

NEWS & VIEWS

A regional newsletter published by the
Potash & Phosphate Institute (PPI) and the
Potash & Phosphate Institute of Canada (PPIC)



Dr. T.W. Bruulsema,
Eastern Canada and
Northeast U.S. Director
January 2000

Does Balancing Nutrients Protect Water Quality?

NUTRIENT MANAGEMENT PLANNING directs the attention of many crop advisers and retail input dealers to nutrient balances. A balance of nutrient supply in comparison to crop removal has been advocated by many as the solution to nutrient overloading and resulting impairment of water quality. It is critical to understand the chemical nature of a nutrient and the processes that influence nutrient loss to water before deciding whether a surplus is indeed a peril to water quality. This *News & Views* will review the characteristics of the three major nutrients, examine their balances in the northeast U.S., and discuss the environmental implications of the balances.

Plants require at least 17 elements as essential nutrients. Each of the 17 is equally crucial to the plant's survival, but some are more likely to become deficient to crops than others. Supplies of the three major nutrients, nitrogen (N), phosphorus (P), and potassium (K), most often need to be managed to ensure adequate quantities of each for crop growth. To understand why they may be deficient, or in excess, the soil inventory of each, their transformations when added to soil, and the common types of flows that add or remove them must be considered.

Nitrogen, prone to losses

Most soils contain large amounts of N in stable organic forms that are unavailable to the plant. Some N is made available when soil organic matter breaks down, but it is absorbed or immobilized when organic matter is being built up by additions of high carbon (C) materials. Forms of N that are most available to crops can easily leave the soil. Nitrate-N may be lost with surface runoff or leach into groundwater, or may be denitrified back into the air. Ammonia-N can volatilize as a gas into the air. The resistance of soil organic matter to breakdown limits the supply from the primary soil N inventory. The transformations and flows contribute to inefficient use of applied N.

Since N is easily lost, good management of N to supply the crop needs should include timing the application as close to uptake as possible and placing the N where it can most easily be absorbed. Because of the unpredictability of weather and soil N cycling, some losses will occur, but most crops recover 50 to 70 percent of the fertilizer N in the year of application. When excesses are applied, however, losses are likely and can impact water quality, both in surface waters and in groundwaters. Thus, it is important to predict N needs as accurately as possible in order to minimize such excesses in N supply, protect water quality, and maximize farm profit. Balancing the use of nutrients from manure available on a farm and farm profitability is even more of a challenge than using fertilizers effectively for crop production.

Phosphorus, prone to fixation

Phosphorus becomes deficient because of its tendency to react with common soil components – clay, calcium (Ca), iron (Fe), and aluminum (Al) – forming stable compounds. As long as these chemical reactions continue, they keep the available P concentration in soil water very low. The objective of fertilizing with P is to increase its concentration in the soil water. When the soil P inventory is low and the reactive components are abundant, this can only be done temporarily. When P is supplied in amounts in excess of crop removal over a long period, as the stable compounds accumulate and the reactive components decrease, the soil solution can maintain higher P concentrations for longer periods of time. To grow optimally, crops need a P concentration in the soil water about ten times higher than that which stimulates algal growth in river and lake water.

Most crops cannot recover more than 30 percent of the P added to a soil in a given year. Typically 10 to 20 percent is recovered, and the rest builds up stable forms of soil P. Only a small percentage of what is applied is lost, primarily

Co-author:

Dr. Tom W. Bruulsema
Eastern Canada and Northeast U.S. Director
Potash & Phosphate Institute (PPI)
18 Maplewood Drive, Guelph, ON, Canada N1G 1L8
Phone: (519) 821-5519
E-mail: tbruulsema@ppi-far.org

Co-author:

Dr. Les E. Lanyon
Professor of Soil Fertility/Dept. of Agronomy
The Pennsylvania State University
116 ASI Bldg, University Park, PA 16802
Phone: (814) 863-1614
E-mail: l@psu.edu

by surface runoff (unless soil erosion is occurring). The buildup of residual P benefits future crops: As it increases, the crop relies less on applied fertilizer and gets more of its P from the soil. However, at some point the buildup may increase risk of P losses in surface runoff large enough to stimulate algal blooms and cause over-enrichment of surface waters. When the buildup is extreme, leaching from the root zone may occur in some coarse-textured or tile-drained soils. Soils with a large P inventory and prone to runoff are the primary concern for preventing losses of excess P.

