PART X
Nutrient Management

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Purpose of nutrient management planning

In 1983, a $27 million, six-year study by the U.S. EPA (1983) revealed that runoff from farmland is contributing to water quality decline in the Chesapeake Bay. Agricultural practices can adversely affect groundwater as well as surface water. Nutrients, particularly nitrogen (N) and phosphorus (P), are a major component of this form of pollution, termed nonpoint source (NPS) pollution. Life within rivers, streams, lakes and bays could not exist without nutrients, but an excess of nutrients can harm aquatic life.

It is estimated that 67% of the nitrogen and 39% of the phosphorus entering the Bay originate from non-point sources, with cropland agriculture contributing 60% of the nitrogen and 27% of the phosphorus entering the Bay. Nonpoint source pollution loadings from agriculture to the Bay must be reduced and managed in concert with other pollution reduction strategies if the degradation that the Bay and other water sources has undergone is going to be reversed.

Nutrient management involves the implementation of practices that permit efficient crop production and protect water quality from nutrient pollution. A nutrient management plan is a site-specific plan that addresses these issues. The goal of farm nutrient management planning is to minimize adverse environmental effects, primarily upon water quality, while optimizing farm profits. It should be recognized that some level of nutrient loss to the environment will occur even when the best nutrient management practices are employed; however, these losses should be lower than what would occur without nutrient management.

Fate and transport of nutrients of concern

Nitrogen

Nitrogen is an essential element for plant growth and animal nutrition and is the nutrient taken up in the largest amount by crops. Nitrate (NO_3^-), the major inorganic form of nitrogen in most soils, is quite mobile and moves freely with soil water. Nitrogen application to soils beyond that required for plant uptake will generally lead to nitrate leaching and long term groundwater degradation.

Elevated levels of nitrate in drinking water may lead to methemoglobinemia in infants, the formation of carcinogenic nitrosamines in the human stomach, and hypertension. A recent national groundwater study by the United States-Environmental Protection Agency (1990) found detectable nitrate in 52% of the 94,600 community water systems tested, indicating widespread movement to groundwater on a national scale. Movement of excessive amounts of nitrogen to surface waters can result in a number of undesirable effects such as eutrophication (nutrient enrichment) and associated algal blooms and oxygen depletion.

Phosphorus

Phosphorus, another major essential plant element, differs considerably from nitrate nitrogen in its water solubility and mobility. Phosphorus is very immobile in soil and seldom migrates downward to any great extent with soil water because it is strongly bound by and/or precipitated as highly insoluble soil minerals. Much of the fertilizer phosphorus applied to soils is retained in the near-surface layer in various inorganic precipitates and organically combined forms that prevent it from leaching.

While the risk of groundwater contamination by phosphorus from crop production systems is limited, the solid forms of phosphorus that accumulate in surface soil are subject to loss via erosion, the major water quality risk from phosphorus. Where erosion risk increases, such as for annual crops with conventional tillage, the total-P loss increases greatly as the phosphorus is moved in solid particulate form with the eroding soil.

Because phosphorus is strongly bound by soils, phosphorus runoff from permanently vegetated areas (e.g., perennial sods or forests) is minimal and largely occurs as traces of orthophosphate ($H_2PO_4^-$ or HPO_4^{2-}) ions in solution. Phosphorus in runoff can become a potential surface water quality problem where organic wastes (e.g., manures and biosolids) have been applied to supply crop nitrogen needs over long time periods. In these cases, high phosphorus concentrations may develop in the soil because the relative amounts of nitrogen and phosphorus applied in organic wastes are similar, but crops do not deplete soil phosphorus as rapidly as nitrogen. A portion of this phosphorus will occur as water soluble P, which is immediately available for biological uptake. Elevated phosphorus loadings lead to algal blooms and mats, heavy growth of aquatic plants and weeds, deoxygenation, and occasional problems with drinking water taste and odor.

Components of a nutrient management plan

Nutrient management plans must be developed on a site-specific basis and must be carefully tailored to specific soils and crop production systems. The following steps will generally be essential:

1. Obtain accurate soil information for each field or management unit, and analyze representative soil samples from each management unit. This may require a new farm soil map or a revision of existing United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) mapping coverage.

