WHOLE-FARM NUTRIENT MASS BALANCE BENCHMARKS FOR NEW YORK DAIRIES

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The long-term sustainability of dairy farms depends on their ability to be profitable while limiting their environmental footprint. The development and implementation of tools and policies that address nitrogen (N), phosphorus (P) and potassium (K) imbalances before they become extreme are essential to the long-term sustainability of dairy farming. At the 2011 Cornell Nutrition Conference, initial data were presented showing that whole-farm nutrient mass balance (NMB) assessments can be used to identify management alternatives that enhance nutrient use efficiency and farm profitability (Ketterings et al, 2011). A NMB approach allows farmers to set targets and then choose the range of practices and approaches to meet goals over time, recognizing that each farm is unique. Case study farms 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. For these reasons, we strongly encouraged dairy producers to participate in an annual NMB assessment and we also urged nutritionists to get involved as imported feed is frequently the single largest contributor to nutrient imports and hence NMBs of dairy farms.

In this paper we evaluate a dataset with NMBs for 102 New York dairies to: (1) examine initial NMB benchmarks based on what 75% of the farms achieved, and (2) identify drivers for nutrient imbalances. Benchmarks offer a potential mechanism to assist farms to meet nutrient use efficiency targets while remaining economically viable and retaining management flexibility.

WHAT IS A WHOLE-FARM NUTRIENT MASS BALANCE?

A whole-farm nutrient mass balance (NMB) is a method for measuring and monitoring the nutrient status of a dairy farm. A NMB is typically calculated by taking the difference between the nutrients imported onto the farm (via feed, fertilizer, animals, bedding and manure), and the nutrients exported from the farm (as animal products crops and manure) (Figure 1) (Soberon et al., 2013). When this difference is expressed per tillable acre, it indicates how well nutrients are recycled in the farm land base. When the difference is expressed per cwt of milk produced, it reflects the farm's nutrient use efficiency. A first NMB assessment characterizes the initial nutrient status of a dairy farm and allows for identification of areas where improvement may be possible. Annually conducting NMBs allows for evaluation of the impact of management changes on the whole-farm nutrient use efficiency.

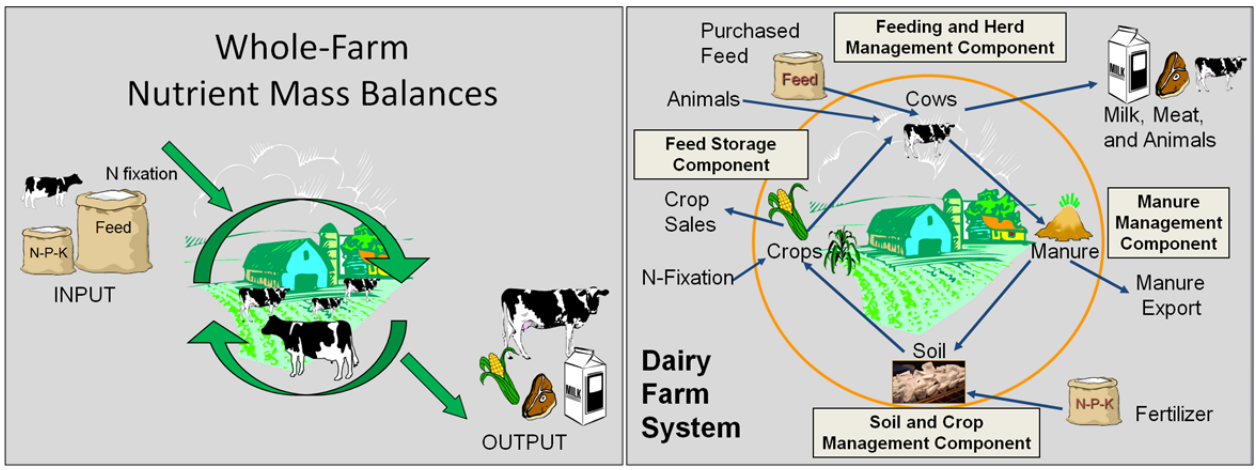

Figure 1. Whole farm nutrient mass balances.

