Nutrient Budgets in North America

By P.E. Fixen and A.M. Johnston

Nutrient budgets are valuable in that they provide insight into the balance between inputs and outputs in crop production. Unlike financial budgets, however, they are only partial budgets because of inaccuracies in determining inputs/outputs. There are many sources of error, including variations in crop removal, estimation of N fixation by legumes, nutrient compositions of various manure sources, etc.

Manufactured mineral fertilizers are the primary nutrient sources (inputs), although significant amounts are provided through N fixation by legumes and the application of manure. In North America, only N fertilizer use increased during the last 20 years of the 20th century, with minor declines in P and K use. The ratio of N to P_2O_5 and K_2O nearly doubled during that time. Also, there was a large increase in the numbers of livestock grown in confined feeding operations, significantly increasing the amounts of recoverable manure nutrients.

Crop nutrient removal (outputs) occurs in the forms of grains, oilseeds, fruits, vegetables, fiber, hay, and forage that are exported from production fields. Other outputs include erosion losses, leaching, dentrification, and volatilization.

Partial N budgets (**Table 1**) show that for North America, the amount of N removed in harvested crops is equivalent to about 77 percent of inputs (fixation, fertilizer, and recoverable manure). Nitrogen recovery in the leading U.S. corn states is about 82 percent, compared to 75 percent for the U.S. as a whole. Recovery in Canada is 94 percent.

Partial nitrogen (N) budgets for North America show that the amount of N removed in harvested crops is equivalent to 77 percent of major inputs. The partial phosphorus (P) budget for North America shows that P removal exceeds P applied as fertilizer by 29 percent. When recoverable manure is included in the evaluation, removal represents 95 percent of inputs. The partial potassium (K) budget shows that crops currently remove 44 percent more than the amount of K being applied as fertilizer or recoverable in manure.

The partial P budget for North America shows that removal exceeds P applied as fertilizer by 29 percent (**Table 2**). When recoverable manure is included in the evaluation, removal represents 95 percent of inputs.

The partial K budget shows that crops in North America currently remove twice the amount of K being applied as fertilizer (**Table 2**). When all recoverable manure is considered, removal still exceeds input by 44 percent. In the leading U.S. corn states, removal of P and K exceeds fertilizer applied plus recoverable manure by approximately 30 percent.

Historical trends in partial P budgets for the U.S. and Canada are shown in **Figures 1** and **2** as the ratio of P removed by common crops to the sum of fertilizer P and recoverable manure P. Over the entire 40-year period in the U.S., P removal has been less than inputs. In fact, in the late 1960s and early 1970s, P removal was only 60 percent of P inputs. This resulted in build up of soil test P in many regions of the U.S., especially the Corn Belt. Since 1970, the removal to use ratio has consistently trended higher

TABLE 1. Partial N budgets for North America (average of 1998-2000).

Region	Crop removal[1]	Legume fixation	Applied fert.	Recoverable manure	Balance[2]	Removed by crop harvest, % without manure	Removed by crop harvest, % with manure
	billion lb						
Six leading corn states	14.5	8.4	8.8	0.5	3.3	84	82
U.S.	32.1	15.6	24.7	2.6	10.8	80	75
Canada	5.02	1.41	3.64	0.28	0.31	99	94
North America	37.1	12.0	28.3	2.9	11.1	82	77

[1]N removed in harvested portion of alfalfa, soybeans, peanuts, 49% of lentils, and 54% dry peas. It was assumed that any fixed N not recovered in the harvested crop was countered by soil N taken up during the growing season.
[2](Fixation + fertilizer + manure) - removal.
Source: Adapted from *Plant Nutrient Use in North American Agriculture*, PPI/PPIC/FAR Technical Bulletin 2002-1.

TABLE 2. Partial P and K budgets for North America (average of 1998-2000).

Nutrient	Region	Crop removal	Applied fert.	Recoverable manure	Balance[1]	Removal to use ratios without manure	Removal to use ratios with manure
		billion lb					
P_2O_5	Six leading corn states	5.1	3.0	0.9	-1.3	1.71	1.33
	U.S.	11.4	8.8	3.3	0.7	1.30	0.95
	Canada	1.87	1.51	0.40	0.04	1.24	0.98
	North America	13.3	10.3	3.7	0.7	1.29	0.95
K_2O	Six leading corn states	6.6	4.1	1.0	-1.5	1.62	1.30
	U.S.	19.3	10.1	3.8	-5.9	1.91	1.39
	Canada	2.64	0.78	0.5	-1.36	3.40	2.06
	North America	21.9	10.9	4.3	-6.7	2.02	1.44

[1](Fertilizer + manure) - removal.
Source: Adapted from *Plant Nutrient Use in North American Agriculture*, PPI/PPIC/FAR Technical Bulletin 2002-1.

and is now over 0.90 for the U.S. as a whole and greater than 1.0 for much of the Corn Belt, as discussed earlier.

