Mass Nutrient Balances - a Management Tool for New York Dairy and Livestock Farms

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Introduction

Animal agriculture has been implicated in degradation of water (USEPA, 1996; Cook, 1998) and air quality (NRC, 2003) and is pressured by public opinion, litigation and state and federal regulation to reduce nutrient losses from farmsteads and fields. To date, state and federal regulation of nutrient management has focused on reducing nutrient loss to surface and ground water by managing applications of purchased fertilizer and manure already on the farm. However, when the amount of nutrients entering a field exceeds nutrient removal with harvest, or when applications are timed such that nutrient uptake is limited, this imbalance could lead to: (1) direct losses to the environment; and/or (2) increases in soil nutrient reserves in the soil, increasing the risk for future environmental losses (Klausner, 1997). Previous mass nutrient balance studies indicated that more than two-thirds of the nitrogen (N), phosphorus (P) and potassium (K) imported on many Northeast dairy farms each year as purchased feed and fertilizer were not exported off of the farm in saleable products (Klausner, 1993; Klausner et al., 1998). In the case of P, this imbalance will lead to soil enrichment when manure is applied beyond crop removal It is not surprising that an assessment of soil test P levels for agricultural soils in New York using agricultural samples submitted to the Cornell Nutrient Analysis Laboratory (www.css.cornell.edu/soiltest) showed that in the past 20 years, the proportion of samples that test high or very high in P increased from 26% to 47% (Ketterings et al., 2005). Unfortunately, current nutrient management efforts do little to reduce importation and subsequent loading of nutrients onto farms and watersheds.

Achievement of a balance between the nutrient inputs and managed outputs is key to minimizing the nutrient related environmental risk associated with livestock production (Koelsch and Lesoing, 1999). Numerous studies have found that nutrient source reduction, increased recycling of farm nutrients and increasing nutrient use efficiency, can decrease farm nutrient losses and maintain or increase farm profitability (Klausner et al., 1998; Wang et al., 2000; Cerosaletti et al., 2003; Spears et al., 2003a; Spears et al., 2003b; Tylutki et al., 2004), so addressing nutrient imbalances could be a win-win situation.

Mass nutrient balances (MNB) provide a useful and achievable metric for assessing nutrient loadings and potential losses on farms. A mass nutrient balance is calculated by summing the nutrients in imported feeds, fertilizers, animals, legume nitrogen fixation and purchased bedding for a farm and subtracting exported nutrients in milk, meat, crops, and manure.

The Dutch MINAS system taxed N and P mass nutrient balances beyond a level established by the government. MINAS effectively reduced nutrient balances with less economic impact than more prescriptive regulations used previously (Ondersteijn et al., 2002). When the Dutch mass balance tool (Nutrient Management Yardstick) was used by producers in Minnesota and Wisconsin, extension educators found it a simple and effective way to initiate discussion about topics that impact nutrient management (Van Miltenburg and Green, 1997). Such efforts suggest that mass nutrient balances can be indicators of potential nutrient losses and heighten producer awareness of nutrient loading. Having a clear understanding of the imbalances between farm nutrient imports and exports and the causes of the imbalance is necessary for the development of long-term solutions and quantification of their impact on the environment.

In the fall of 2004 we started a project to: (1) quantify current mass balances on a large number of New York dairy and other livestock farms; (2) investigate and quantify the relationships between nutrient imbalances, farm business characteristics, farm location, crop rotation, yields, and animal density across a wide range of farms; and (3) communicate the findings to producers and their advisors to stimulate discussion and achieve realistic reductions in nutrient imbalance over time. To date, 38 New York State dairy and beef farms participated in this project. This paper presents a description of the data collection procedures and provides an initial assessment of a variety of mass nutrient balance parameters. ***This assessment is preliminary as the dataset is still relatively small***. More farms will be included with multiple years per farm over the next 2 years so that we can identify opportunities and quantify the impact of implementation of best management practices on nutrient losses and farm profitability.

Materials and Methods

Mass Nutrient Balance Software

A data collection questionnaire was developed to collect N, P and K farm import and export data (Table 1). An MS Excel© spreadsheet, "Mass Nutrient Balance (v.2)" (http://nmsp.css.cornell.edu/projects/massbalance.asp), was developed to accumulate and analyze the mass balance data. This spreadsheet was based on earlier work by Klausner (1997). The spreadsheet was modified to collect and analyze additional farm data such as animal units, crop and tillable pasture acres and quantity of farm produced grains and forages. Equations in the spreadsheet were updated to reflect new research on animal body nutrient composition.

Table 1: Mass nutrient balance data collected.

Primary Category	Secondary Category	Data Collected
Farm characteristics	Farm contact information Acres tillable crop and pasture Balance year Average number of animals	Name, address, phone, email Number of acres Year Group, number, weight
Farm produced feed	Item	Tons/year, %DM, % grain Beginning year inventory Ending year inventory
Imports	Feeds (purchased)	Tons/yr, %DM, % grain Crude protein, P and K (%DM) Beginning year inventory (tons) Ending year inventory (tons)
	Fertilizer	Tons, %N, $\%P_2O_5$, $\%K_2O$ Comment
	Animals (purchased)	Number, weight (lbs) Comment
	N Fixation-Legume Crops, Pasture	Legume (% and total acres) %DM, yield (tons/acre) Crude protein (% DM)
	Bedding and miscellaneous	Tons/year N, P, and K (%DM)
Exports	Milk	lbs/year, milk protein (%)
	Animals (sold)	Number, weight (lbs)
	Crops (sold)	Tons/year, %DM Crude protein, P and K (%DM)
	Other (sold)	Tons/year, % DM, N, P and K (%DM)