2. Determine the crop yield potential for each field, based on the known productivity of the soils coupled with the intended management practices.

3. Identify the total plant nutrient needs to achieve this expected yield potential.

4. Determine the plant-available nutrients in manures or biosolids to be used, considering the type of organic material to be used and its method of application.

5. Estimate the nutrient contribution that can be expected from residual effects or carryover from previous fertilizer, manure or biosolid applications.

6. Include credit for nitrogen supplied to row crops following a previous legume.

7. Recommend application rates for manure, other organic sources, and/or commercial fertilizers to supply the needed nutrients at the appropriate time for optimal crop production.

This process must be followed for all fields and production systems within a given planning area. The nutrient planning process is totally dependent upon the synthesis of information and data on the soils, cropping systems, manures, and management practices being employed over time. Therefore, care should be taken to ensure that the information used to specify the nutrient management plan is current and accurate.

Recognizing environmentally sensitive sites

The potential for plant nutrients (particularly N and P) to migrate to surface and groundwater is largely dependent upon soil and site conditions. An important part of nutrient management planning for agriculture is the recognition and delineation of environmentally sensitive sites and conditions and the development of specific management practices (Best Management Practices, BMP) to avoid detrimental effects. The soils and landscapes of Virginia vary greatly, but the following soil/landscape features and properties are particularly conducive to the loss of nutrients from agricultural practices:

1. Soils with high leaching potentials: This includes soils with very coarse textures and those where the water table is at or near the surface during the winter. If accurate soil survey information is available, the leaching index for a given soil can be obtained by following the procedures outlined in the USDA-NRCS Field Office Technical Guide (USDA Soil Conservation Service, 1990).

2. Lands with karst (sinkhole) drainage regimes: Sinkholes are landscape features commonly found in areas underlain by limestone bedrock or other highly soluble carbonate bearing parent materials. These areas mainly occur in the Valley and Ridge physiographic province but may also occur in the lower Coastal Plain. Sinkholes are formed by the long term dissolution of carbonates underlying the surface that eventually leaves a cavity that collapses over time. Sinkholes form a direct connection between surface water and groundwater and dye tracer tests have shown that water entering a sinkhole can contaminate nearby drinking wells within hours.

   If a sinkhole is located in an isolated high area of a field, a grassed buffer should be placed around it. If the sinkhole occurs on a sideslope or below a cropped field, significant runoff may drain into the sinkhole. The field area draining into the sinkhole would be best used for hay crops, pasture, or trees to reduce runoff. If the area is cropped, nutrient management practices should be intensive.

3. Shallow soils over fractured bedrock: Soils that are shallow (< 40 in.) to bedrock that is fractured should be managed like soils with a high leaching index. Although many of these soils are not highly leached, the water and any dissolved nutrients can move rapidly to groundwater once the soil water percolates to the fractured rock. Lists of shallow soils in each state can be obtained from the NRCS and by reviewing county soil surveys. Nutrient management should include such practices as split applications of nitrogen on crops and the use of winter cover crops to scavenge residual soil nitrogen in fields containing significant areas of these soils.

4. Tile drained lands: Fields that have been artificially drained should be treated as environmentally sensitive due to the direct connection of the tile outlets to surface watersheds. These lands are typically drained because they have a high seasonal water table, which can potentially pollute both the surface water with their drainage discharge and the local water table if nutrients are over-applied relative to crop uptake.

5. Irrigated lands: Fields receiving irrigation, because of the increased input of water, are prone to runoff and leaching of water and nutrients. The leaching index approach cannot be used on these areas since it would underestimate the actual leaching potential. To maximize water use efficiency and minimize leaching and runoff, irrigation scheduling methods should be used. These include the use of gypsum blocks, tensiometers, or computerized systems. When these indicators show the need for irrigation, rates and amounts of water should be based upon the soil type and water holding capacity to further reduce water and nutrient losses.

6. Excessively sloping lands: Lands with steep (i.e., >12 to 15 percent) and long slopes pose a high risk for the surface loss of applied nitrogen and phosphorus. Significant amounts of nutrients bound to sediment can be lost during heavy rainfall events if tillage is employed to incorporate nutrients. Manure applications on such slopes should be limited by P soil test needs or crop uptake estimates. Injection is the preferred manure application method. Soil conservation measures should be practiced on highly erodible lands.

