The U.S. Nutrient Budget Is in the Red

By G.W. Wallingford

A nutrient budget is a balance sheet showing nutrient exports (removals) and imports (additions) for a farm. Nutrients are exported when plant material or animal products are sold off the farm. Nutrients can be imported in animal feeds, off-farm waste products and commercial fertilizers or added to the soil by legume fixation of nitrogen (N).

FOR A FARM TO BE SUSTAINABLE, its nutrient budget must balance. If there is a net loss of nutrients, the farm's soils will eventually be depleted of nutrients. Productivity will decline. If there is a net gain of nutrients, which most often occurs on farms with relatively large numbers of livestock, environmental problems can occur due to the combined effects of nutrient accumulation in the soil and soil erosion.

The two nutrients most susceptible to depletion through crop removal are phosphorus (P) and potassium (K). Unlike N, which can be partially replenished by rotation with legume crops, there is no biological method of replacing P and K. Once soil supplies are depleted through crop removal, the only method of replacement is through the importation of outside sources.

Nutrient removal is perhaps the most critical factor when evaluating the sustainability of a farming system. Simply put, if the nutrients removed are not replaced the system is not sustainable.

The U.S. Nutrient Budget

Nutrient budget calculations can also be applied to a region or a nation. There are examples all over the world of farming systems which have failed because nutrients removed in harvested crops were not replaced. The result is a decline in soil productivity and loss of the nation's ability to feed its people.

Figure 1 shows the nutrient budget for the major U.S. crops since 1965. The N budget for the U.S. is slightly positive and has been

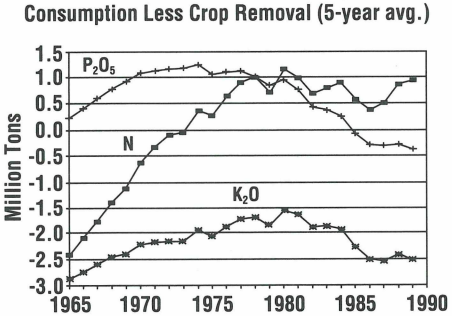


Figure 1. The nutrient budget for 20 major U.S. crops, 1965-1989. The amounts of N, P_2O_5 and K_2O removed in the harvested portion of 20 major U.S. crops were subtracted from the amounts applied to all crops in commercial fertilizer. The data shown are five-year running averages. (Data from USDA analyzed by the author.)

fairly stable since 1980. The P budget is now negative after being positive for most of the 1960s and 1970s. The K budget continues to be strongly negative. In 1989, U.S. crops removed 2.6 million more tons of K_2O than were applied in commercial fertilizer.

Strengths and Limitations of the Nutrient Budget Approach

The technique used to calculate the nutrient budgets shown in **Figure 1** is useful when evaluating the overall sustainability of U.S. agriculture. The application of commercial fertilizers has come under criticism in recent years partly

Dr. Wallingford is Eastcentral Director of the Potash & Phosphate Institute (PPI) and is located in Columbus, OH.

because of the belief that overuse has built up nutrient levels in soils beyond crop needs. The data clearly show, however, that the nation as a whole is experiencing a nutrient deficit for P and K.

A limitation of this approach is the masking of differences among crops and regions of the country. The high native soil levels of K, for example, in the western states will forestall problems resulting from K deficits for many years. On the other hand, forage crops such as alfalfa normally remove more nutrients from the soil than are returned through commercial fertilizer.

Impact of Soil Erosion and Animal Manures

The nutrient budgets shown in **Figure 1** do not take into account losses of nutrients by soil erosion or the addition of nutrients in animal manures and other waste products. The quantity of nutrients lost to soil erosion annually has been estimated at 3 million tons of N, 5 million tons of P_2O_5, and 45 million tons of K_2O[1]. If these numbers were subtracted from the values in **Figure 1**, the nutrient budget for the U.S. would look much worse.

These large losses of N, P, and K are not all available forms of the nutrients. Most are unavailable or slowly available forms found in the mineral and organic portions of the soil. Many clays and silt particles, for example, have a high content of K.

U.S. farmers are using improved tillage and residue management techniques to reduce these large losses of nutrients by soil erosion. As an example, surveys by the Conservation Technology Information Center found that in 1990 more than 26 percent of the planted crop acreage was in conservation tillage systems which leave over 30 percent of the soil surface covered by crop residue. Corn acreage was 32 percent conservation tilled, while winter wheat and soybeans were each 27 percent conservation tilled.

The quantities of nutrients in animal manures available for application to soils have been estimated to be 1.9 million tons of N, 0.5 million tons of P_2O_5 and 1.2 million tons of K_2O[2]. These estimates reflect handling losses but do not allow for losses which may occur after field application. These values are significant but much less so than the estimated losses to erosion.