The questionnaire and spreadsheet requested data in the format and units most accessible to the producer. The spreadsheet converted data to tons of N, P and K on a dry matter basis. Adjustments for annual changes in inventory were incorporated into the assessment. The nutrient value of dairy and beef cattle purchased and sold was based on total body composition (VanAmburgh, personal communication). Nitrogen imported from N fixation was calculated from the percent legume in the stand, total dry matter yield and crude protein content (Heichel, 1986). Phosphorus and potassium content of milk sales was estimated from Wong et al. (1999). Milk protein is entered as it is reported to producers ("true protein") and converted to N according to Fox et al. (2003).

Data Collection

Pilot study participants were identified and contacted by university personnel, Cornell Cooperative Extension (CCE) educators and Soil and Water Conservation District (SWCD) employees. Caroline Rasmussen and/or CCE and SWCD staff conducted on-farm interviews with producers to collect the data. An initial farm assessment was provided to the producer at the time of data collection or shortly afterwards. An example of the initial farm mass nutrient balance assessment is in Appendix 1. A follow-up assessment of how the farm compared to others included in the project was sent to all participants at the end of the initial data collection period.

The time required for data collection and primary farm assessments varied from 45 minutes to 5 hours. Farm financial records and crop and dairy production records were used to provide the necessary data. In many cases additional information was provided by nutritional consultants and feed and fertilizer company representatives. For materials with unknown nutrient contents, such as newspaper and cardboard bedding, samples were collected at the farm and analyzed by the Cornell Nutrient Analysis Laboratory.

Thirteen of the 18 farms were located in the Upper Susquehanna Basin (South-central New York), 11 in Northern New York, 9 in Central New York and 5 in the Cannonsville Reservoir Watershed (Southeast New York). The geographic distribution of the pilot study was dictated by producer interest and funding. Mass balances were compiled for a calendar year, January to December. Six mass nutrient balances contained 2003 data while the remaining farms worked with 2004 data.

Feedback to Producers

At the end of the pilot study data collection period, a comparative farm analysis was sent to all participating producers, CCE educators and SWCD staff. The purpose of the comparative analysis was to allow producers to compare their MNB performance to other farms and highlight areas requiring management attention. The report was customized for each individual participating farm and included the following tables and figures:

- Table 1. Summary of mass nutrient balance results.
- Table 2. Selected farm characteristics and N balance factors for farms with <75 lbs/acre N remaining, 75 to 125 lbs/acre, and >125 lbs/acre N remaining (three groups). This table lists the participating farm's data in the first column and data for all farms sorted into the three groups based on the lbs of N remaining per acre.
- Table 3. Selected farm characteristics and P balance factors for farms with <7 lbs/acre P remaining, 7 to 14 lbs/acre, and >14 lbs/acre P remaining (three

groups). This table lists the participating farm's data in the first column and data for all farms sorted into the three groups based on the lbs of P remaining per acre.

- Table 4. Selected farm characteristics and K balance factors for farms with <15 lbs/acre P remaining, 15 to 45 lbs/acre, and >45 lbs/acre K remaining (three groups). This table lists the participating farm's data in the first column and data for all farms sorted into the three groups based on the lbs of K remaining per acre.
- Figure 1. N remaining in terms of total tons and lbs/acre. This scatter chart shows N remaining lbs/acre and tons for each farm ranked by farm size (total animal units). The data points for the individual farm are highlighted.
- Figure 2. P remaining in terms of total tons and lbs/acre. This scatter chart shows P remaining lbs/acre and tons for each farm ranked by farm size (total animal units). The data points for the individual farm are highlighted.
- Figure 3. K remaining in terms of total tons and lbs/acre. This figure shows K remaining lbs/acre and tons for each farm ranked by farm size (total animal units). The data points for the individual farm are highlighted.
- Figure 4. Total N exports and imports (lbs/animal unit). This figure shows exports and imports per animal unit for each farm ranked by farm size (total animal units). The data points for the individual farm are highlighted.
- Figure 5. Total P exports and imports (lbs/animal unit). This figure shows exports and imports per animal unit for each farm ranked by farm size (total animal units). The data points for the individual farm are highlighted.
- Figure 6. Total K exports and imports (lbs/animal unit). This figure shows exports and imports per animal unit for each farm ranked by farm size (total animal units). The data points for the individual farm are highlighted.

Extension meetings were held to discuss results with the producers and their advisors.

Results and Discussion

General Farm Characteristics

The 38 farms varied in size from 53 to 2,698 animal units (au=1,000 lbs live weight), representing animal densities of 0.15 to 1.42 animal units per acre. Livestock farms included 2 beef cow calf enterprises, 2 farms with beef cow-calf and dairy enterprises and 34 farms with dairy enterprises. On the dairy farms, milk production ranged from about 800 to 20,000 lbs of milk per acre and from 11,000 to 27,000 lbs of milk per cow per year. One farm was a certified organic farm. Two of the dairy farms had colored breeds (e.g. Jersey, Brown Swiss, etc.) and the remainder had Holsteins. Crop and tillable pasture acres ranged from 140 to 2700 acres. Eighteen of the farms sold crops off the farm. The percentage of purchased feeds, as a percentage of all livestock feed on a dry matter basis, ranged from 1% to 67%. This metric was available for all farms except two. A summary of general farm characteristics is presented in Table 2.