Over time, there has been a trend toward intensification (an increase of animal density) of dairy farming in NY and elsewhere (NASS, 2010). Intensification is typically associated with higher nutrient imports (mainly through feed and fertilizer), which can result in higher NMBs depending on how resources are managed. Positive whole-farm NMBs are inevitable (and desirable) because plants and animals are not 100% efficient in nutrient use. However, very large NMBs reflect low nutrient use efficiencies at the farm-level, increase costs of production, waste valuable resources, and increase potential nutrients losses to the environment. Excess N can increase ammonia volatilization to the atmosphere, nitrate leaching to ground water, or denitrification and greenhouse gas emissions. Excess P can build up in the soil and contribute to P runoff, P leaching, and eutrophication of surface waters. Excess K can also build up in the soil and lead to elevated K concentrations in forages, potentially impacting herd nutrition programs.

WHAT IS AN ACCEPTABLE NUTRIENT MASS BALANCE FOR DAIRY FARMS?

Previous studies reported NMBs for dairy farms in the US, but they included only a small number of farms. Theoretical assessments suggest that farms can balance for P as long as animal densities do not exceed 1 animal unit (AU) per acre (Cela et al., 2014). Current regulations in the U.S. tend to be driven by the number of animals or animal density (USDA-USEPA, 1999). However, with crop and manure exports, it is possible to manage the farm's NMB, effectively reducing the stocking density. As far as we know, none of the currently published studies include benchmark or acceptable/feasible NMB ranges for dairies. We believe NMB-based benchmarks can be more effective in addressing production and environmental sustainability than imposing limits on animal densities because it puts decisions in the hands of producers who are in the best position to understand the capabilities of farm resources. In this study, we characterized the NMBs of 102 dairy farms in NY and established initial NMB benchmarks for further discussion based on what 75% of these farms achieved

NEW YORK FARM BALANCE EVALUATIONS

Nitrogen, P, and K mass balances were calculated from 102 dairy farms in NY using data from 2006. The 102 farms were located in 26 different counties and in 11 different NY watersheds. Based on Concentrated Animal Feeding Operation (CAFO) thresholds, 75 dairies were small (<200 cows), 15 were medium (200-699 cows), and 12 were large (>700 cows). Compared to all NY dairy farms, this database is skewed toward larger farms as it represents 1.5% all small dairies and 4.6% of all medium and large dairies in NY in 2007. Dairy farms were selected based on the willingness of managers to participate and the availability of adequate records to complete the NMB assessment. Thus, the dataset does not represent an exact cross-section of the NY dairy industry; it may be somewhat skewed toward managers with better record keeping. Medium and large farms had more cows, more acres, higher milk production per cow and per acre, and higher animal densities than small farms.

NUTRIENT MASS BALANCES FOR NY DAIRY FARMS

The 102 farms were operating in 2006 with N balances ranging from -35 to 211 lbs N/acre (median = 58 lbs N/acre), P balances ranging from -7 to 45 lbs P/acre (median = 8 lbs P/acre) and K balances ranging from -41 to 132 lbs K/acre (median = 21 lbs K/acre) (Figure 2A, 2B, and 2C). In this study, N balances exclude estimates of N fixation due to the substantial uncertainty associated with its determination. There were significant differences in NMBs per acre among the three farm sizes, with medium and large farms typically having greater N, P, and K balances than small farms. However, there was a large range in NMBs within each farm size category, indicating that low and high NMBs per acre can be found regardless of farm size.

Nutrient mass balances per cwt milk produced ranged from -1.25 to 2.61 lbs N/cwt milk (median = 0.88 lbs N/cwt milk), from -0.11 to 0.47 lbs P/cwt milk (median = 0.11 lbs P/cwt milk), and from -3.22 to 1.69 lbs K/cwt (median = 0.30 lbs K/cwt milk). Fifty percent of the farms produced at least 114, 909, and 333 lbs of milk per lb of surplus N, P, and K, respectively. In comparison, the least efficient farms only produced 38, 211, and 59 cwt of milk per lb of surplus N, P, and K, respectively. The median NMB per cwt of milk produced did not vary among farm sizes, suggesting that large farms were not necessarily more or less efficient in terms of nutrient use than small farms.

Five to 10% of the dairies exhibited negative NMB (imports < exports). The actual N balances for these farms may be less negative or slightly positive if N fixation was included, but still low, and it is likely that crop yields suffer as a result. For P and K, negative NMB reflect mining of soil nutrients over time, which is only desirable for a period of time if initial soil P and K levels are very high. In farms with low initial soil test P and K, negative P and K balances can also negatively impact crop yields.

