ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Integrating Record Keeping with Whole Farm Nutrient Mass Balance: A Case Study

Jack van Almelo[1], Quirine M. Ketterings[2] & Sebastian Cela[2]

[1] Agricultural Consulting Services Inc., Ithaca, NY, USA

[2] Nutrient Management Spear Program, Cornell University, Ithaca, NY, USA

Correspondence: Quirine M. Ketterings, Nutrient Management Spear Program, Department of Animal Science, Cornell University, Ithaca, NY 14853, USA. Tel: 1-607-255-3061. E-mail: qmk2@cornell.edu

Received: April 3, 2016 Accepted: May 9, 2016 Online Published: May 15, 2016

doi:10.5539/jas.v8n6p22 URL: http://dx.doi.org/10.5539/jas.v8n6p22

Abstract

A whole farm nutrient mass balance (NMB) assessment gathers information on farm characteristics, nutrient imports and exports; provides indicators of farm production efficiency, potential environmental footprint; and helps identify opportunities for management improvements. Simplifying the data collection process facilitates wider NMB adoption. Our objectives were to: (1) integrate the NMB assessment into "Fields and Crops Manager", an on-farm crop management program; (2) evaluate existing, on-farm, software packages for their ability to supply data for the assessment; and (3) document farmer response prior to and after conducting an NMB with the integrated record system. Software evaluated included the DRMS DHI-202 Herd Summary report, Centerpoint Accounting, PCDART and Quickbooks Accounting software, FeedWatch and TMR Tracker feeding systems, and Dairy Comp 305 herd management software. Six dairy farmers participated in the evaluation. The NMB results were presented and discussed in group meetings with each farmer. The records in the Fields and Crops Manager program and other software packages were not complete enough to allow for automated transfer of data into the NMB tool. Instead, the new NMB function within Fields and Crops Manager was used as a platform to enter, calculate, and store the NMB. Despite initial hesitation about participating, all six farmers concluded that (1) the NMB assessment was worth the data collection effort; and (2) meetings with farm advisors (crop planner, nutritionist) greatly improved the value of the NMB. The biggest obstacle to calculating NMBs can be overcome if purchases are recorded in the farm's accounting software as invoices are entered.

Keywords: dairy farms, management, mass nutrient balance, nutrients, profitability

1. Introduction

Dairy farmers access information to make tactical decisions about herd, crop, soil, and business management on a daily basis. The information sources used to make these decisions tend to focus on only one of the farm's many different enterprises at a time (ration software, crop nutrient software, etc.). A Nutrient Mass Balance (NMB) assessment can help farmers make strategic decisions at the whole farm level, aiding in evaluation of management alternatives that address the farm's long-term nutrient sustainability and farm profitability (Soberon et al., 2013, 2015; Cela et al., 2014, 2015, 2016; Daatselaar et al., 2015). An NMB assessment takes into account the difference between nutrients imported onto the farm (via feed, fertilizer, animals, bedding, and manure), and nutrients exported (as animal products, crops, and manure) as documented by Soberon et al. (2013). The difference (imports minus exports) divided by the total tillable hectares is an indicator of the potential environmental footprint of the farm, while a division by total milk production reflects the farm's nutrient use efficiency.

An evaluation of the nitrogen (N), phosphorus (P), and potassium (K) balances of 102 NY dairy farms (Cela et al., 2014) resulted in the establishment of "feasible" NMBs for high-producing NY dairies: $\leq$ 118 kg of N/ha (excluding N_2 fixation) $\leq$ 13 kg of P/ha, and $\leq$ 41 kg K/ha based on the NMB at or below which 75% of the farms operated in the study. Cela et al. (2014) also reported feasible balances per Mg of milk at $\leq$ 8.8 kg of N/Mg, $\leq$ 1.1 kg of P/Mg, and $\leq$ 3.0 kg K/Mg, based on what 50% of the farms achieved in that database. Farms were classified as operating in the "optimum operational zone" when meeting (i.e. not exceeding) the feasible NMBs per ha *and* per unit milk produced (Cela et al., 2014).