Table 2. Selected farm characteristics, mean, median, minimum and maximum for thirty-eight New York dairy and beef farms, 2003 and 2004.

Selected farm characteristics	Mean	Median	Minimum	Maximum
Animal units	522	241	53	2699
Animal density	0.72	0.73	0.15	1.42
Tillable crop and pasture (acres)	635	342	140	2700
Legume crop (%)[1]	30	30	0	75
Purchased feeds (% dry matter)[2]	30	30	1	67
Farm produced forage (%DM)[2]	92	100	65	100

[1] Percentage of total number of tillable crop and pasture acres.
[2] Purchased feed % and farm produced forage % values include 36 case study farms.

Nutrient Management Benchmarks

Financial and production benchmarks are universally defined and well understood within industries. Measures such as "percent equity", "return on investment", "yield/acre" and "rolling herd average" are used by farmers and their advisors to assess the farm business over time and compare performance to other like businesses. However, such benchmarks to measure a livestock farm's nutrient management performance do not currently exist. Farm mass nutrient balance analysis and associated farm specific measures can provide a useful and achievable metric for assessing nutrient loadings and potential losses from farms. Some of these potential benchmarks are discussed below.

Quantity of nutrients imported, exported and remaining

The most obvious MNB benchmarks are the quantities of nutrients imported and exported. These were categorized as feed, fertilizer, etc. in the initial farm analysis. The import and export totals and the "remaining" differences between imports and exports were reported as whole farm total tons as well as pounds per tillable crop and pasture acres on the initial on-farm analysis report (Appendix 1).

Selected N and P mass balance factors for the 38 case study farms are presented in Tables 3 and 4. Per farm, the total annual tons of N "remaining" ranged from -2.46 (more N exported than imported) to 218 tons. The total amount of P "remaining" per farm ranged from negative 0.34 to 17.24 tons for the year studied (Tables 3 and 4).

The amount of N per acre "remaining" ranged from -18 lbs N/acre to 296 lbs/acre. The P balance was -2 to 30 lbs P/acre. Although tons of nutrients imported, exported and remaining are a gross measure of nutrient imbalance, these measures may be more closely related to farm size than nutrient management performance or efficiency (Figure 1). Nutrient excess per acre may be more indicative of the risk of nutrient loss to the environment than an imbalance stated in total annual tons per farm. Although related, the total N and P remaining per farm and per crop acre are not highly correlated for these 38 farms (Figure 2).

Table 3. Selected farm nitrogen balance factors, mean, median, minimum and maximum for thirty-eight New York dairy and beef farms, 2003 and 2004.

Selected nitrogen balance factors	Mean	Median	Minimum	Maximum
N remaining (imports – exports)				
N remaining (tons)	44.18	18.06	-2.46	218.37
N remaining (lbs/acre)	108	99	-18	296
N remaining (%)[1]	58	66	-80	87
N imported as purchased feeds				
N feed import (tons)	40.51	13.06	0.09	208.71
N feed import (lbs/acre)	98	87	1	284
N imported as purchased fertilizer				
N fertilizer import (tons)	14.15	8.57	0.00	75.04
N fertilizer import (lbs/acre)	39	32	0	98
N imported as nitrogen fixation				
N fix import (tons)	9.46	4.18	0.00	65.40
N fixation (lbs/acre)	23	21	0	56
N exported as milk sales				
N milk sales (tons)	15.62	6.40	0.00	89.12
N milk sales (lbs/acre)	41	39	0	103
N exported as crop sales				
N crop sales (tons)	2.76	0.00	0.00	49.34
N crop sales (lbs/acre)	7	0	0	45

[1] Excludes a farm with - 2,050% N remaining.

Nutrients remaining per animal unit

The initial on-farm analysis reports the total remaining nutrients divided by farm average animal units. A figure showing total imports and exports per animal unit was part of the comparative farm analysis. The data points that represent the individual participant's results were highlighted in the copy they received. There was a greater farm-to-farm variation for N and P imports than for exports when nutrient flows were considered on a per animal unit basis suggesting that farms differ widely in the amount of nutrient inputs they use to generate similar levels of outputs. A better understanding of these differences in input/export ratios is needed to evaluate potential management opportunities.

Percent N and P remaining

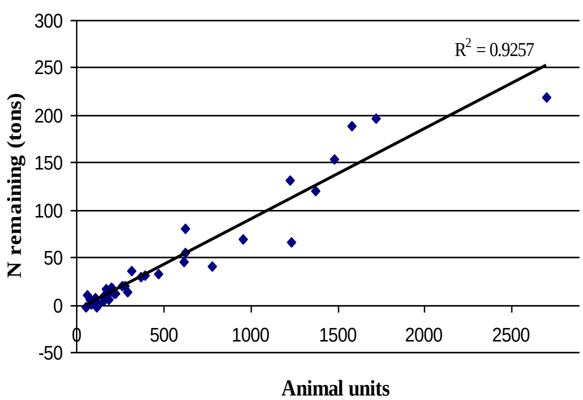
The percentage of nutrients imported that did not leave the farm through exports of milk, animals, crops, and/or manure ([imported–exported]/imported) is a commonly reported nutrient management metric (Klausner, 1993). The percent N and P remaining (Tables 3 and 4) contain very large ranges for the 38 farms (-80 to 87% and -53 to 81% for N and P, respectively). One farm, due to a very small quantity of nutrient imports, had -2,050% N and -1,133% P remaining. Because this was a unique situation, unrepresentative of the total dataset, this farm was not included when means were calculated.