BENCHMARK NUTRIENT MASS BALANCES FOR NY DAIRY FARMS

Including all study farms, 75% were operating with NMBs equal to or lower than 105 lbs N/acre, 12 lbs P/acre, and 37 lbs K/acre (Figure 2A, B, C). Including only medium and large (regulated) dairies, 75% operated at or below 146 lbs N/acre, 15 lbs P/acre, and 58 lbs K/acre (Figure 2D, E, F). This reflects that though there were high and low animal density farms across all farm size categories, more medium and large farms on average operated at a higher animal density than small farms in the study. The peer group benchmark for comparison should be NMBs on higher density farms, where managing nutrients more carefully will be needed for limiting environmental impact.

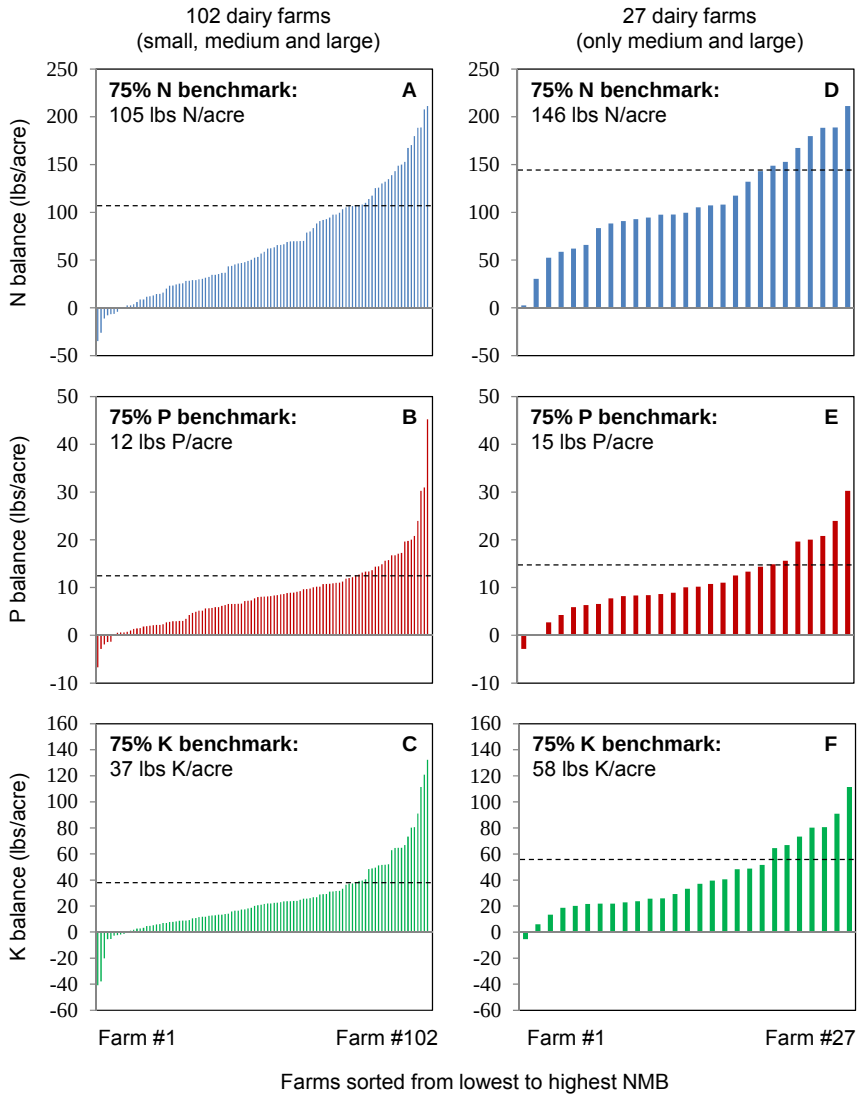

Figure 2. Nitrogen (N), phosphorus (P), and potassium (K) balances (lbs/acre) sorted from the lowest to the highest value, for 102 farms (on the left), and for 27 medium and large farms (on the right).