Sustainability Versus Fertilizer Use Efficiency

In order to maintain soil productivity and the sustainability of food production, nutrients removed from the soil must be replaced. Research and practical experience have shown that in order to maintain soil test levels in soils not susceptible to significant erosion losses, nutrient replacement of P and K through commercial fertilizer must roughly equal 110 percent to 120 percent of crop removal. An ideal nutrient efficiency of 100 percent is difficult to achieve because of such factors as soil chemical fixation and losses to water and wind erosion which occur even on well managed soils.

Achieving a steady-state nutrient balance in the 110 to 120 percent range assumes that soil tests have already been raised to sufficient levels for optimum yields. This is not the case for millions of acres in the U.S. which still test in the low and medium categories. These soils need nutrient applications greater than crop removal in order to attain their full production potential.

Figure 2 shows that, as a percentage of crop removal, fertilizer use is now less than 100 percent for both P and K. In other words, U.S. farmers are now, on the average, mining their soils of P and K. Rather than nutrient buildup, nutrient depletion is occurring.

Attempts at further improvements in fertilizer use efficiency run the risk of accelerating the rate of nutrient depletion. Many programs aimed at improving efficiency depend primarily on lowering fertilizer application rates. While this may achieve short-term economic benefits on

[1]Frye, W.W., O.L. Bennett and G.J. Buntley. 1985. In *Soil Erosion and Crop Productivity*, R.F. Follett and B.A. Stewart, eds. American Society of Agronomy, Madison, WI. p. 341.

[2]Van Dyne, D.L., and C.B. Gilbertson. 1974. Estimating U.S. Livestock and Poultry Manure and Nutrient Production. USDA Economics, Statistics, and Cooperative Services. ESCS-12. (Estimates for 1974 livestock numbers updated to 1987 by the author).

Nutrient Budget . . . from page 17

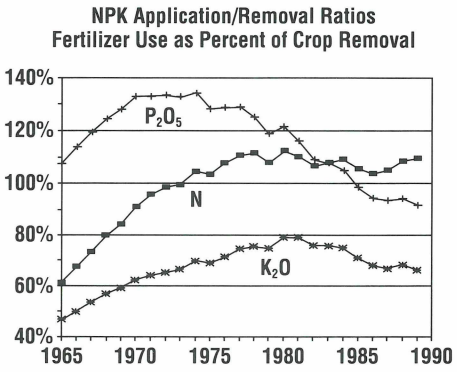


Figure 2. Fertilizer use as a percentage of crop removal for 20 major U.S. crops, 1965-1989. The percentages or ratios were obtained by dividing nutrient consumption by crop removal. The data shown are 5-year running averages.

soils testing high in P or K, a red flag should be raised anytime the application rate is less than crop removal. The danger is that the long-term sustainability of agriculture may be jeopardized by attempts to achieve short-term economic gains.

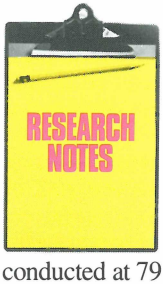
Selection of Nutrient Sources

From the standpoint of plant nutrition, the source used to replace nutrients makes no difference long-term. The challenge is to select the most efficient and environmentally sound technology to replace nutrients in order to maintain soil fertility and productivity. A corn plant responds equally well to K, for example, whether it is applied to the soil in the form of manure or commercial fertilizer.

Systems which encourage nutrient recycling help to lessen the need to import off-farm sources. Nutrient sources produced on the farm should receive first attention in recycling efforts. Returning nutrients contained in animal manures, livestock bedding, and plant residues to the soil, for example, is economically wise and environmentally responsible. With regards to sewage sludge and manufacturing by-products, high transportation costs and limited availability in agricultural regions have discouraged their widespread use as off-farm nutrient sources.

In the long-run, it is not the source but the quantity of nutrients applied that determines if soil fertility and productivity can be sustained. Most farmers find commercial fertilizer to be the most desirable nutrient source because of its relatively low cost, wide availability, high analysis, ease of handling and application, and predictable nutrient availability. ■

Nebraska



Nitrogen and Irrigation Management Practices to Minimize Nitrate Leaching from Irrigated Corn

PRACTICES related to management of fertilizer nitrogen (N) and irrigation water for corn were evaluated in a series of studies conducted at 79 sites in Nebraska from 1984 through 1988. Practices evaluated included N credit from nitrate (NO_3^-) in soil, N credit from NO_3^- in irrigation water, realistic yield goal selection, and irrigation scheduling according to crop water use. The procedure for determining the recommended fertilizer N rate provided adequate N without reducing yields. Averaged over the 79 sites, yield goal was 170 bu/A; recommended fertilizer N rate was 130 lb/A. Average yield was 173 bu/A, and fertilizer N reduction due to accounting for various N sources was 45 lb/A. This study emphasizes the importance of crediting other N sources in order to maximize crop production efficiency and minimize NO_3^- losses. ■

Source: R.B. Ferguson, C.A. Shapiro, G.W. Hergert, W.L. Kranz, N.L. Klocke, and D.H. Crull, Institute of Agricultural and Natural Resources, University of Nebraska. Published in J. Prod. Agric. 4:186-192 (1991).