover and sweet clover, also contribute to the available N supply, but the amount is usually less. The amount of credit given for legume N fixation depends on how long the legume has been growing, and the density of the legume when renovated. See Table II for suggested N credits for previous crops.

Table I. Suggested nitrogen credit for various soil organic matter levels

Soil organic matter	*Nitrogen credit**
-%-	*-lb N/A-*
0-4	0
4-8	(+) 20-40
8	(+) 40-80

*Subtract this amount of N from the recommended rate.

Manure has long been recognized as a source of plant nutrients. All of the crop nutrient requirements can be met by manure if sufficient amounts are applied, but frequent applications of manure often result in a buildup of residual N and P. Extremely high soil P levels should be avoided, because runoff or erosion from this land is likely to contribute to excess P loading of lakes and streams. This leads to growth of unsightly weeds and aquatic plants in the water and reduces its recreational value.

Manures and other biological wastes should be analyzed periodically to determine the appropriate credit for the nutrients they can supply. Fields

Table II. Suggested nitrogen credit for the previous crop

Previous crop	Nitrogen credit*
	-lb N/A-
Alfalfa, 60-100% stand	(+) 80-100
Alfalfa, 30-60% stand	(+) 60-80
Alfalfa, 0-30% stand	(+) 40-60
Red clover & other clovers	(+) 40-60
Soybeans, dry edible beans	(+) 0-40
Small grains, corn & sugar beets	0

*Subtract this amount of N from the recommended rate.

that are heavily manured should also be frequently tested to evaluate nutrient buildup. Manure should not be applied to frozen or snow-covered land unless suitable soil and water erosion control practices are adopted.

Fertilizer Placement

Band-applied starter fertilizer to the side and below the seed is considered the most efficient placement for P, K and most micronutrients. Broadcast applications are less efficient and will normally result in lower yields than band applications, particularly when soil test levels are low. When soil test levels are high, broadcast applications are not likely to improve yields but will help to build or maintain soil test levels. Broadcast applications should be incorporated to improve nutrient recovery by plants and to prevent excessive runoff. Surface applications of fertilizer on snow-covered or frozen sloping land should be avoided.

Deep Sampling for Nitrate

Soil testing for residual nitrate N has been used for years in several Western states. Recent studies in Michigan and Wisconsin have shown that spring deep soil sampling for nitrate N can be effectively used to improve N fertilizer recommendations for corn. Fall soil sampling and testing programs are common in Western states but are not satisfactory in areas of high fall and winter precipitation. On fine- to medium-textured soils, a preplant sample to a depth of 2 to 3 feet is recommended. On sandy soils, deep sampling should be delayed until sidedress time, because nitrate N losses from these soils between preplant and sidedress time can be very significant.

Forms of Nitrogen Fertilizer

Certain forms of N fertilizer are more subject to loss than other forms. Nitrate N in calcium nitrate and ammonium nitrate is a readily available source of N for plants, but it is also subject to immediate leaching when added to soil. Nitrate forms of N should not be used where leaching is a serious problem. Ammonium forms of N, such as urea or anhydrous ammonia, are preferred sources of N for most crops because they are not subject to immediate leaching when added to soil. Ammonium N must first be converted to nitrate N before it can be leached or denitrified. This conversion to nitrate occurs rapidly under warm, moist conditions.

Urea and N solutions containing urea are subject to volatilization loss as gaseous ammonia if surface applied and not incorporated. Because the volatilization loss is difficult to assess and represents an economic loss to the farmer, all urea-containing fertilizers should be incorporated.

Timing of Nitrogen Fertilizer and Split Applications

Spring applications of N in the semi-humid regions of the United States have clearly been shown to be superior to fall applications. Climatic conditions from fall to spring significantly affect the amount of N lost. Estimates of N losses from fall applications vary from 10 to 20 percent on fine- to medium-textured soils (clay, clay loams and loams) and from 30 to more than 50 percent on coarse textured soils (sandy loams, loamy sands and sands). There may be certain economic benefits for applying N in the fall on fine-textured soils, but in general, the environmental risks of this practice outweigh the economic benefits. Fall applications of N are not warranted in Michigan and should be discontinued.

Yield benefits of split or sidedress N applications for corn have frequently been observed on coarse-textured soils. Although the benefits of sidedress N on fine-textured soils are rarely seen, there is no question that sidedress N applications on fine-textured soils can improve N recovery. For these reasons, farmers should seriously look at sidedress N applications on all soil types to improve N efficiency.