Evaluation of NMB trends over 4 to 6 years for 54 NY dairy farms showed that 63 to 76% of the NMB decreased over time (depending on the nutrient), and > 50% of the farms did so while increasing milk production per cow (Soberon et al., 2015). Farms were able to improve their NMB by making changes in feed and fertilizer imports, animal density, percentage of farm-produced feed and nutrients, and feed nutrient use efficiency, highlighting the opportunities of an adaptive management approach that includes NMB assessments. In a follow-up study with a set of 27 farms with 6 to 10 years of data, Cela et al. (2015) concluded that the percentage of farms with N and P balances in the "optimal operational zone" increased from 22-26% over the first 2 yr (depending on the nutrient) to 43-56% over the last 2 yr of assessments. Similar improvements were shown in longer-term trends for both NY and the Upper Susquehanna Watershed (Cela et al., 2016). Thus, farmers who participated in the annual NMB assessment for multiple years in a row tended to make changes that improved balances over time.

Work to date has shown that NMB assessments can help a farmer implement an adaptive management approach, where improvements in resource management are obtained in a systematic way that includes experimentation, evaluation, and monitoring over time, while still complying with the 590 Natural Resources Conservation Service (NRCS) nutrient management standard (NRCS, 2006; Ketterings et al., 2014). However, the time required to conduct a NMB can deter farmers from participating. The information necessary to complete the NMB requires the gathering of information from multiple sources, including record systems already being used on farms. Where those records systems are software based, there is opportunity for electronic collection and transfer of the necessary information into a NMB calculator. Identification of records systems that can be linked to a NMB assessment tool can streamline the data collection and entry process, and aid in data quality assessment, possibly reducing a barrier to adoption of NMB assessment statewide.

Our objectives were to: (1) integrate the NMB assessment into Fields and Crops Manager, an on-farm crop management program; (2) evaluate existing, on-farm, software packages for their ability to supply the necessary data for the NMB assessment; and (3) document farmer attitude towards NMB assessment prior to and after conducting an NMB with the integrated Fields and Crops Manager system.

2. Method

The information necessary to complete the balance for a farm can be divided into three categories: (1) Imports: feed, fertilizer, animals, manure, and bedding; (2) Exports: milk, animal, crop, manure; and (3) Farm production characteristics and practices. Eight on-farm software management systems were evaluated for their potential to supply data for the NMB assessment (Table 1). Six of the eight packages were used on the case study farms in this project. The exceptions were PCDART and Quickbooks Accounting, two software packages that were added to the evaluation because of their overall prevalence on NY farms.

Table 1. Common on-farm software package used by New York dairy farmers to make tactical decisions and store/collect/track/generate information that is of essence for whole farm nutrient mass balance (NBM) assessment.

Information source	Category	Reliability as a source	Originator
Fields & Crops Manager	Acres, fertilizer, manure exports, yields	Inconsistent	Agrinetix
Dairy Comp 305	Animal numbers (live and sold, young and mature)	Reliable	Valley Ag Software
PCDART	Animal numbers (live and sold, young and mature)	Reliable	DRMS Raleigh
DHI Records Summaries	Animal numbers (live and sold, young and mature)	Reliable*	DRMS Raleigh
Feed Watch	Purchased feeds fed	Must qualify**	Valley Ag Software
TMR Tracker	Purchased feeds fed	Must qualify**	Digi-star International
Center Point Accounting	Purchased and sold feeds, fertilizers and sold livestock	Reliable***	Red Wing Accounting
QuickBooks Accounting	Purchased and sold feeds, fertilizers and sold livestock	Reliable***	Intuit

Note. There are four different DHI processing Centers used in the Northeast by the approximately 50% of farms that use DHI records. The adult animal information, including purchased and sold is highly reliable. Heifer information should be qualified. This information is normally redundant with that kept on the farms cow management software. Feed Watch and TMR Tracker control the diets fed on farms by measuring all of the feed as rations are mixed. They will not total the feed fed on days when the system was not functioning. Fortunately, due to the critical nature of the feeding system they are rarely off-line – but this should be verified. Also the totals will not include storage and loading losses. The accounting software is only reliable if the farm records the quantities of each product purchased as they record each invoice. Most accounting systems allow for optionally creating a database of items purchased and sold that can then be quantified as accounting transactions are recorded.