RELATIONSHIPS BETWEEN MILK PRODUCTION AND NUTRIENT MASS BALANCES

In this study, milk production per cow and NMBs were not correlated (Figure 3). There were small, medium, and large farms with similar milk production per cow and NMBs ranging from very low to very high (Figure 3). In other words, a lower balance did not imply a reduction in milk production. This suggests that there are opportunities for reducing NMBs without a negative impact on milk production per cow.

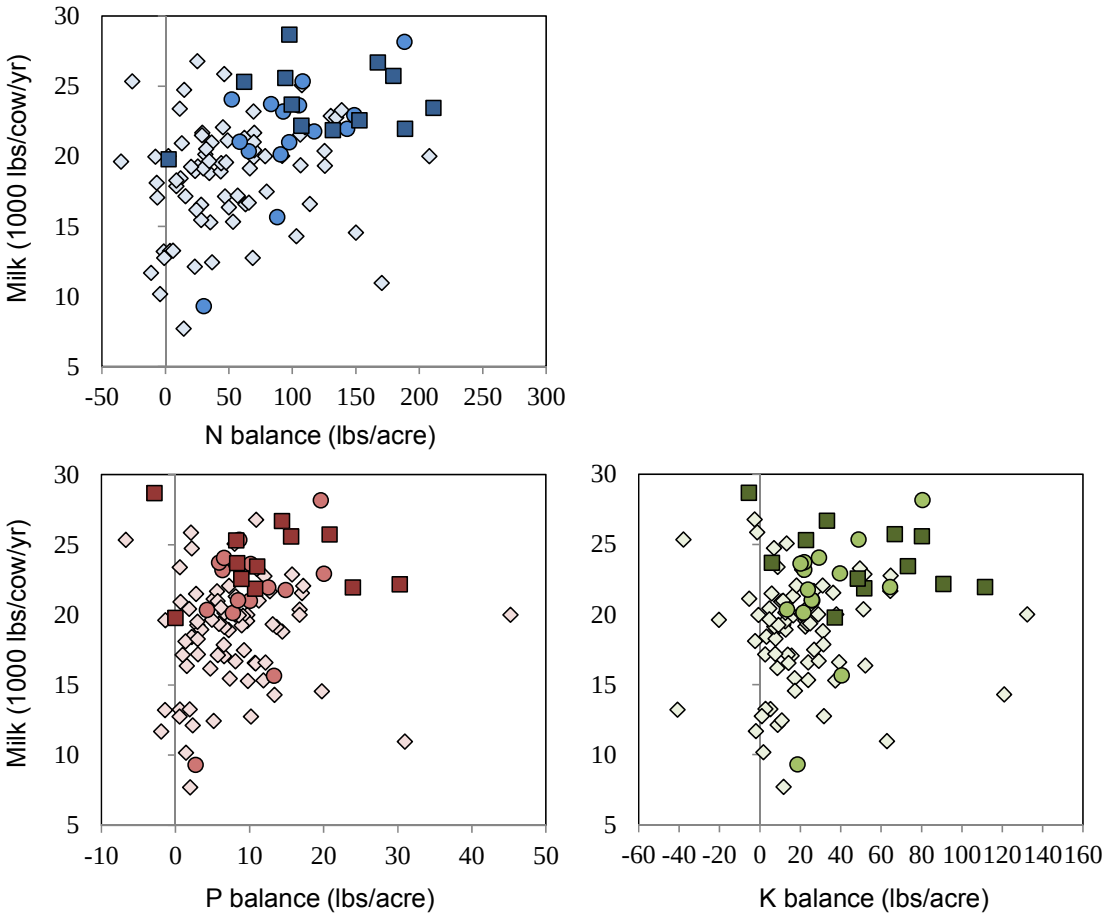

Figure 3. Milk production per cow as a function of the N, P, and K balances per acre. Diamonds, circles, and squares represent small, medium, and large farms, respectively.

MAIN DRIVERS OF NUTRIENT MASS BALANCES

Not surprisingly, imported feed was the single largest contributor to the total nutrient imports. There was a positive and linear regression between the NMBs (without manure exports) and the amounts of N, P, and K purchased via feed (Figure 4A, B, C). In turn, increases in feed imports were highly correlated with increases in animal densities (Figure 4D, E, F). Results show that farms operating with animal densities ≤1 AU/acre typically met the 75% benchmarks NMB, whereas most farms with animal densities

exceeding 1 AU/acre would need to export crops or manure to meet the benchmark NMBs.