Waiting until the corn is well established before applying large amounts of N has two major advantages: (1) Nitrate N losses between preplant and sidedress are eliminated, and (2) Yield potential can be more accurately determined at sidedress time. Poor stand, poor weed control and/or dry weather at sidedress time are good reasons for adjusting the yield goal downward and reducing the total amount of N applied. The risks of being unable to sidedress N because of wet weather can be greatly reduced if corn is sidedressed when it is 3 to 4 inches tall

Table III. Potential for an economic response to the use of nitrification inhibitors with anhydrous ammonia on corn for different application times and soil management groups.

Soil management group	*Time of nitrogen application* Early fall >50 F.	Late fall <2 F.	Early Spring <2 F.	Late Spring >50 F.	Sidedress
Clays (0,1)	Good	Good	Good-Fair	Poor-Fair	Poor
Clay loams (1.5)	Good	Good-Fair	Fair-Good	Poor-Fair	Poor
Loams (2.5)	Fair-Good	Fair-Good	Fair	Fair	Poor
Sandy loams (3)	Fair	Fair	Fair	Fair	Poor
Loamy sand (4)	Fair-Poor	Fair-Poor	Fair	Fair	Poor
Sands (5)	Poor-Fair	Poor-Fair	Fair-Poor	Fair	Poor

KEY:
Good = Economic response expected at least 60% of the time.
Fair = Economic response expected 40-50% of the time.
Poor = Economic response expected less than 30% of the time.

instead of 1 foot tall. The benefits of sidedressing N when the corn is 1 foot tall or higher rather than earlier are minimal.

Nitrogen fertilizer applications through the irrigation system, often referred to as nitrogation, offer several advantages for irrigators:

- N can be applied when the crop's demand is greatest;
- The technique requires little energy for application,
- The practice is well suited to sandy soils where irrigation is needed and leaching is a problem. Approximately two-thirds of the total N requirements of corn may be supplied by this method. For example, some irrigators choose to apply one-third of their N at planting, one-third at sidedress time, and one third through the irrigation system. Depending too much on the irrigation system to "spoon feed" the crop in Michigan can be a disadvantage, however. Rain during the early growing season may prevent farmers from using their irrigation systems. This could result in a N shortage early in the season if no previous N was applied. To eliminate this problem, some farmers have regeared their center pivot systems to apply only a very small amount of water in one application so they can irrigate regardless of rainfall patterns.

Plant Analysis

Plant analysis during the season offers the grower an opportunity to assess the status of nutrients in the growing plant. High or excessive levels of a nutrient in the plant tissue are an indication that more nutrients may have been applied than were necessary for optimum growth. Once the fertilizer or manure has been applied, little can be done, but N rates can be reduced in future years to bring the nutrient levels back into the normal or sufficiency range. Research on corn is being conducted to determine if plant analysis for N early in the growing season can be used to help determine the amount of N to apply. Once the corn plant is past the sidedress stage, however, growers may encounter other difficulties with applying N fertilizer. The only equipment available for non-irrigators is high-clearance equipment and aerial applicators. In addition, N applied at later stages may not be beneficial. Research indicates that N applied to corn after silking is not efficiently utilized.

Nitrification Inhibitors

Farmers in many states have successfully used nitrification inhibitors to delay the conversion of ammonium forms of N to nitrate N. By preventing rapid conversion of ammonium to nitrate, farmers reduce the amount of nitrate N that is available for denitrification or leaching early in the season. Table III gives the potential for economic response to the use of nitrification inhibitors on corn for various times of the year and for various soil types. Farmers should consider using nitrification inhibitors when it is not feasible to use delayed N applications, such as by sidedressing or applying through the irrigation system. Nitrification inhibitors can be beneficial if N applications are made early and leaching and/or denitrification conditions exist. However, the amount of N used is very critical to the successful use of a nitrification inhibitor. Nitrification inhibitors will work best when the amount of N applied is slightly limiting. If the rate of N fertilizer applied is excessive, no benefits can be expected. In summary, nitrification inhibitors can improve N recovery when used appropriately, but they should not be used as a substitute for following other best management practices.

Calibration of Equipment

Evidence of uneven fertilizer distribution due to improperly adjusted fertilizer spreaders can be seen almost every year, particularly on winter small grains. The uneven distribution of fertilizer results in overfertilization in some areas of the field and underfertilization in others. The result is less than optimum yields and potential loss of excess nutrients to surface water and groundwater.

All fertilizer applicators need to be accurately calibrated. If farmers are unsure whether the equipment they are using is properly calibrated, they should recalibrate the equipment to avoid crop yield loss and potential risk to the environment. Improving the calibration of fertilizer applicators will result in more uniform distribution of the fertilizer at the proper rate.

Crop Rotations, Forages and Cover Crops

Crop rotations can be very beneficial in a successful crop production system. For example, a corn-soybean rotation is preferable to a continuous corn rotation because continuous corn requires more N fertilizer to obtain the optimum yield. Some of the noted yield improvement may be due to the rotational effect (better disease, insect and weed control and improved soil tilth) and some to N fixation by soybeans. Other non-legume rotations also have been shown to produce better yields of corn with less N fertilizer.

