STATE, REGIONAL AND FARM-SCALE NUTRIENT BALANCES: TOOLS FOR ENHANCED EFFICIENCY OF WHOLE-FARM NUTRIENT USE

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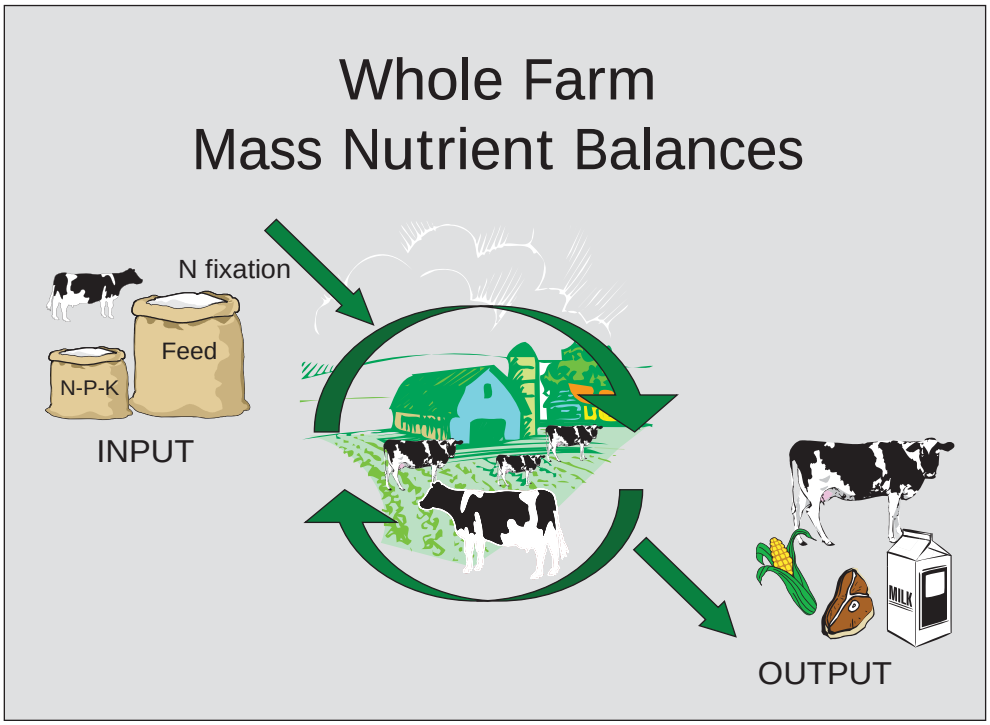
There are many concerns about nutrient use locally, regionally, nationally and in some cases, globally. Most of us are familiar with concerns relating to phosphorus (P) use and impacts based on freshwater quality impacts such as algal blooms and a general increase in plant growth and decay in inland waters. More recently, nitrogen (N) has been receiving attention by scientists. In contrast to fresh waters, coastal/salt water bodies are N limited so additions of N can increase algae and plant growth and decay in these water bodies. Further, the role of the N cycle at a national and global scale are increasingly recognized, as exhibited by a recent report from the Environmental Protection Agency (EPA) Science Advisory Board entitled "Reactive Nitrogen in the United States: an Analysis of Inputs, Flows, Consequences and Management Options" (http://yosemite.epa.gov/sab/sabproduct.nsf/WebReportsLastMonthBOARD/67057225CC780623852578F10059533D/$File/EPA-SAB-11-013-unsigned.pdf). This EPA report describes "reactive" N (N_r) as essentially all chemically and biologically reactive N that is in the air, or in and on the soil, distinct from inert N_2 gas that comprises about 78% of our atmosphere. Much of the N_r generated annually is for or a result of food production and much of this N is eventually released into the environment, where it may remain for years or decades in various forms contributing negatively to human health and the environment. Indeed, the National Academy of Engineering has identified management of N as one of the "grand challenges" facing this country.

In this paper we will look at trends in N and P balances in New York State at the farm, Chesapeake Bay watershed, and state levels, and suggest a way forward to assist farms to meet nutrient use efficiency expectations while remaining economically viable.