Table 4. Selected farm phosphorus balance factors, mean, median, minimum and maximum for thirty-eight New York dairy and beef farms, 2003 and 2004.

Selected phosphorus balance factors	Mean	Median	Min	Max
P remaining (imports – exports)				
P remaining (tons)	4.08	1.66	-0.34	17.24
P remaining (lbs/acre)	11	10	-2	30
P remaining (%)[1]	51%	58%	-53%	81%
P imported as purchased feeds				
P feed import (tons)	5.09	2.22	0.02	26.45
P feed import (lbs/acre)	13	11	0	37
P imported as purchased fertilizer				
P fertilizer import (tons)	2.04	1.03	0.00	20.96
P fertilizer import (lbs/acre)	5	6	0	16
P exported as milk sales				
P milk sales (tons)	2.24	0.92	0.00	13.05
P milk sales (lbs/acre)	6	6	0	15
P exported as crop sales				
P crop sales (tons)	0.42	0.00	0.00	7.74
P crop sales (lbs/acre)	1	0	0	8

[1] Excludes a farm with -1,133% P remaining.

Farms with a large percentage of N and/or P remaining may not necessarily have the greatest excess per acre of cropland as this depends on the total acreage (Figure 3). The two data points at the extreme left of the graph are farms with a combination of farm enterprises that includes off-farm forage crop sales and relatively small animal numbers.



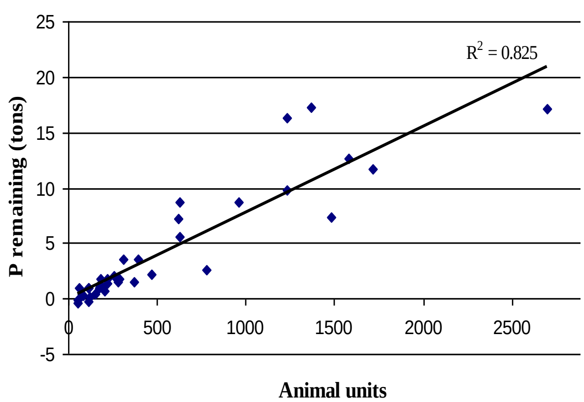


Figure 1: Tons of nitrogen and phosphorus remaining tons are positively related to farm size as measured in animal units; 1 animal unit equals 1,000 lbs live weight.

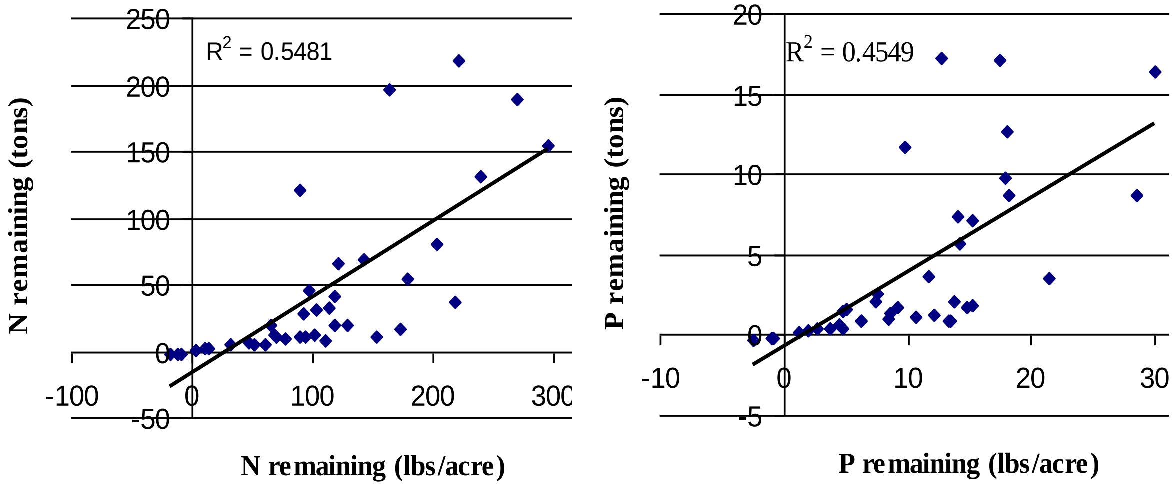


Figure 2: Total N and P remaining per farm and per crop acre are not highly correlated for 38 New York State beef and dairy farms.