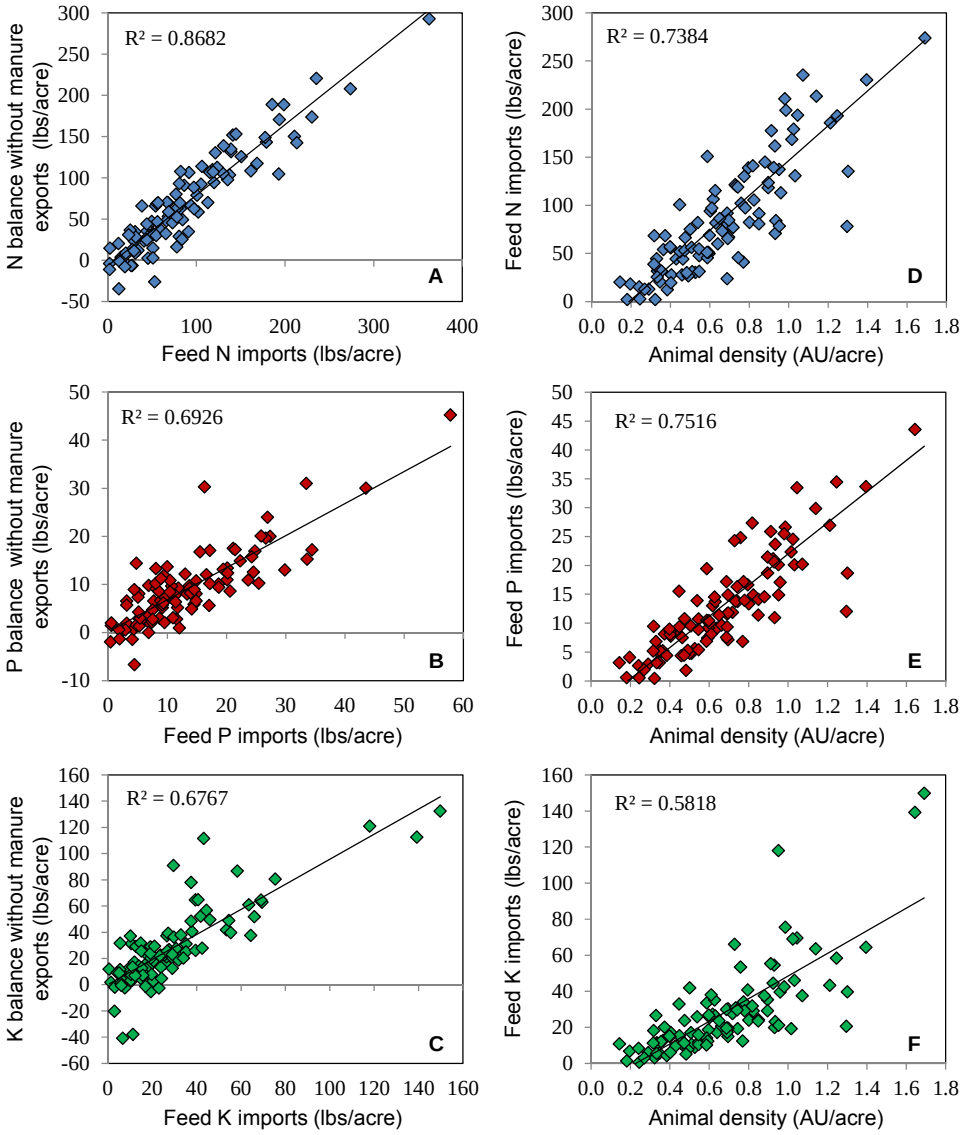

Figure 4. Relationships between nutrient balances per acre and nutrients imported via feed (left), and between nutrients imported via feed and animal density (right).

MANAGEMENT OPORTUNITIES TO IMPROVE NUTRIENT MASS BALANCES

There was considerable variation in the nutrients imported via feed and in the NMBs at a given animal density, suggesting that there are opportunities to reduce NMBs without reducing the animal density.

Homegrown Feed: increasing the percentage of feed grown in the farm can help decrease feed purchases. Homegrown feed can be increased by increasing the land base (purchasing or renting more acres), by increasing crop yields per unit land (e.g., through precision management), and by improving homegrown feed quality. Farms in our database produced from 35 to 97% of the feed (DM) at the farm (median = 76%) and only 9 of 102 farms were producing less than 60% of the feed on the farm, which has been proposed as one of the benchmarks for farmers who want to implement precision feed management in NY (Cerosaletti and Dewing, 2008).