TRENDS IN FARM BALANCES

More efficient management of nutrients involves managing the nutrients that remain on the farm to the greatest degree possible. This will require a shift away from use of insurance applications/additions and book values to implementation of practices that include precision feed and forage management and a focus on ***optimizing nutrient use efficiency***. The key solutions lie in practices that allow farms to safely and confidently manage nutrient use (both agronomic and purchased feedstuffs) and thereby increase farm nutrient use efficiency and reduce loadings to watersheds while finding value in remaining nutrients or carbon sources. Knowing a farm's nutrient mass balance is one step toward improving our understanding and management of nutrient movement onto, within, and away from any particular farm.

Figure 1: A farm nutrient mass balance is the difference between nutrient (N, P, and K) imports and exports expressed, for dairy farms, on a per cwt milk production or a per acre cropland basis.

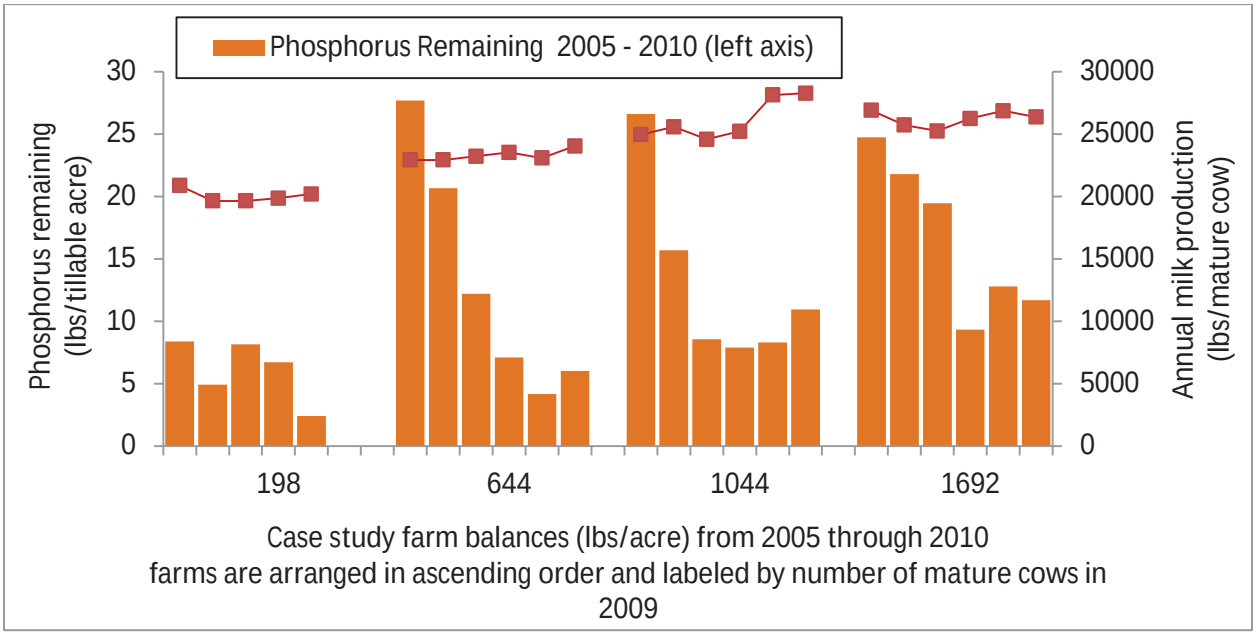


These reductions reflect both the willingness of the producer to reduce balances over time and the potential for making changes that improve production efficiency and reduce risk of nutrient to the environment. Similar trends were seen in a database of 54 New York State dairy farms who participated in the mass balance assessment project for 4 or more years. When contrasting the mass balances of the first two years in the project with those in the last two years in the project, reductions in nutrients ranged from 28 to 53%. The largest gains were made by farms that had large surpluses in their starting year (Table 1).

The mass balance assessments require records be kept for purchase of feed, fertilizer, animals and imported bedding, and for exports of nutrients through sales of milk, crops, animals, and/or export of manure. Such balances, when done annually, can reveal trends that are important for longer-term decision making, and monitoring of the impact of management changes on potential of environmental loss. Not only can such N, P and K balances be reduced without a reduction in milk production, but some farms experience an increase in milk production, as is shown in P balances of the farms in Figure 2. The farms participating in the annual assessment shown in Figure 2 have demonstrated clearly that independent of size of operation, gains can be made to reduce annual nutrient excess without the loss of production.