The algorithms used in the Cornell whole farm NMB calculator (Soberon et al., 2013) were used to build a NMB module in Fields & Crops Manager, a program designed to keep field crop records. Alpha and beta testing of the NMB tool functionality was done collaboratively with Cornell University staff, using previous years of NMB records from one of the case study farms. Once beta testing revealed identical output from both the Cornell NMB calculator (Soberon et al., 2013) and the integrated Fields & Crops Manager program, data linkages were identified that could transfer NMB information from existing on-farm software into the NMB module in the integrated Fields & Crops Manager program (Table 2).

Table 2. Characteristics of six New York (NY) case study dairy farms that participated in the whole farm nutrient mass balance assessment program, and the interquartile range (quartiles 1 to 3) (IQR) of the same characteristics for 102 NY dairy farms, as reported by Cela et al. (2014)

	F1	F2	F3	F4	F5	F6	IQR of 102 NY dairies	High likelihood of exceeding feasible balances if
Farm Size								
Mature cows	800	1050	526	539	1829	1200	63 to 218	-
Animal units (AU)	1704	2322	1164	935	3536	2201	111 to 393	-
Tillable acres (ha)	1590	1020	488	326	1240	592	92 to 275	-
Herd management								
Milk per cow per year (kg)	10633	11205	12123	11667	11835	10781	7767 to 10043	< 9000
Homegrown feed (% DM)	88	69	67	67	62	57	67 to 84	< 62
Homegrown forage (%)	80	69	67	67	60	57	64 to 78	-
Homegrown grain (%)	8	0	0	0	3	0	0 to 6	-
Feed (Mg DM/AU)	8.2	5.9	6.1	6.3	5.3	6.5	5.0 to 7.6	-
Crop management								
Land in legumes (%)	25	40	62	48	45	45	16 to 72	-
Acres receiving manure (%)	51	85	94	74	54	82	45 to 87	-
Overall yield (Mg DM/ha)	7.8	9.6	9.0	12.1	13.0	13.9	5.4 to 10.5	< 8.3
Density								
Animal density (AU/ha)	1.1	2.3	2.4	2.9	2.9	3.7	1.1 to 2.2	> 2.4
Milk sold (kg/ha)	5351	11537	13055	19302	17452	21836	4689 to 10339	> 13000

Note. One animal unit equals 454 kg of life weight.

Ten farmers who use Fields & Crops Manager were approached to participate in the study. The farms were concentrated feeding operations (CAFOs), selected because of their familiarity with and use of software programs to make farm management decisions (including Fields & Crops Manager). Candidates were contacted by telephone, the project was explained to them, and they were invited to participate. If the farmer agreed to participate, a plan for collection of the necessary data was created, and the farmer was emailed data collection forms (data survey). Of the ten farmers that were approached, six agreed to participate. The two most predominant reasons for not participating were lack of time to collect the data and uncertainty about the benefits of participation in the project. In addition, farmers expressed concerns about the accuracy of their records and voiced concerns about confidentiality of information. For one of the farms, the son of the farmer, conducted the NMB as an assignment for a capstone course on whole farm nutrient management taught at Cornell University

(Albrecht et al., 2006).

The six farms included two medium-sized (between 300 and 700 cows) and four large CAFOs with more than 700 milking cows (Table 2). All six case study farms are family farms that have grown in size over multiple generations. Managing cows is the farmers' first priority; the cropping enterprise is maintained to provide feed for the cows. Across all six farms, the herds averaged 991 milking cows, the tillable land averaged 876 ha, and milk sales per year averaged 11,374 kg yr^{-1}. Each farm's milk production per cow exceeded the 2012 New York state average of 9,829 kg cow^{-1} (USDA-NASS, 2014). Animal densities ranged from 1.1 to 3.7 animal units (AU) ha^{-1}. One of the farms greatly exceeded 2.4 AU ha^{-1}, the density beyond which the likelihood of a farm exceeding the feasible balances for NY as identified in Cela et al. (2014), is high. Two other farms were just above 2.4 AU ha^{-1} while the remaining three were lower than 2.4 AU ha^{-1}.