Forage crops such as sudangrass and alfalfa are well suited to recovering nitrate N from soils and thereby preventing excessive nitrate leaching. Although alfalfa fixes its own N, it does so only when all of the nitrate N in the soil is gone. Alfalfa's deep rooting system makes it ideal for taking up N that has moved deep in the soil profile. The disadvantage of alfalfa is that it is slow to establish, so a longer growing period is needed before it can prevent nitrate leaching.

Cover crops such as rye can be very beneficial in preventing wind and water erosion. They protect the soil surface from erosion and thereby reduce the risk of nutrient losses by runoff as soluble nutrients or erosion as sediment. Cover crops may also be used as green manure crops to take up nitrate and prevent it from being leached to groundwater. This practice is well suited to many soils in Michigan and could be used more effectively than it is now. One of the keys to successfully utilizing cover crops is to get them established in early fall so that they have a chance to take up excess nitrate N before winter dormancy and excessive precipitation occur.

Irrigation Management

When crops are irrigated, conscientious management of irrigation water is necessary for good N management. Excess water from irrigation or precipitation can cause nitrates to move below the root zone. Precise scheduling of irrigation water during the growing season can minimize these percolation losses.

There are several methods of accurately scheduling irrigation water. All methods require knowing the soil's water-holding capacity and being able to determine or estimate the available soil moisture at any time during the growing season. The soil moisture procedure requires an estimate of soil moisture. Irrigation begins when 50 percent of the available soil moisture is depleted. Tensiometers, which measure the tension with which soil holds water, are excellent tools for use on sandy soils. Their use on fine-textured soils, however, is usually unsatisfactory. Soil moisture blocks, which measure water conductivity, are more useful on these soil types. The water balance approach requires an estimate of crop water use (evapotranspiration). Computerized programs do an excellent job of estimating crop water use and keeping track of soil moisture. Additional information on irrigation scheduling can be found in Chapter 12 of the Michigan Irrigation Guide, which is available from the MSU Cooperative Extension Service.

Summary

Many management strategies exist for achieving effective and efficient use of nutrients without risk of reducing yield or contaminating water. Here are several important management practices that farmers should follow:

1. Soil test every two to three years and follow MSU fertilizer recommendations.

2. Choose a realistic yield goal that can be achieved 40 to 50 percent of the time.

3. Take credit for nutrients supplied by organic matter, legumes, and manure or other biological wastes containing nutrients. Manures and other wastes should be tested to determine the amounts of N, P and K that they can supply.

4. Use ammonium forms of fertilizer to reduce nitrate N losses where leaching is a serious problem.

5. Avoid fall applications of N on all soils where winter and spring precipitation causes runoff or leaching.

6. Use delayed or split applications of N to prevent excessive leaching of nitrates on sandy soils.

7. Consider taking deep soil samples to measure residual soil nitrate and adjust N applications accordingly.

8. Consider using nitrification inhibitors when it is not feasible to use delayed or split N applications.

9. Consider using plant analysis to determine how well you have done in supplying crop nutrients. Consider using crop rotations rather than monocultures to reduce the

Continued on back page

need for N and assist with pest control.

10. Use cover crops and forages to prevent wind and water erosion and excessive loss of N to groundwater.

11. Frequently check fertilizer application equipment for proper calibration.

12. Use modern irrigation scheduling techniques to avoid applying excessive amounts of water that could leach nitrate N below the rooting zone.

13. Develop a total farm nutrient management plan, particularly for a livestock operation that is generating manure nutrients. Planning for best utilization of all available nutrients — whether from manure, soil organic matter, legumes or fertilizers — will return economic benefits as well as reduce risks to water quality.

For more information on water quality, consult the following publications, available from your county Cooperative Extension Service office:

E-498, "Sampling Soils for Fertilizer and Lime Recommendations," free.

E-550, "Fertilizer Recommendations: Vegetable and Field Crops in Michigan," $1.00, for sale only.

E-1616, "Soil Sampling for No-Till and Conservation Tillage," free.

WQ05, "Phosphorus: Pollutant and Essential Plant Food Element," free.

WQ06, "Nitrogen Management Strategies for Corn Producers," free.

WQ07, "Nitrogen Fertilizer Management for Efficient Crop Production and Water Quality Preservation," free.

WQ08, "Understanding Sediments: Problems and Solutions," free.

WQ09, "Nitrogen Management Strategies for Potato Producers," free.

WQ12, "Livestock Manure Management for Efficient Crop Production and Water Quality Preservation," free.

New 2:90 5M-KDP-SP, Price 40 cents

FILE: 28.36 Water and Water quality
32.3 Soils (Fertilizers)