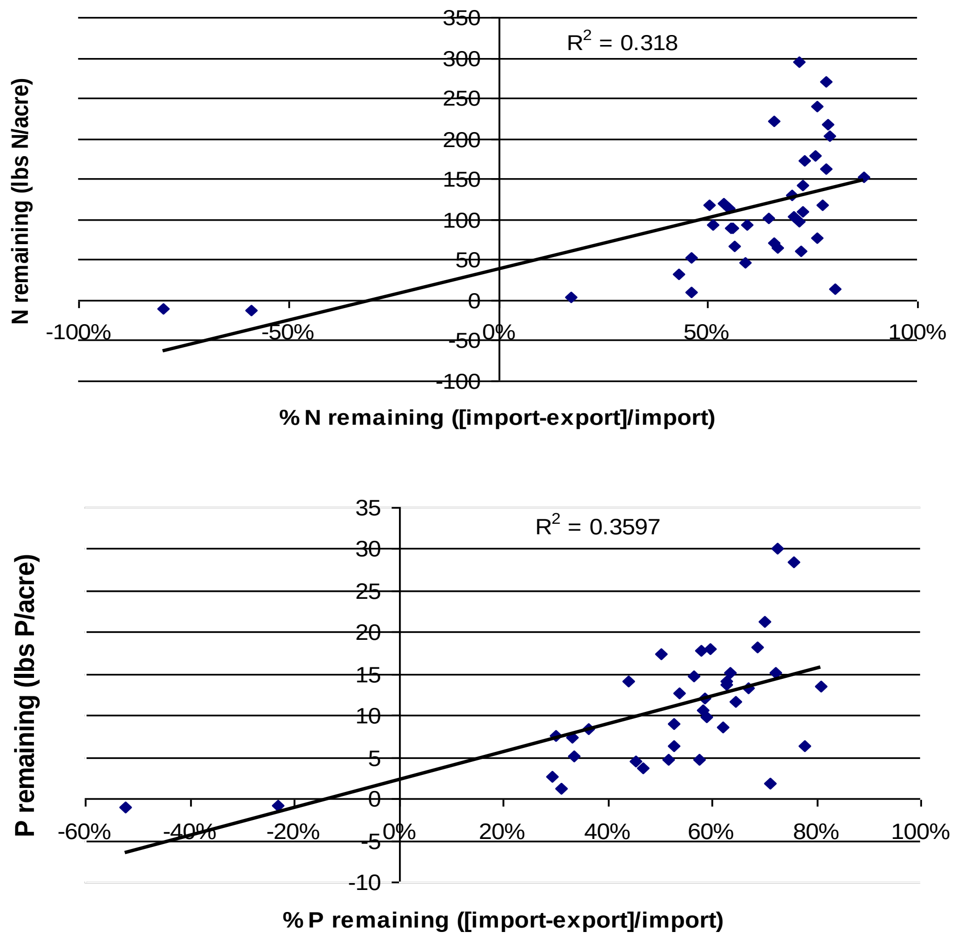


Figure 3: The percent remain nitrogen and phosphorus [(import-export)/import] is not closely related to the amount of nutrients remaining per acre.

Animal density

Animal density, measured as animal units (1,000 lbs live weight) divided by crop and tillable pasture acres, ranged from 0.15 to 1.42 (Table 2). There was a closer relationship between animal density and excess nutrients per acre than total animal units and excess nutrients per acre (Figure 4). Note that most of the farms in the data set are small farms; 24 farms had less than 200 mature cows.

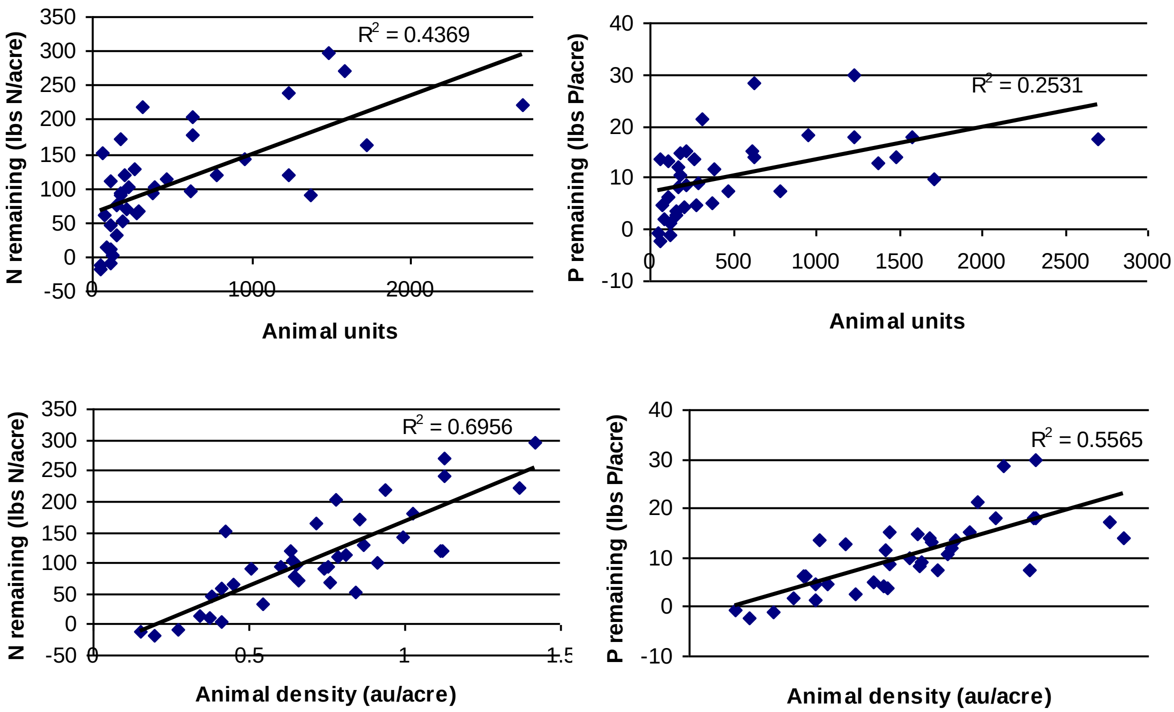


Figure 4: There is a closer relationship between animal density and excess nitrogen and phosphorus per acre than total animal units and excess nitrogen and phosphorus per acre.