7. Floodplains and other lands near surface waters: Agricultural land close to surface water can have a more direct impact on surface water quality. Surface flow of runoff water has little chance to be filtered before discharge into adjacent waters if channelized flow develops. Subsurface flow in groundwater can also directly seep into the adjacent surface water body. Wetlands can also reduce the potential for nitrogen contamination of surface waters by identifying nitrate contaminated water that enters the wetland. If manure or biosolids must be applied to a floodplain, incorporation or injection application methods should be used to minimize losses if flooding occurs.

The list of environmentally sensitive sites given above is not all-inclusive, but does include most of the major types of land with these concerns in Virginia. Appropriate setback or buffer areas should be established between these areas and any field receiving nutrient applications, and intensive nutrient management practices should be employed on any lands adjacent to sensitive areas.

On-farm Nutrient management planning

Nutrient cycles and management on different farm types

Considering some representative farm types and the management consequences of the nutrient cycles on each is helpful in understanding nutrient management planning. Nutrients come to a modern cash-crop farm in fertilizers and other materials applied directly to the fields (Figure 1a). Crops harvested from the fields remove a fraction of the applied nutrients which leave the farm when the crops are sold. Improper management of nutrients can result in significant losses other than removal in cash crop and negative economic consequences for the farmer; therefore, the cost of practices that reduce nutrient losses on a cash-crop farm can be at least partially offset by decreased costs in purchased fertilizer.

On farms with livestock (e.g., a dairy), a large proportion of the plant nutrients that were in the crops produced as feed for the animals are returned to the fields in manure from the animals (Figure 1b). Supplementing on-farm crop production with fertilizer, off-farm feeds or other animal inputs is more likely on a modern crop and livestock farm with ruminant animals than on traditional self sufficient crop and livestock farms. Thus, the manure produced by the animals is no longer spread on the fields where the crops were produced. The plant nutrients in the feed inputs can offset the nutrients removed from the farm as sold animal products.

Feed inputs enable farms to have more animals on fewer acres. Sometimes, these off-farm feed nutrients can exceed what is needed for crops grown on-farm and result in excessive manure nutrients that can be potential sources of water contamination. All sources of plant nutrients being applied to fields must be determined to protect the environment from negative impacts associated with the over-application of nutrients to crop fields.

Trends in animal housing and the success of crop production on cash-crop farms in specialized geographic regions have made it possible to concentrate large numbers of animals, such as poultry and swine, on small land areas. Most, if not all, of the feed necessary for these animals can be economically transported to the farm where the animals are housed (Figure 1c). Although poultry and swine farms may produce crops for off-farm sale, the land areas involved can be quite limited because the focus of the management activity is on animal production. The cash-crop farm and the intensive, modern livestock farm are connected by the flow of feed; however, nutrients in this flow often do not cycle back to their original locations. The application of nutrients to the fields on these farms is not closely related to the major production activity of the farm (i.e., selling animals or animal products). This will usually result in levels of nutrients in excess of the crop needs on the farm and a high potential for environmental problems.

Field-based agronomic practices may be of limited effectiveness in assimilating the total quantity of nutrients on intensive livestock farms because of the small land area on the farm. It is unlikely that environmental quality can be protected on poultry and swine farms solely by recycling nutrients for crop production. Successful management of nutrients to protect the environment will depend on support from off-farm people and organizations.

Animal density and nutrient balance

Animal density and the proportion of feed coming from off the farm are important features in determining the nutrient status of a farm. On low animal density farms (<1.25 animal equivalent units [AEU's] per acre) or those where little feed (<50%) comes from off the farm, manure nutrients produced on the farm will not meet total crop nutrient needs. In this group an appropriate management objective would be to maximize nutrient use efficiency on the farm. The environmental impact of these operations can be minimal if sound nutrient management principles are applied. Management decisions should be made based on expected crop response to nutrients (i.e., increasing yields or decreasing purchased inputs). Plans should utilize soil tests and manure analysis to assure distribution and timing of manure applications to maximize nutrient availability from the manure and minimize purchase of commercial fertilizer. Examples of practices that would be appropriate on this group of farms include: spring application of manure, immediate incorporation of manure, use of cover crops to scavenge nutrients, no manure spread on legumes, and efficient manure storage.