The previous P budget analysis includes all recoverable manure P in the U.S. even though an unknown quantity of that manure is applied to pastures and disposed of in ways other than in accordance with the nutritional needs of crops. Thus, the analysis utilizes an inflated estimate of the P agronomically applied to the common crops included in the removal estimates. In an attempt to avoid the over estimation of manure P in the budget, **Figure 3** utilizes the estimates of manure P applied to corn, soybeans, wheat, and cotton derived from USDA-ERS surveys for 1990 to 1996. Using this estimate of manure P, the P removal to use trend line crosses 1.0 in the late 1980s and suggests that P removal exceeded use by approximately 20 percent in the year 2000.

In Canada, P removal was slightly less than inputs (utilizing all recoverable manure P) during much of the 40-year period (**Figure 2**). The low point in the trend line was 0.75 and occurred in about 1980. During the 1990s, P inputs and outputs were essentially equal. Considering that the problems associated with distribution and agronomic utilization of manure P in the U.S. are equally relevant in Canada, a good portion of Canadian crop production is dependent on soil P reserves.

Similar to P, K in most agricultural soils is well-buffered by soil reserves, making it important to relate current nutrient budgets to past budgets and to soil test levels and trends. Unlike with P, the trend line for the K removal to use ratio has been greater than 1.0 for the entire 40-year period in both the U.S. and Canada (**Figures 1** and **2**). In Canada, it has

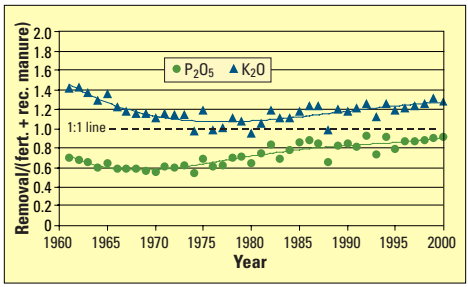

Figure 1. Ratio of P and K removal by common crops to fertilizer P and K use plus recoverable manure in the U.S.

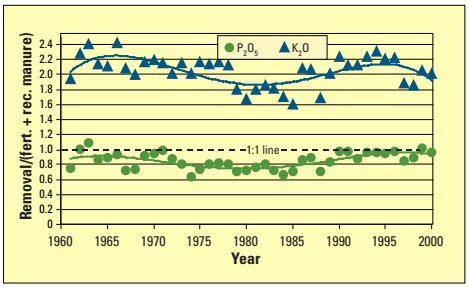

Figure 2. Ratio of P and K removal by common crops to fertilizer P and K use plus recoverable manure in Canada.

generally been near 2.0, while in the U.S. it was at 1.4 in the early 1960s, decreased to about 1.1 in the late 1970s, and has since been increasing to where it is today, near 1.3. Restricting manure K estimates to what is applied to corn, soybean, wheat, and cotton, increases the ratios and results in a current value near 1.6 (**Figure 3**).

Although the nutrient budgets presented and discussed in this article are fraught with limitations and assumptions, we believe this to be one of the most comprehensive attempts ever made at estimating and understanding the application and use of plant nutrients in North America. Overall, it paints a picture of fairly high and improving efficiency of nutrient use.

For the nutrient budget of North America as a whole, there is no evidence of P or K surpluses. All the fertilizer P and K currently being used and all the P or K recoverable from manure can be used in crop production. However, with increasing numbers of confined livestock and, thus, more recoverable manure, nutrient management is becoming more of a challenge. Because of high costs of transporting manure, over-application on lands near confined animal areas is a potentially serious problem. The dilemma of manure distribution makes the development of realistic nutrient budgets a serious challenge for agriculture.

The nutrient budgets identify another reason for concern. Many of our historically most productive soils are at risk of being systematically depleted of nutrients necessary to maintain their productivity. This chronic under-replacement of essential nutrients will eventually reduce the productivity and competitiveness of agricultural systems in these regions. Care must be used to avoid mistaking management practices that cause soil fertility depletion with practices that appear to increase nutrient use efficiency.

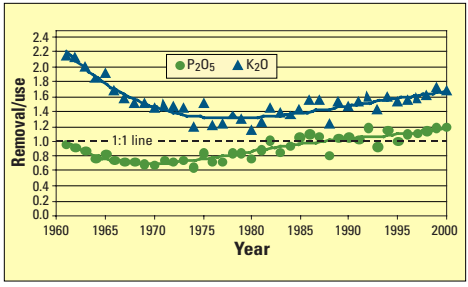

Figure 3. Ratio of P and K removal by common crops to fertilizer use plus manure nutrients applied to corn, soybeans, wheat, and cotton in the U.S.

Dr. Fixen is PPI Senior Vice President, North American Programs, located in Brookings, South Dakota; e-mail: pfixen@ppi-far.org. Dr. Johnston is PPI Western Canada Director, located in Saskatoon, Saskatchewan; e-mail: ajohnston@ppi-ppic.org.