For all farms, the common rotation was 3-4 years of alfalfa (*Medicago sativa* L.) and grass mixtures followed by 3-4 years of corn (*Zea mays* L.) silage, although two of the farms included some wheat (*Triticum aestivum* L.) in the rotation. The tilled area per farm ranged from 326 to 1590 ha of which 51% to 94% received manure (Table 2). The percent homegrown forage in the diet ranged from 57 to 80% and two of the farms produced some homegrown gain as well (Table 2). The farm with the lowest animal density (1.1 AU/ha) and the highest percent of homegrown forage (88%) grew soybeans (*Glycine max* L.) and grain corn, selling some of the grain.

Each of the six farmers used cow management software on a daily basis. For five of the six farms, the farm managers had used Fields & Crops Manager software for at least two years, with actual years of experience with the software ranging from 2 to 6 years. The software was used to improve farm record keeping, particularly manure spreading records, rather than to manage cropping systems. Each farmer works with a certified nutrient management planner. Two of the farms emailed completed data entry forms for NMB assessment to the authors while the other four farms were visited to help complete the data collection forms. A project facilitator entered the data and completed the NMB in the integrated Fields & Crops Manager NMB module. Follow-up with farmers to clarify inputs was done primarily by email. Once completed, the data entry forms and data summaries were sent back to the farmer via email, with a request to review for accuracy. Issues identified by the farms at that time were corrected and balances re-run.

The finalized NMB assessment was emailed to the farmers, followed by in-person meetings of the authors and four of the farms, and team meetings via webinars for the two other farms. The feedback supplied to the farmers in advance of these meetings included the NMB result tables and figures that shows the farm's NMB compared to the feasible balances and optimal operational zone established by Cela et al. (2014). The farm teams present in the meetings included at a minimum the owner and one advisor, and for one farm included the owner, farm managers, the farm's crop consultant and nutrient management planner, and the nutritionist.

In August of 2015, after completion of all farm meetings, each farmer received a survey via US mail along with another copy of their farm's NMB inputs and results. The 15 questions survey asked farmers about their motivation to participate in this study, feedback on the results for their farm and NMB assessments in general, and motivation to conduct NMBs in future years. The survey was conducted by phone and answers were recorded and summarized.

3. Results and Discussion

3.1 Integration of the NMB Assessment into Fields and Crops Manager

The NMB was programmed into Fields & Crops Manager using Delphi version XE5 Object Pascal. The data were structured to create and save a balance by crop year. The data are stored in a table in a 2012 Microsoft SQL Server database which forms the database backbone for Fields & Crops Manager software. Fields & Crops Manager with the NMB module can be run via Remote Desktop allowing facilitator and farm manager to access the data at will.

Programming the NMB into the Fields and Crops Manager program was done with a development team of three people: a project manager, a development manager, and a developer. The project manager was experienced in implementing software on farms and served as the overall coordinator of the project while also beta testing and implementing the NMB assessment on the case study farms. The development manager served as the architect and technical resource, and the developer did the actual programing and alpha testing. It took 560 hours of development time to complete the programming, not counting beta testing and non-programming work.

Early in the beta testing phase it became clear that the software had to allow for flexibility in data entry for the NMB module, allowing for completion of data entry over time (i.e. saving of incomplete modules and revising of inputs as more accurate information was obtained). The software entry function required a format that allowed for entry of a farm's information as it became available, and for easy identification of missing data. To address this, a spreadsheet-like data entry interface was created with color coded cells. Cells with missing data were displayed in orange, and cells with suspect data (outside of expected ranges) were displayed in yellow. The interface allowed for addition and changing of information at will.

3.2 Evaluation of On-Farm Software Packages for Their Ability to Supply Data for an NMB Assessment

Basic farm information such as animal numbers and weights and hectares of cropland was the easiest to access. For all farms, the animal input data needed for the NMB assessment were obtained from Dairy Comp 305. Other programs commonly used in NY such as Scout and PCDART can also provide the necessary animal numbers. Because of the role of herd management software on the farm (ration and animal management focused), animal inventory information was typically complete and up-to-date. If a farmer does not use herd management software but has DHI information, animal numbers for milking cows will be reliable but young stock numbers and weights should be verified with the farm. Cropland acres were typically recorded in the farm's Comprehensive Nutrient Management Plan (CNMP).