Potassium, prone to both losses and fixation

Potassium is present in large quantities in most soils, but as a constituent of soil minerals. It becomes deficient in sandy soils because the available forms are lost by leaching, and in clay soils mainly because of fixation between the layers of clay minerals. Like N, K is removed in large quantities by harvested crops. Like P, residual K can build up in soils and contribute to future crops.

While some fraction of applied K can leach out with the groundwater or be lost to surface runoff, it does not degrade water quality from an environmental point of view.

Nutrient Balance: Impact on Water Quality

The supply of a nutrient relative to its removal by crops influences the size of the nutrient inventory, the most common transformations, and the potential flows in the soil. A simple nutrient balance compares the potential supply from fertilizers and manures to the actual nutrient removal by crops. Balances of the three major nutrients (N, P, and K) for the cropland of eastern Canada and the northeast U.S. are shown in **Figures 1 to 3**. This region includes the provinces of Ontario, Quebec, Nova Scotia, New Brunswick, and Prince Edward Island and the states of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

Over the past 38 years agricultural N balance has gone from a small deficit to a small surplus, as shown in **Figure 1**. However, this requires careful interpretation. Fixation of N by legumes is difficult to measure, so it was not included in the balance. Much of the manure N is lost to the air by either ammonia volatilization or denitrification. Also, the large inventory of organic N in the soil may either be increasing (immobilizing available N) or decreasing (releasing available N).

The flow of N resulting from each of these three unmeasured processes is difficult to estimate. The amount of N fixed by legume crops is not likely to have decreased. On the other hand, the soil is not likely to be releasing as much N from native organic matter now as at the beginning of the period, as soil organic matter levels have stabilized in many agricultural soils. The environmental impact for a nutrient like N is controlled more by use of best management practices (BMPs), including the balancing of N from all

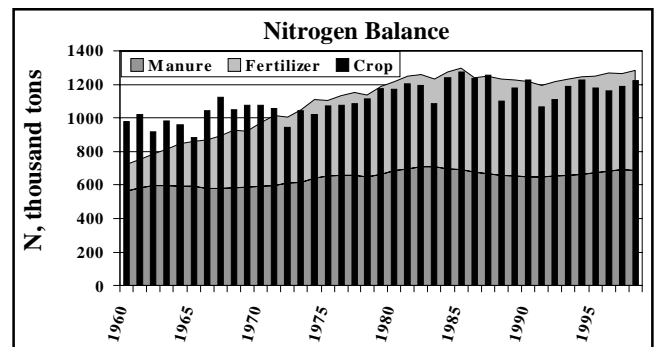


Figure 1. Nitrogen in fertilizers and manures and the quantity removed by crops across eastern Canada and northeast U.S. from 1960 to 1998. (Note that legume crop N fixation is not included)

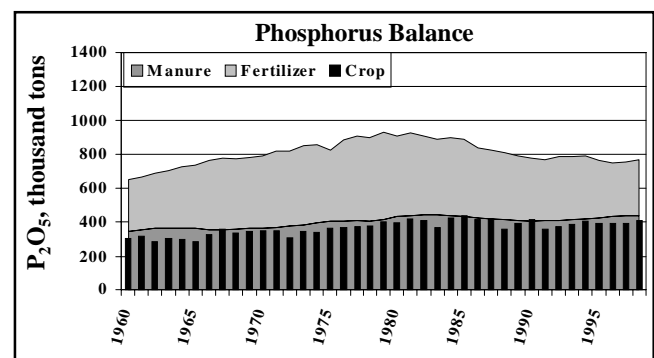


Figure 2. Phosphorus in fertilizers and manures and the quantity removed by crops across eastern Canada and northeast U.S. from 1960 to 1998.