Distribution of farm imports and exports

The distribution of farm imports and exports can provide useful farm management information. The contributions of feed, fertilizer, N fixation, purchased livestock and bedding to total nutrient imports were listed on the initial farm analysis. Producers were often surprised to learn that more than 20% of their N or P imports may be coming onto the farm as a single feedstuff source.

As observed by Klausner (1993, 1998) and Spears et al. (2003a) most of the N, P and K entered the farms as purchased feed (Table 5). Purchased fertilizer and N fixation were also major nutrient imports. Purchased animals and bedding had very little impact on nutrient imports. On average, most nutrients left the farm as milk. Animal and crop sales were also major forms of nutrient export with manure export being a very minor factor. Four of the farms exported most of their and N and P as crops sold, while two farms had 7 to 21% of their P and K exported as manure.

Table 5: The average distribution of nitrogen, phosphorus and potassium imports and exports for thirty-eight New York State dairy and beef farms (2003 and 2004 data).

	Nitrogen	Phosphorus	Potassium
Annual imports			
Feed	57%	68%	58%
Fertilizer	26%	29%	37%
N fixation	15%		
Animals	1%	1%	0%
Bedding	1%	2%	5%
Annual exports			
Milk	74%	69%	72%
Animals	11%	16%	5%
Crops	14%	15%	22%
Manure	1%	0%	2%

Crop sales

The dataset to date suggests that farms with a crop sales enterprise have lower nutrient balances. Table 6 contains selected farm and nutrient balance data for the 20 case study farms that did not sell any crops and 18 farms that did sell crops. Farms that exported crops averaged 715 acres of land (0.64 animal units per acre) while those that did not export crops averaged 562 acres (0.79 animal units per acre). The farms that sold crops had less excess N (tons and lbs/acre) and P (tons and lbs/acre) than farms that did not sell crops. Purchased feed as a percentage of all livestock feed averaged 24% for farms that sold crops and 36% for farms that did not. Farms with crop sale enterprises imported fewer nutrients as feed than those that did not sell crops. Consequently, farms with crop sales enterprises exported more crop nutrients off the farm (5.82 and 0.89 tons per farm for N and P, respectively).

Spears et al. (2003a) found that the proportion of P in the milk and meat per unit of P in feed (both purchased and farm produced) was the most important management factor in determining P balance on farms where crops were grown. Our initial results confirm that the percent purchased feed and forage may not be as critical to nutrient balance as the quality of the feed and associated feed management practices, such as storage, ration formulation, etc.

Table 6: Selected farm characteristics and farm nitrogen and phosphorus balance factors, mean and median for 18 farms with crop sales and 20 farms without crop sales.

	18 farms with crop sales		20 farms with no crop sales	
Selected farm characteristics	Mean	Median	Mean	Median
Animal units (au)	520	223	523	267
Animal density (au/acre)	0.64	0.66	0.79	0.78
Tillable crop and pasture (acres)	715	366	562	332
Purchased feed (%)[1]	24	25	36	36
Nutrients remaining (imports – exports)				
N remaining (tons)	40.26	11.85	47.72	25.23
N remaining (lbs/acre)	75	79	137	119
P remaining (tons)	3.51	1.52	4.60	2.70
P remaining (lbs/acre)	7	7	13	14
Nutrients imported as purchased feeds				
N feed import (tons)	35.04	12.62	45.43	17.78
N feed import (lbs/acre)	73	64	121	101
P feed import (tons)	4.67	2.22	5.47	2.31
P feed import (lbs/acre)	11	9	15	13
Nutrients imported as fertilizer				
N fertilizer import (tons)	16.40	6.27	12.12	10.18
N fertilizer import (lbs/acre)	34	28	42	34
P fertilizer import (tons)	2.43	0.92	1.69	1.31
P fertilizer import (lbs/acre)	5	5	6	6
Nutrients imported as N fixation				
N fixation (tons)	12.07	4.31	7.10	3.93
N fixation (lbs/acre)	24	24	22	20
Nutrients exported as milk sales				
N milk sales (tons)	15.73	6.40	15.52	7.31
N milk sales (lbs/acre)	37	38	44	44
P milk sales (tons)	2.24	0.92	2.25	1.05
P milk sales (lbs/acre)	5	6	6	6
Nutrients exported as crop sales				
N crop sales (tons)	5.82	2.09	0.00	0.00
N crop sales (lbs/acre)	16	11	0	0
P crop sales (tons)	0.89	0.31	0.00	0.00
P crop sales (lbs/acre)	2	2	0	0

[1] Mean and median values for farms with crop sales, "Purchased feed %" include 17 case study farms. Mean and median for farms with no crop sales, "Purchased feed %" include 19 case study farms.

Percent farm produced forage and feed

For the 36 farms that provided data on this benchmark, the % of total livestock feed dry matter that was purchased ranged from 1% to 65% (Table 2). The two beef cow-calf farms purchased less than 2%. Purchased feed and amount of N and P remaining per acre showed only weak correlations (Figure 5). The relationship between % purchased feed and tons of N and P remaining was similarly weak (r^2 values of less then 0.1).