As shown in Table 1, mass balance trends over time can differ depending on the initial levels at which the farm was operating, with a tendency to larger reduction where initial balances were above levels achievable by 75% of all farms in the New York State dataset. Gains will be region specific, too. Assessment of balances in the Upper Susquehanna Watershed showed a 50% reduction in P balance of farms that participated 3 or more years (9 lbs P/acre in 2004 versus 4.4 lbs P/acre in 2009). Similarly, the P balance per cwt was reduced from 0.16 to 0.07 lbs P/cwt. (Figure 3). In this group the P imported as purchased feed decreased 29% from 2004 to 2009.

Figure 2: Phosphorus balance (P remaining per tillable acre) for four farms ranging in animal numbers from 198 to 1692 cows, over five to six years of participation in the Cornell Nutrient Management Spear Program annual mass balance project.



TRENDS IN STATEWIDE BALANCES

The improvements illustrated by the individual farm balances are reflected in the statewide P balance as well. In New York, the statewide P balance (manure P plus fertilizer P minus P in crop harvest), has shown a drastic reduction from 14 and 17 lbs P/acre in 1987 and 1992, respectively, to 1.5 lbs/acre in 2007 (Figure 4).

The trends in balance reflect a reduction in P fertilizer use (Figure 5) from 17-20 lbs P/acre in 2000-2003 to 10 lbs P/acre in 2009. This change was due to was an increased demand for fertilizer blends with less P, as reflected in a steady decline in the P_2O_5/N ratio since 2000 (figure 5). Similarly, a reduced use of mineral P for dairy cow rations and large improvement in precision feeding and home-grown forage production over these years contributed greatly to the lower P balance, illustrating the potential for changes across management units on the farm.

Table 1: Percent reduction in excess N, P and K for 54 dairy farms that participated in the Nutrient Management Spear Program mass balance assessment project. Farms are separated into two groups depending on their initial N, P and K balances.

	Average N remaining for farms with beginning N balance less than 105 lbs N/tillable acre.	Average N remaining for farms with beginning N balance greater than 104 lbs N/tillable acre.	Average N remaining for all 54 farms that participated for four years or more.
Average of first 2 yrs	40	174	67
Average of last 2 yrs	28	124	48
Percent reduction	30%	29%	28%
Number of farms	43	11	54
	Average P remaining for farms with beginning P balance less than 13 lbs P/tillable acre.	Average P remaining for farms with beginning P balance greater than 12 lbs P/tillable acre.	Average P remaining for all 54 farms that participated for four years or more.
Average of first 2 yrs	7	22	10
Average of last 2 yrs	5	11	6
Percent reduction	29%	50%	40%
Number of farms	43	11	54
	Average K remaining for farms with beginning K balance less than 39 lbs K/tillable acre.	Average K remaining for farms with beginning K balance greater than 38 lbs K/tillable acre.	Average K remaining for all 54 farms that participated for four years or more.
Average of first 2 yrs	16	53	22
Average of last 2 yrs	11	25	14
Percent reduction	31%	53%	36%
Number of farms	45	9	54

Figure 3: Phosphorus balance for dairy farms in the Upper Susquehanna Watershed dairy farms monitored from 2004-2009 (211 farm balances).