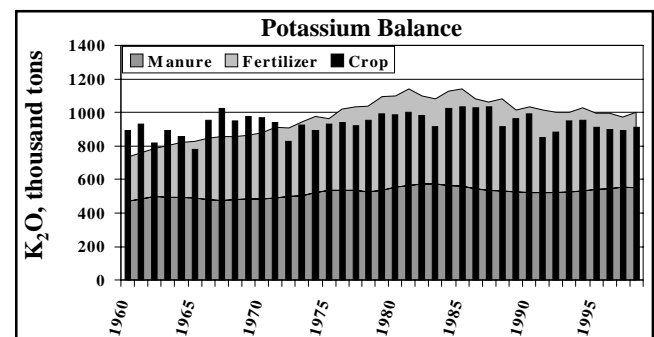


Figure 3. Potassium in fertilizers and manures and the quantity removed by crops across eastern Canada and northeast U.S. from 1960 to 1998.

sources with the crop requirements on a field and farm basis rather than by surpluses and deficits in simplified regional balances.

The P surplus has been larger than the N or K surplus for the entire period (see **Figure 2**). Yet, during the last 30 years, water quality trends in many lakes and rivers are improving, with P concentrations in the water decreasing. For example, Lake Erie has reached the point where fisheries agencies have called for a halt to further reductions in P

loading. The agencies are concerned that lower P levels in the lake would not be enough to support the current level of fish productivity. Agriculture is generally regarded as being compatible with good water quality when BMPs for water quality protection are followed. The U.S. EPA estimates that 91 percent of New York's rivers and streams have good water quality that fully supports aquatic life uses.

The size of the P surplus is declining. It was smaller in 1998 than at any other time since 1962. The decline in surplus P has likely helped to improve water quality, but optimum agricultural productivity may require a continued surplus for specific fields on individual farms. The chemical nature of P makes it necessary to add more than the crop removes on soils with low P inventories.

Soils vary greatly in their capacity to retain P. Some soils in Quebec have a fixation capacity as high as 17,000 lb P₂O₅/A. Most soils have much lower fixation capacities. Soluble P increases as the soil's fixation capacity is filled. In some European countries, soils with more than 25 percent of their fixation capacity filled are considered at risk of losing P to the detriment of water quality. Some calcareous soils have been reported to have unlimited P retention capacity, but other calcareous soils also lose P. Conventional soil tests do not indicate the soil's P fixation capacity. While most soils testing low to medium have substantial sorption capacity, soils testing high or above may differ in the amount they can absorb before P losses become a problem. New tests that diagnose such soils are under development.

Even though there may have been surpluses in agricultural P and K in the past 38 years, soil test summaries show that a substantial proportion of the soils of the northeast U.S. could benefit from applying more than the crop removes. **Table 1** gives the percentage of soils testing medium or less for P and K by province and state. Across the region in 1997, 45 percent of soils still tested medium or less in P; 42 percent in K. These soils produce suboptimal crop yields without annual additions of nutrients. Unfortunately, surplus manure nutrients rarely reach them. Phosphorus inventories in many soils receiving high rates of manure over a long period of time may be quite large. These soils have the greatest potential to lose P. Future technologies and policies to encourage their use may direct more manure nutrients to the soils that can benefit most from them.

Water Quality and High Yields

Some northeast lakes and rivers are still impaired by excess nutrients, and agriculture is a contributing factor. Water quality impacts quality of life. Since the public will continue to set high standards for water quality, agriculture must continue its efforts to protect water quality. In order to continue improving, N and P losses must be controlled with BMPs. Long-term N management objectives will be to set realistic yield goals, to meet the crop N requirements by fully accounting for the potential N contributions from all

Table 1. Soil test summaries in the northeast U.S., 1997.

Province or State	Percentage of soils testing medium or lower in:	
	Phosphorus	Potassium
Maine	30	49
New Brunswick	34	52
New Hampshire	29	81
New Jersey	16	26
New York	47	34
Nova Scotia	47	50
Ontario	41	30
Pennsylvania	54	62
Prince Edward Island	51	66
Quebec	56	46
Rhode Island	20	60
Vermont	47	60
Weighted average:	45	42

sources, and to use efficient N management practices. Long-term P management objectives should be to build low fertility soils into the optimum range for economic crop production, to reduce the extent of soils with excessive P, and then to ensure a balance between inputs and outputs so that neither deficiencies nor excesses develop in the future.