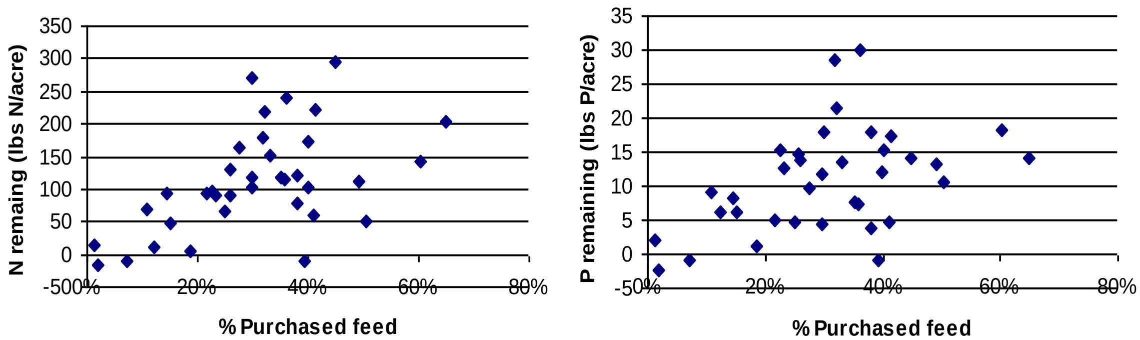


Figure 5: Purchased feed proportion and N and P remaining per acre for 36 dairy and beef farms in New York State (2003 and 2004 data).

On-farm production accounted for 67 to 100% of all forages fed. Of those farms reporting farm produced feed data, 21 farms produced all of their forage and 15 farms purchased between 1 and 33% of forage. It is difficult to draw conclusions from Table 7, which contains selected farm and nutrient balance averages for the farms that produced all farm forages and those that purchased some forages. Because there were such wide ranges in most of the measures in this table, it is difficult to draw conclusions when comparing the average values of the two datasets. Generally, the farms that purchased forages tended to be larger in total animal units and crop acres. The average animal density, and N and P remaining (lbs/acre) seemed higher for farms that purchased forage. However, when excesses in nutrients per acre were plotted against the percentage of farm produced forage, there did not seem to be a significant correlation (Figure 6).

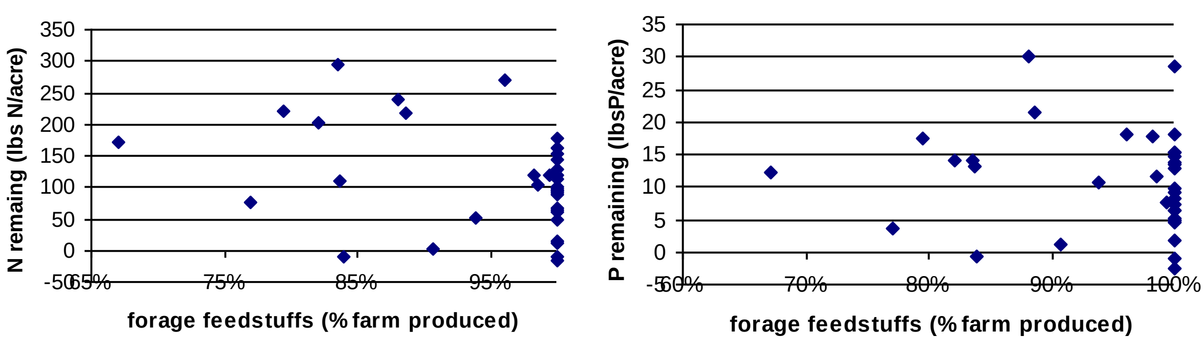


Figure 6: There does not seem to be significant correlation between % home-grown forage production and nitrogen and phosphorus imbalance, N and P on a per acre basis, for 36 dairy and beef farms in New York State (2003 and 2004 data).

Table 7: Selected farm characteristics and farm nitrogen and phosphorus balance factors, mean and median for 21 farms with all farm produced forage and 15 farms with some purchased forage.

	21 farms with 100% home-grown forage		15 farms with some purchased forage	
Selected farm characteristics	Mean	Median	Mean	Median
Animal units (au)	397	222	741	392
Animal density (au/acre)	0.61	0.63	0.89	0.86
Tillable crop and pasture (acres)	620	320	700	615
Purchased feed (%)	24	25	39	38
Nutrients remaining (imports–exports)				
N remaining (lbs/acre)	86	93	146	121
P remaining (lbs/acre)	9	8	13	13
Nutrients imported as purchased feeds				
N feed import (lbs/acre)	75	66	138	139
P feed import (lbs/acre)	11	9	17	17
Nutrients imported as fertilizer				
N fertilizer import (lbs/acre)	35	29	46	45
P fertilizer import (lbs/acre)	6	6	5	6
Nutrients imported as nitrogen fixation				
N fixation (lbs/acre)	19	14	27	27
Nutrients exported as milk sales				
N milk sales (lbs/acre)	32	35	53	52
P milk sales (lbs/acre)	5	5	8	7
Nutrients exported as crop sales				
N crop sales (lbs/acre)	9	4	5	0
P crop sales (lbs/acre)	1	0	1	0

Concluding Remarks and Future Work

In 1993, Klausner wrote that "*Mass nutrient balances are mere estimates of the nutrient status of farms and should be used as a tool to help with management decisions*." Farm mass nutrient balances can provide an achievable and useful tool for tracking the impact of management decisions on nutrient imports and exports. Mass nutrient balance measures, presented with associated farm characteristics, can serve as performance benchmarks which can be used to focus management attention on areas of concern.