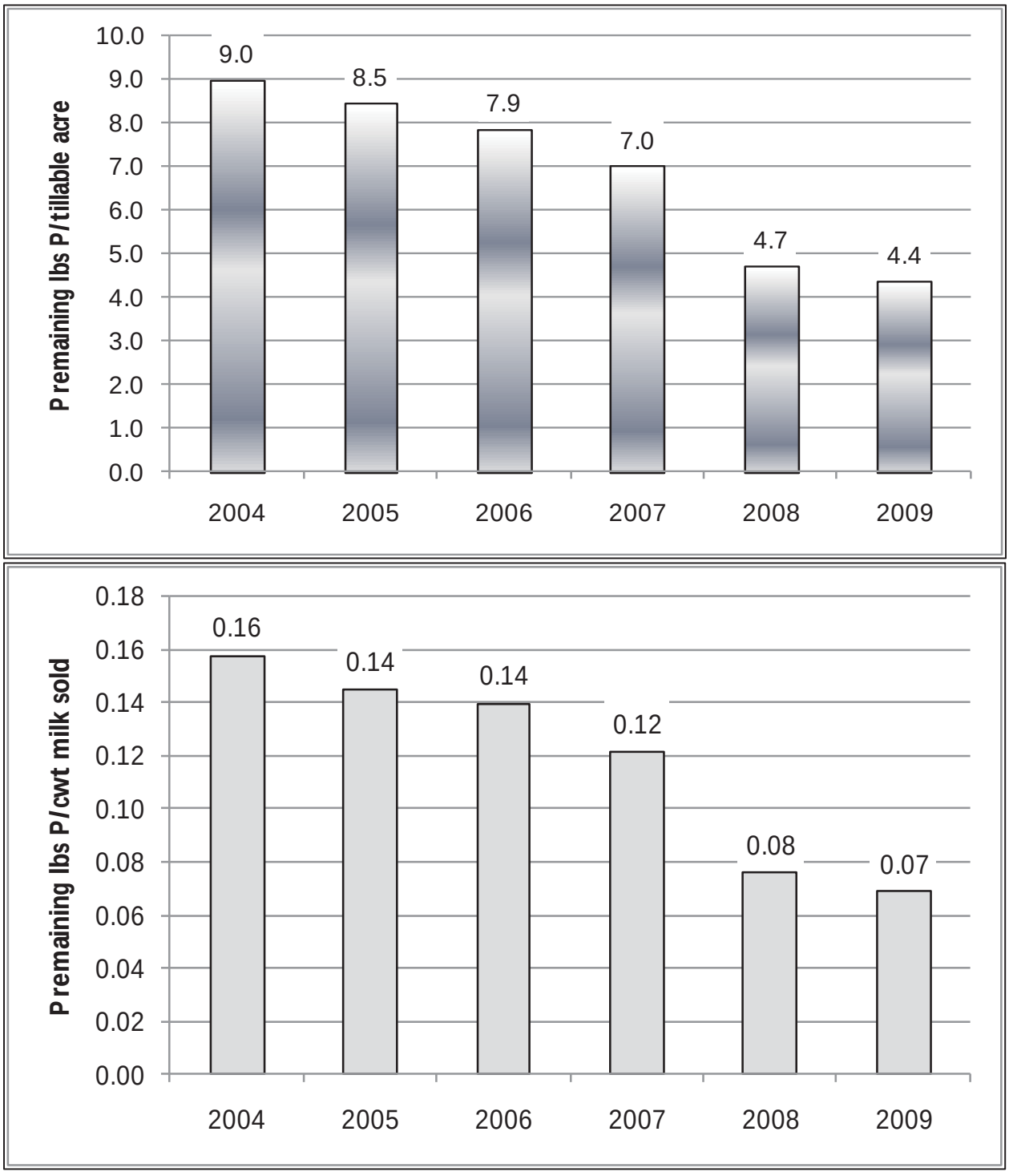