To manage P for minimal impact on water quality, it is important to consider its transport. Erosion and runoff are the two major processes that transport P. Reduced tillage or no-tillage systems can reduce P losses by 80 percent or more. Buffer strips beside watercourses can reduce N and P loss by 40 to 90 percent. An **Environmental P Index** that evaluates both source and transport factors can identify areas most at risk of losing P to water. Applied site-specifically, it can be an innovative tool for nutrient management that allows producers to capitalize on the benefits of manure in the areas least likely to generate water quality problems. For more information on this **Index**, consult the publication *Site-Specific Application of the Environmental Phosphorus Index Concept* by C.S. Snyder, T.W. Bruulsema, A.N. Sharpley and D.B. Beegle (1999; SSMG-1; available from PPI, Norcross, GA).

Many maximum crop yield records have been set on soils with a history of manure use. Manure use builds up not only the nutrients in soil, but also organic matter, thereby improving soil structure. Soil areas that can benefit safely from manure applications need to be identified, and may often occur on soils of cash crop farms rather than on livestock farms. It is on these areas that producers and crop advisers should focus the flows of manure nutrients to meet crop needs, to build soil inventories, and to achieve high-yield crop production.

The ag retailer can provide value by offering farm nutrient management planning services, helping both livestock and cash crop producers optimize their use of resources for production and water quality protection. The

question a crop input supplier needs to address is “What role can I play to link crop and animal production with fertilizer and feed supply in the local agricultural community?” If the role you can play is of value to the local community, there can be profit opportunities as well.

Conclusions

How should a progressive crop input supplier address nutrient imbalances?

- ◆ be conscious of the environmental impacts of nutrient use
- ◆ recognize the continuing need for nutrient inputs in crop production
- ◆ deliver information and resources for soil and water conservation BMPs
- ◆ deliver technologies to handle and place manure as a nutrient source
- ◆ help the crop producer choose varieties, inputs, and other management practices for higher crop yields that maximize both profit and nutrient removal
- ◆ use the tools of precision agriculture to assist livestock producers in nutrient management planning and on-farm nutrient balancing
- ◆ apply an **Environmental P Index** site-specifically:
 - to limit risk of water contamination in sensitive areas
 - to build soil organic matter and fertility with manure applications in areas less prone to erosion and surface runoff

Does balancing nutrients protect water quality? In agricultural soils that are contributing to accelerated nutrient loss, balance is critical for N and the ultimate goal for P. Intermediate steps to reduce P transport from these soils and delivery to watercourses may be necessary while the means are developed to achieve these balances. Yet there are many soils which can benefit from additional P inputs beyond crop removal. Directing nutrient flows to

improve these soils can lead to higher yielding crops in harmony with clean water. ■

A note on the nutrient balance figures

Complete nutrient balances are difficult to compile. Some of the largest inputs and outputs are uncertain. For example, forage crops still account for about a third of the total crop removal of N and P and half that of K, but acreages and yields of forages and pastures are the least certain of all crop statistics. Manure nutrients are estimated from animal inventory numbers, but output per animal is not likely the same today as it was several decades ago. For N, input from N fixation by legumes (soybeans, alfalfa, etc.) is large but difficult to estimate.

The balances in this article were computed using Statistics Canada and USDA-NASS data for field crops including corn, soybeans, dry beans, wheat, other small grains, potatoes, hay, and pasture. Pasture was assumed to remove one-third as much nutrient per acre as hay. Nutrient content of crops was assumed constant over time, using estimates appropriate for the region from tables provided by the Canadian Fertilizer Institute. Fertilizer data were obtained from Agriculture and Agri-Food Canada and the USDA-ERS. Manure nutrient output was calculated from animal numbers for total cattle, total pigs, and total poultry, assuming 7 percent less manure output per head per decade past. The nutrients are as excreted, with no adjustments for losses or availability, and include manures excreted on pasture. Normally, a substantial fraction of manure N is lost before, during, and after application. Comparison with USDA-RCS figures for 1992 suggests that only 30 percent of the excreted manure N and about 55 percent of the excreted P and K are recoverable.

RN 99203

NEWS & VIEWS

Eastern Canada and
Northeast U.S.
January 2000



Potash & Phosphate Institute (PPI)
655 Engineering Drive, Suite 110
Norcross, GA 30092-2837