Feed Use Efficiency: dairy farms can reduce their NMB per acre and per cwt of milk produced by increasing the feed use efficiency (e.g., through precision feeding). In our database, the average whole-farm feed use efficiencies were 18% for N, 24% for P, and 9% for K (Table 1). These whole-farm feed use efficiencies include handling and storage losses, so animal feed use efficiencies will be higher. In our database, some farms were feeding up to 21.5% CP, 0.9% P, and 2.7% K in the diet, far exceeding the NRC (2001) standards. These values and the range in feed use efficiencies among farms suggest considerable room for improvement on some farms.

Fertilizer Imports: in some cases, farmers can reduce fertilizer use through improved crop management without negative impacts on crop yields. For N, a better accounting of N sources already on the farm (manure, compost, crop residues in rotations etc.) is essential, while for P and K, improvements can be based on soil test results (Ketterings et al., 2005).

Crop Exports: crop export is a possibility for farms that already produce all the forage they need for the animals. This may be feasible for lower animal density farms but is less likely an option when animal densities increase beyond 1 AU/acre and every tillable acre is under forage production to feed the cows at the farm.

Manure Exports*:* this is an important way to reduce NMB, especially for farms that operate with high animal densities (>1 AU/acre). Many NY dairy farms have elected to export manure where feasible to reduce long-term build up and the risk of future problems.

CONCLUDING REMARKS AND CALL TO ACTION

Milk production per cow and NMBs were not correlated, suggesting that there are opportunities for reducing NMBs without a negative impact on milk production per cow. The 75% benchmark NMB fell at 105 lbs N/acre, 12 lbs P/acre, and 37 lbs K/acre for the 102 farms, and at 146 lbs N/acre, 15 lbs P/acre, and 58 lbs K/acre for the medium and large farms. Improvements in feasible farm benchmark goals can be obtained when more farms participate in the assessment. The ultimate goal is to explore feasible benchmarks NMBs for NY dairy farms and stimulate those operating above the benchmarks to evaluate opportunities for improvement. Farms operating below the benchmarks may choose to make changes as well. This will require continued annual

assessments. We urge farmers, crop consultants and nutritionists to get involved and contribute to the statewide dataset.

CONTACT INFORMATION

To get more information on assessment of NMBs and participation in the statewide dataset, contact Quirine M. Ketterings, Nutrient Management Spear Program, Cornell University, Department of Animal Science, 323 Morrison Hall, Ithaca NY 14850. Input sheets for the assessment can be found at: http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html.

REFERENCES

Cela, S., Q.M. Ketterings, K.J. Czymmek, M. Soberon, and C. Rasmussen. 2014. Characterization of N, P, and K mass balances in dairy farms in New York State. In review.

Cerosaletti, P., and D. Dewing. 2008. What is precision feed management? Northeast 686 Dairy Bus., 687 Dec. 2008, Page 15.

Ketterings, Q.M., K.J. Czymmek, P. Ristow, C. Rasmussen, and S. Swink. 2011. State, regional and farm-scale nutrient balances: tools for enhanced efficiency of whole farm nutrient use. 73rd Cornell Nutrition Conference for Feed Manufacturers October 18-20, 2011. Syracuse, NY. Proceedings pages 180-189.

Ketterings, Q.M., S.N. Swink, G. Godwin, K.J. Czymmek, and G.L. Albrecht. 2005. Maize yield and quality response to starter phosphorus fertilizer in high phosphorus soils in New York. J. Food Agric. Environ. 3:237‐242.

NASS (National Agricultural Statistics Service). 2010. Overview of the United States Dairy Industry.

NRC (National Research Council). 2001. Nutrient requirements of dairy cattle. 7rh revised ed. 779 National Academy Press, Washington, DC.

Soberon, M.A., Q.M. Ketterings, C.N. Rasmussen, and K.J. Czymmek. 2013. Whole Farm Nutrient Balance Calculator for New York Dairy Farms. Nat. Sci. Educ. 42:57–67.

USDA-USEPA. 1999. Unified national strategy for animal feeding operations. USDA-USEPA, Washington, DC.