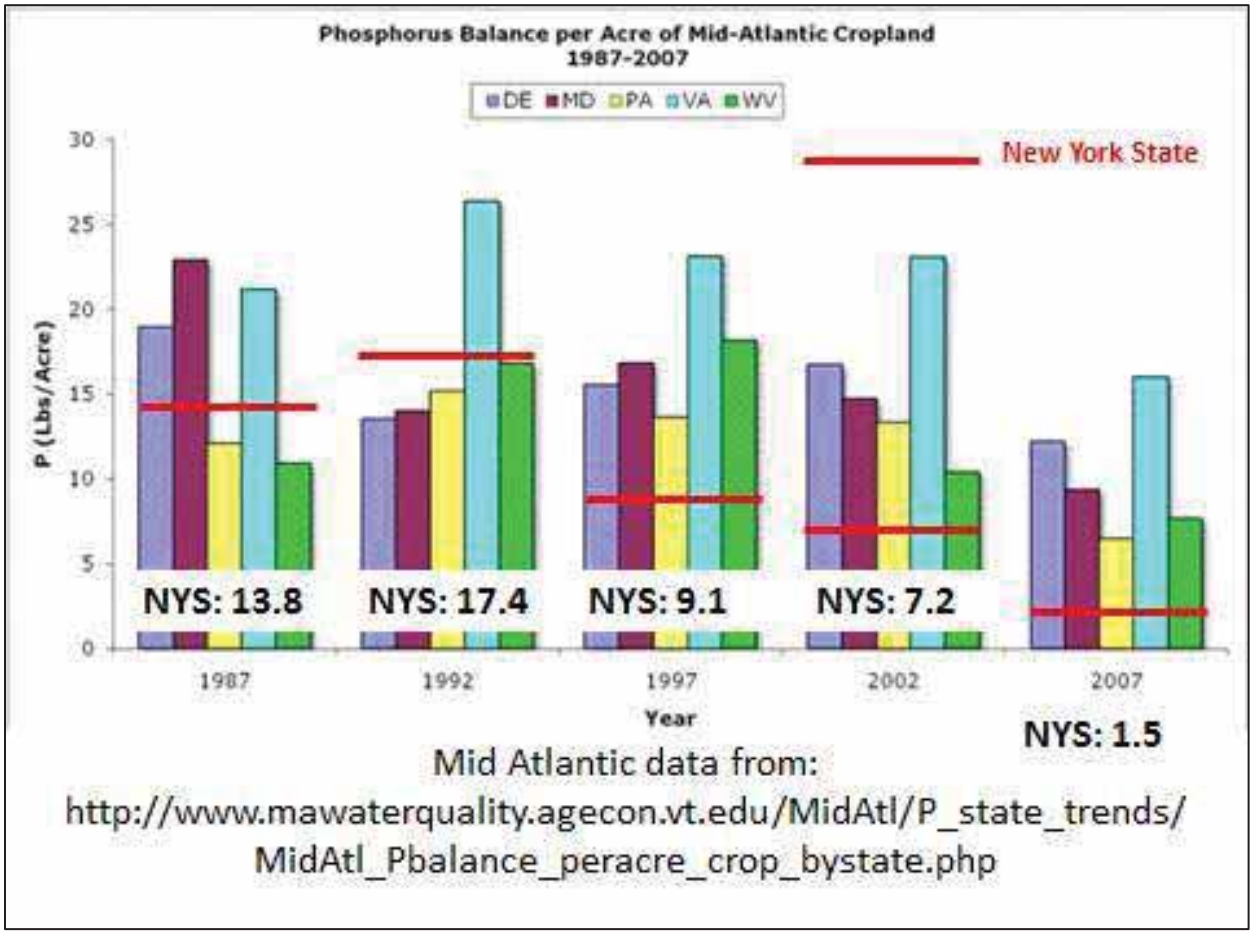