In our study, the range for nutrients remaining (total per farm or per land unit) was remarkably large. These large ranges indicate that (1) low mass nutrient balances are achievable; (2) some farms are depleting their nutrient sources; and (3) individual farm resources and farm management practices have great impact on mass nutrient balances.

More collaborative work with farms and their advisors is needed to identify the mix of farm practices that could aid in economically and environmentally optimal nutrient use efficiencies on the farms. Developing benchmarks that producers can use to identify these practices will require an on-going effort.

In our pilot study, a university and/or a CCE or SWCD staff member visited the farm to collect the necessary data after providing the form to the producer via mail or email. Where possible, the analysis was entered into “Mass Nutrient Balance (v.2)”, the initial analysis printed out, and the results discussed, during the farm visit. This approach was very beneficial, as the producer could see the direct link between the data entered and the results of the balance assessment. Also, the analysis provided an excellent platform for discussion of farm management goals and nutrient management options.

A larger dataset is needed to investigate the impact of changes in management on whole farm balances and to derive management indicators that have major impacts on these balances (i.e. identify management options to reduce imbalances for long-term sustainability of the farms). Integrating farm financial data with the MNB analysis is essential. Discussing the MNB results with farmers, their advisors and other stakeholders and getting their feedback about the process will help create a the needed evaluation tool.

Additional farms will be included in 2005. In the pilot study we collected only one measure of farm land base, “tillable crop and pasture acres”. Saam et al. (2005) used animal density to estimate the risk of nutrient loss and found this was highly dependent on whether the calculation was based on total cropland, tilled cropland or land receiving manure. Determining what percentage of the cropland receives manure will provide a useful measure of the flexibility of the farm to handle nutrient loads. This will be included in future assessments. Data for the 2005 cropping year will be collected from a broader distribution of farm sizes, management systems and locations and over multiple years for the development of a robust dataset resulting in more accurate analysis.

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Appendix 1. Initial on-farm analysis (an example).

MASS BALANCE v. 2 OUTPUT Sample Farm 2004
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Category	N	P	K	N	P	K
Imports	-------- tons per year --------			------ lbs per acre per year ------		
Feed	208.71	26.45	94.99	212	27	96
Fertilizer	63.92	7.62	103.24	65	8	105
N Fixation (legumes)	49.77			51	-	-
Animals	0.22	0.05	0.02	0	0	0
Miscellaneous	8.56	0.11	1.45	9	0	1
Total Imports	331.18	34.22	199.70	336	35	203
Exports	-------- tons per year --------			------ lbs per acre per year ------		
Milk	89.12	13.05	24.68	90	13	25
Animals	8.84	2.13	0.61	9	2	1
Crops	5.02	0.73	2.34	5	1	2
Miscellaneous	9.82	1.16	8.01	10	1	8
Total Exports	112.80	17.08	35.65	115	17	36
Tons Remaining	218.37	17.15	164.05			
Lbs Remaining/acre	222	17	167			
Lbs Remaining/AU	162	13	122			
% Remaining	66%	50%	82%			

DISTRIBUTION OF IMPORTED NUTRIENTS

	N	P	K
Source	------------------ % --------------------		
Feed	63	77	48
Fertilizer	19	22	52
N Fixation	15		
Animals	0	0	0
Miscellaneous	3	0	1

DISTRIBUTION OF EXPORTED NUTRIENTS

	N	P	K
Source	------------------ % --------------------		
Milk	79	76	69
Animals	8	12	2
Crops	4	4	7
Miscellaneous	9	7	22

DIAGNOSTICS

Animal Density (au/acre)	1.37
Milk Production (lbs/acre)	17,899
Purchased Feed (% of total feed dry matter)	41%
Farm Produced Forage (% of total forage dry matter)	79%

Fertilizer Value: 17 lbs P remaining/acre = 40 lbs P2O5/acre
167 lbs K remaining/acre = 201 lbs K2O/acre

Itemized N, P, K imports			
Import % from purchased feed	% N	% P	% K
High Mix	28%	21%	16%
Haylage 1st	2%	2%	2%
Corn Meal	2%	4%	1%
Soy Plus	2%	2%	1%
Haylage	14%	19%	22%
Dry Shell Corn	7%	17%	7%
Canola	9%	15%	1%
Import % from purchased fertilizers	% N	% P	% K
32-0-0	14%		
18-13-0	5%	14%	
0-0-60			48%
0-0-65			1%
7-28-28	0%	6%	2%
Import % from legume fixation	% N	% P	% K
Alfalfa	15%		
Import % from purchased animals	% N	% P	% K
calves	0%	0%	0%
heifers	0%	0%	0%
cows	0%	0%	0%
Import % from miscellaneous imports	% N	% P	% K
Paper Pulp	2%		
Green Sawdust	0%		
		0%	
	100%	100%	100%

Distribution of exported N,P,K			
Export % from milk sales	% N	% P	% K
	79%	76%	69%
Export % from crop sales	% N	% P	% K
Corn Silage	1%	1%	2%
TMR	3%	3%	4%
Hay	0%	0%	0%
Export % from animal sales	% N	% P	% K
calves	1%	1%	0%
cull cows	7%	11%	1%
bulls	0%	1%	0%
Export % from miscellaneous exports	% N	% P	% K
liquid manure	2%	2%	9%
heifer solid manure	1%	0%	3%
calf manure	2%	2%	5%
prefresh bedded pen	3%	2%	5%