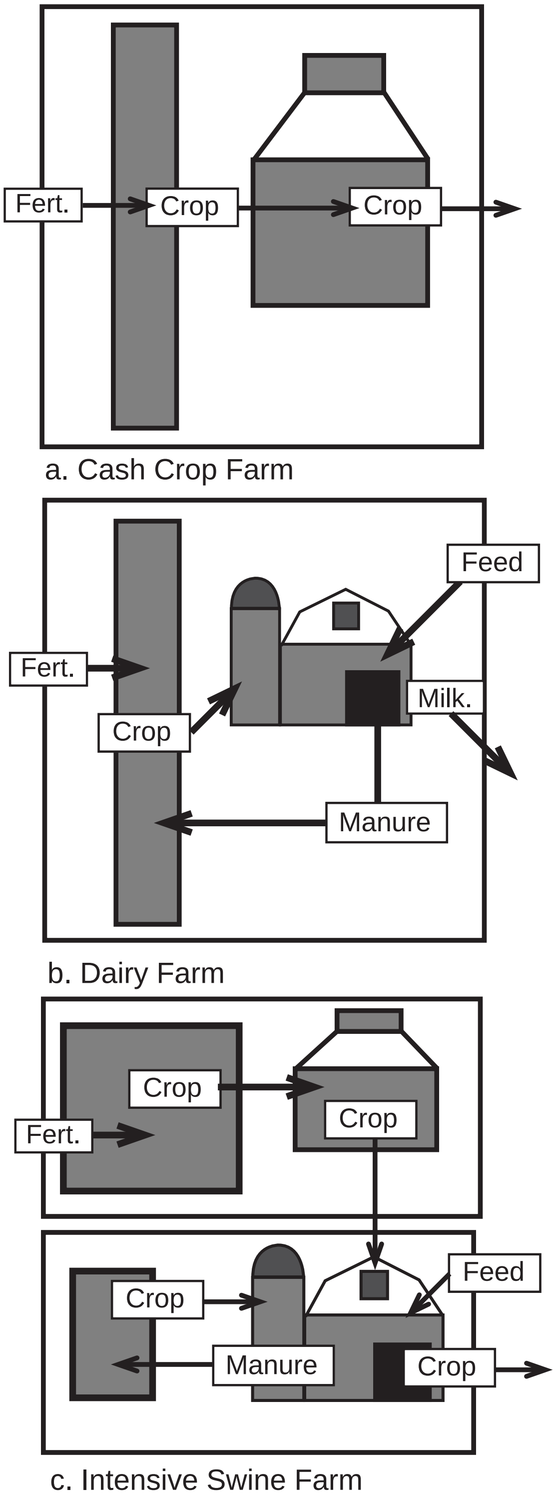

Figure 1. Nutrient Cycles on Different Types of Farms

Farms with medium animal density (1.25 - 2.25 AEU's/acre; 50-80% feed from off farm) supply manure nitrogen roughly equivalent to total crop needs, but excessive phosphorus supply is likely. An appropriate management objective for these farms would be to maximize environmentally safe nutrient use on the farm. Nutrient use efficiency will likely be a secondary concern if there is enough or more than enough nutrients on the farm to meet crop requirements. The major concern will be safely using all of the manure produced. There is good potential for environmental benefits from improved management on these farms. Changes in the overall farm management, such as altering the cropping system, may be necessary on this group of farms. A detailed manure management plan, based on nutrient balance rather than crop response, will probably be necessary on these farms.

On high intensity farms (>2.25 AEU's/acre; >80% feed from off farm), livestock manure production often significantly exceeds total crop nutrient needs. On these farms, the management objective will be to use every available means to remove excess manure not needed for crop production. Alternative off-farm uses for the manure will need to be explored. Often, this will mean locating a market for the manure and arranging the logistics of transportation and appropriate application. The on-farm plans for this group of farms will involve determining the maximum amount of manure that can be safely applied on the farm and the appropriate timing of application to minimize environmental impact. High intensity farms have the highest potential to negatively impact the environment. In many cases, unless a favorable marketing arrangement can be developed, implementing improved nutrient management on this group of farms will have a negative economic impact on the farm.

References

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