Figure 4: Phosphorus balance per acre (lbs P/acre) for New York and the mid-Atlantic States reflect the drastic changes implemented by New York State dairy farms.



The decline in balance was also apparent in an evaluation of the counties that make up the Upper Susquehanna Watershed. However, for the Upper Susquehanna Watershed, the P balance is now negative, with insufficient manure P and fertilizer P use to maintain current soil test levels - a trend that needs to be viewed with concern.

IMPLICATIONS

The negative P balance for the Upper Susquehanna Watershed is reflected in a change in soil test P levels, showing a decrease from 14% between 1995 and 2000 testing above the agronomic optimum soil test P for crops like corn to 8% in 2004-2006 (Figure 6). Although analysis of field-by-field distribution of P is needed, these state and watershed trends raise concerns about impact of further reductions in P balances on the long-term sustainability of farming in low or negative P balance regions.

Figure 5: Changes in on-farm fertilizer P use in New York State since 2000 reflect greatly reduced P fertilizer use. Crop yields increased over this time period.

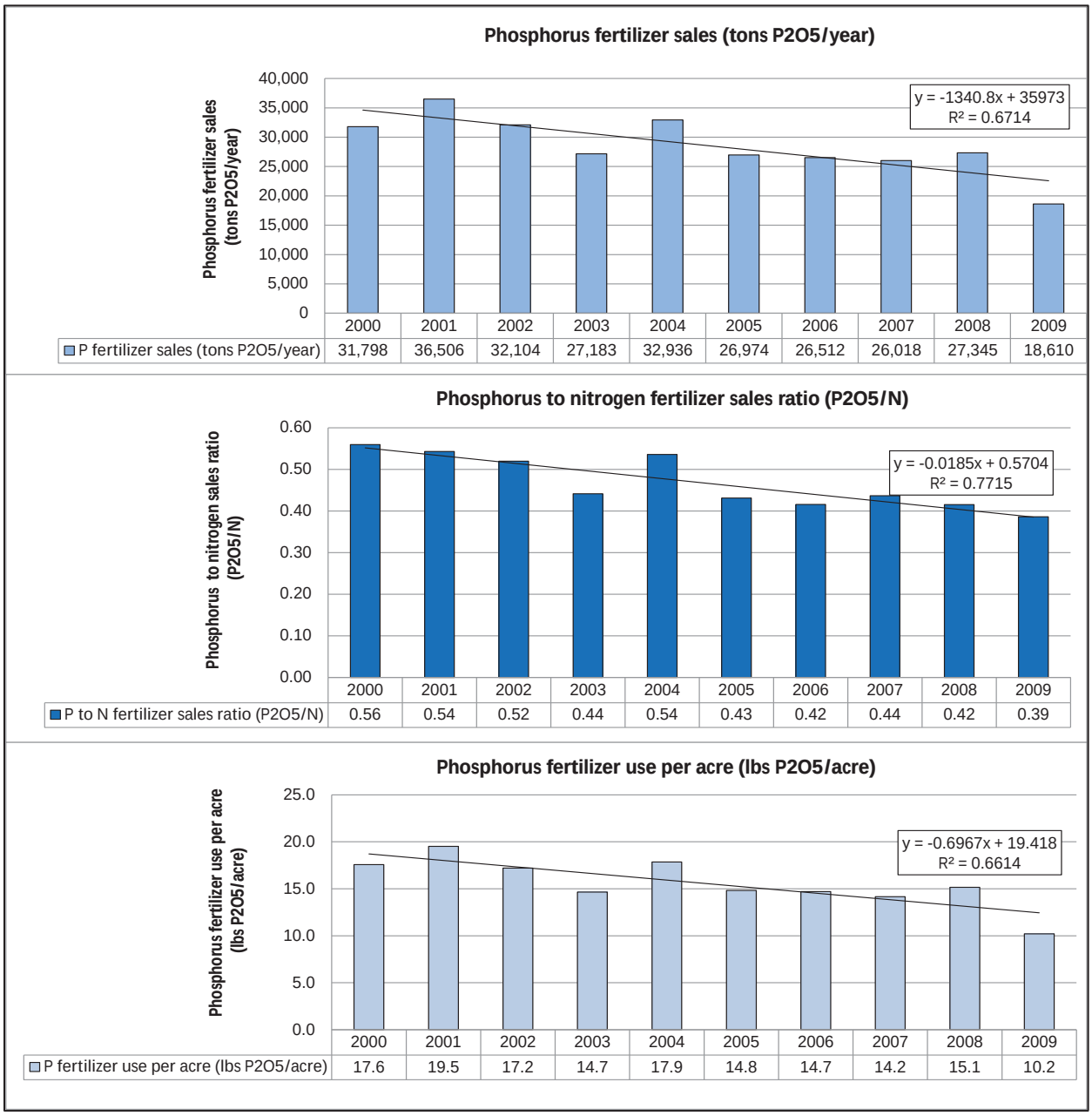
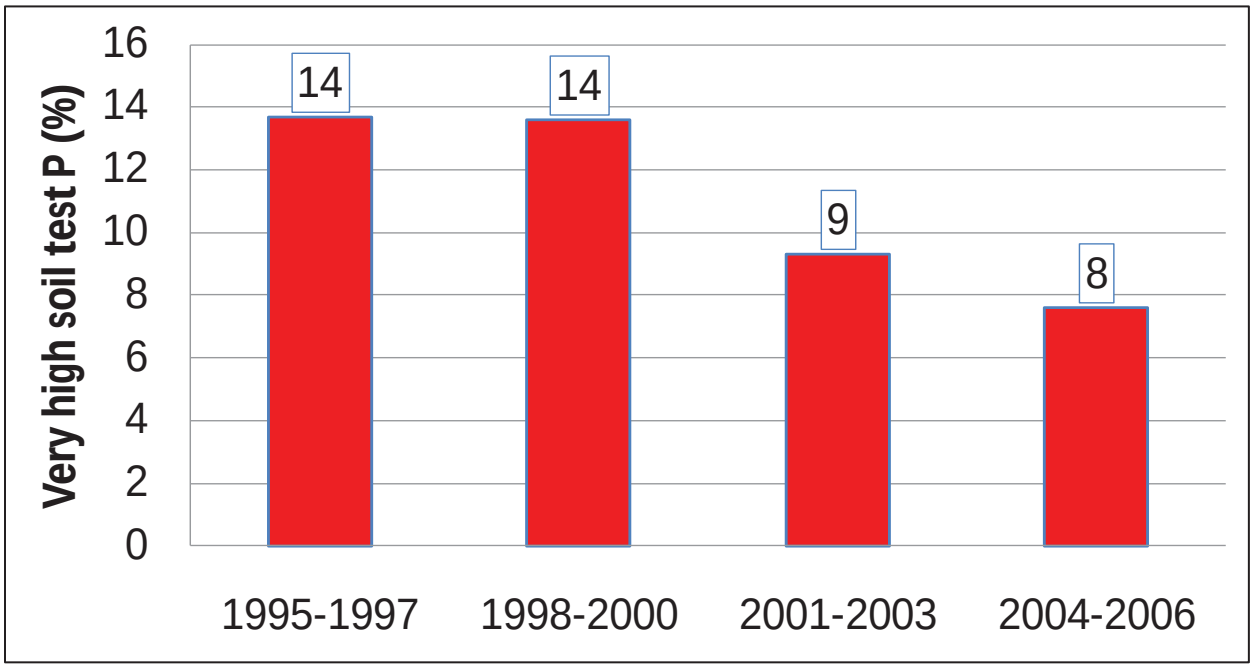


Figure 6: Soils Very High in agronomic soil test P (>40 lbs/acre Cornell Morgan test) for Upper Susquehanna Watershed fields.



Statewide, regional and farm N balances have shown a decline over the past two decades as well, mostly driven by a reduction in the total pool of N excreted in manure. The current gross balances of 55 lbs N/acre (statewide) and 29 lbs N/acre (Upper Susquehanna Watershed) indicate many fields are not receiving adequate N to support optimum yields given that neither fertilizer N nor manure N has 100% uptake efficiency. This raises questions of sustainability for farms that routinely operate this way. Losses of ammonia in the barn, losses from storage, and losses from land application of manure present opportunities, indicating that current manure and fertilizer management could be improved to some extent, but the overall negative balances indicate such improvements need to go hand in hand with addition of N from other sources (cover crops, greater reliance on N fixation, shorter rotations, etc.) to optimize both crop production and nutrient use efficiency. The current status further illustrates the need to both document farm-level balances and to manage these balances for improvements in nutrient use efficiency (N, P, K and other nutrients), for profitability, and for a reduced environmental footprint (Figure 7). This requires the engagement of the farm managers and their advisors, including the nutritionist and the crop advisor.

CALL TO ACTION

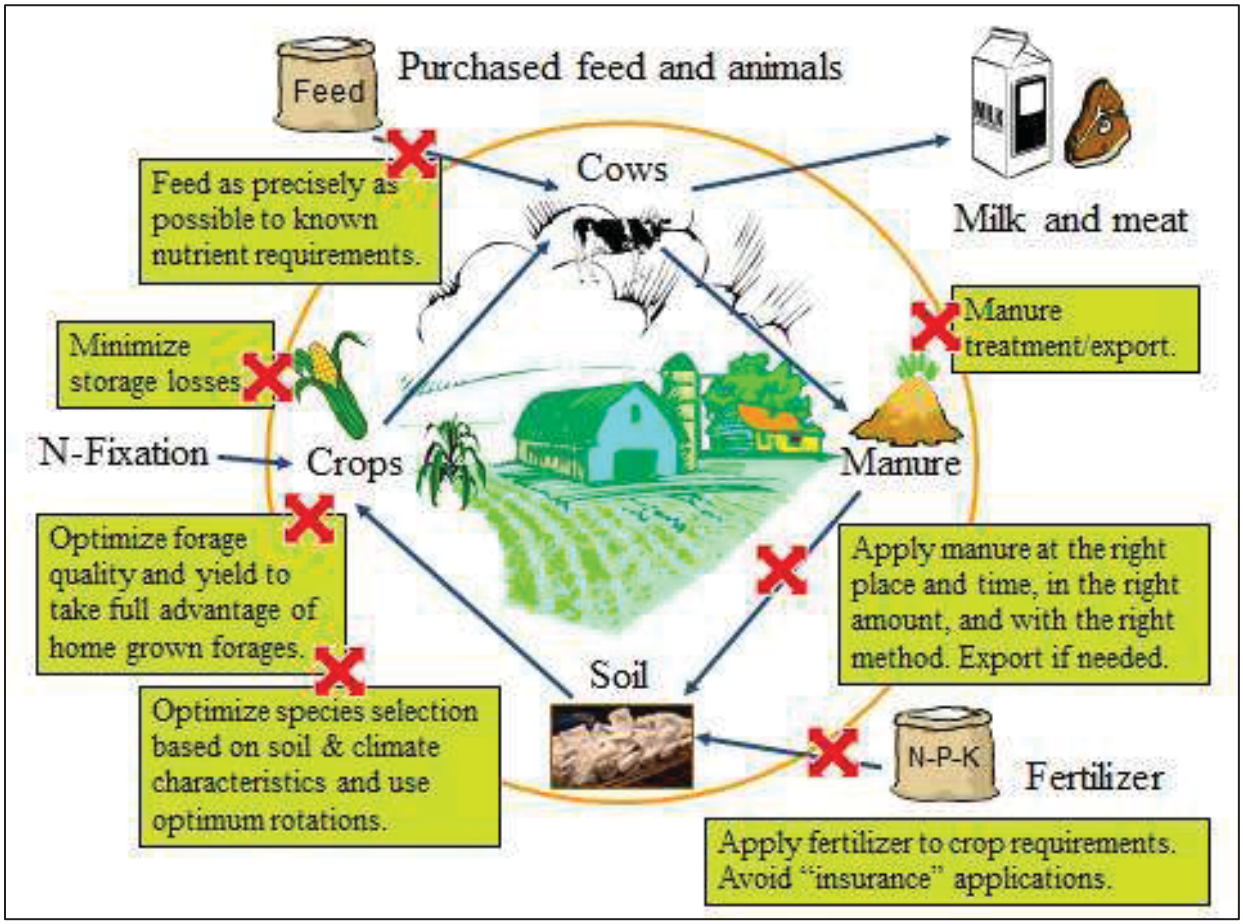
Experiences with farms that participated in mass balance assessments over the past 4-6 years have shown that improvements will be implemented where economically feasible and that the annual mass balance assessment is a great tool to guide and monitor such changes. A balance analysis helps farm managers to benchmark from year to year, to compare their performance to other like operations, and to determine

nutrient management strengths and also where nutrient use inefficiencies occur. To help with on-farm assessments, a software program was developed to allow users to:

- Calculate the amount of nutrients being imported to the farm as purchased feeds (i.e., not homegrown), fertilizers, animals, and bedding material, and being exported from the farm as milk, animals, crops, and manure/compost.
- Generate reports that show farm N, P and K imports and exports in tons for the whole farm and in pounds per acre cropland, per pound of product sold, or per animal unit.
- Identify areas of concern and opportunities for more efficient nutrient use that, if addressed, could increase profitability and reduce environmental impact.

For more information on how to use the software and data collection necessary to use the program, see the Nutrient Mass Balance webpage of the Nutrient Management Spear Program: http://nmsp.cals.cornell.edu/projects/massbalance.asp.

Figure 7: Whole farm mass balances can be used as an indicator of nutrient use efficiency across all farm management units (herd, crop, bunk/storage, and manure management) and aid in implementation of changes in best management practices that help the farm's profitability and reduce its environmental footprint.



CONCLUDING REMARKS

For the sustainability of the dairy sector in any state, it is important to find ways to enhance profitability while minimizing environmental loss of N and P. Farm nutrient mass balances can illustrate environmental and economic imbalances quickly, independent of location of the farm. Balance assessments are useful for livestock, dairy and crop farms alike; they can help identify management alternatives that enhance nutrient use efficiency and farm profitability. We urge farms to consider participating in the annual assessment, as case study farms have clearly illustrated the potential for large gains in nutrient use efficiency when monitoring of progress becomes part of the package of best management practices, and when producers have complete control of where to make changes in their individual operations. We also urge nutritionists to get involved as imported feed is for most dairies the single largest contributor to nutrient imports and hence farm balances of dairy farms.

RELEVANT LITERATURE

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