The best source for quantity of purchased and sold feed was the farm's accounting software, assuming the farmer recorded total purchases (mass and nutrient composition) and sales as they entered invoices. Most accounting programs allow for tracking of quantities of material purchased and sold, but this is not required for financial accounting purposes and many farms do not use the feature, complicating data collection for the NMB assessment. An alternative to the use of the farm's accounting program to retrieve feed use is feed management programs such as Feed Watch or TMR Tracker. Three of the farms in this project included feed quantities in their accounting software while for the other three farms, the feed management programs were used. Caution is warranted when using a feed management system to retrieve quantities of feed because any day the system is not functioning, the quantities of feeds fed are not recorded. Additionally it is important to be aware that the feeding system only records what is loaded into the feed truck, and does not account for feed that was delivered to the farm but lost prior to feeding. Thus, the final accounting of total quantities fed will be lower than reality if the feeding system was operating less than 365 days in the year (J. Gloss, Dairy One Feed Watch, personal communication, 2015) and does not account for storage losses.

Due to inconsistencies in naming of feed sources, aligning feed composition data and feed quantities required the help of the operators and their nutritionists. As feed imports are typically a large driver for balances on NY dairy farms (Cela et al., 2014, 2015, 2016; Soberon et al., 2015), only farms that regularly record quantities of feed purchases or use a well-functioning feeding management system can efficiently conduct a NMB.

Fertilizer purchases were easy to retrieve from the farm's financial accounting system, because there are relatively few products involved at any given farm and the transactions are typically in narrow windows of time. Since all of our farms were regulated CAFO's, crop acres, manure application information (acres receiving manure), and manure exports (quantity and N, P and K content) were readily available from the farms' nutrient management plans. Except for total cropland, the information in the farm's crop management software was not reliable enough to be useful for NMB assessment. None of the participants recorded their cropping operations completely enough to generate reliable totals for fertilizer and manure inputs.

Bedding imports were difficult to determine as compositional data are typically absent but bedding is only a very small portion of the nutrient imports onto a farm and hence less important for NMB assessment (Cela et al., 2014). The only exception is when hay is purchased for bedding given its larger percentage and greater range in nutrient content.

Crop yield records were often not maintained, unless crops were sold off the farm and sales records were kept (this was the case for two of the six farms in the project). Use of yield monitoring equipment for silage harvest (corn and alfalfa/grass) will aid in collection of more accurate yield data in future years and allow for improvements in NMB assessment over time (Long et al., 2016).

3.3 Nutrient Mass Balances and Main Drivers

Farm NMBs per ha of cropland ranged from 44 to 299 kg N/ha, 2 to 22 kg P/ha and 10 to 59 kg K/ha while balances per Mg of milk produced ranged from 7.0 to 11.6 kg N/Mg, 0.2 to 1.3 kg P/Mg and 1.9 to 4.5 kg K/Mg (Table 3; Figure 1). Three of the case study farms had N and P balances that exceeded the suggested operational benchmarks (Table 3), and these farms exceeded the 2.4 AU/ha density (Table 2). These results are consistent with data reported by Cela et al. (2014) that showed that most of the farms exceeding 2.4 AU per hectare and not exporting manure exceeded the feasible balances set for NY dairies. Two of the three farms with $\leq$ 2.4 AU per ha (F1 and F3) had NMBs in the optimum operational zone for all three nutrients (Figure 1). The third farm (F2) with an animal density of 2.3 AU/ha was in the optimum operational zone for P but exceeded feasible balances for both N and K (Table 3; Figure 1). For N and K, balances per ha increased exponentially with the animal density, and this variable explained 92 and 75% of the variability in N and K balances, respectively. For P, animal density explained only 25% of the variability in P balance per ha, suggesting differences in P management among the farms, independent of animal density. Similarly, the percent homegrown forage was closely related to N and K balances per acre, while less related to P balance per acre. The relationships between percent homegrown forage and nutrient balances were documented in Soberon et al. (2015) and Cela et al. (2014, 2015) for a larger set of farms in NY. These trends for N and K are not surprising for farms with high nutrient densities, as beyond an animal density of 2.4 AU per hectare^{-1}, farms will need to import more feed to meet animal dietary needs.

Table 3. Whole farm nutrient balances for six New York dairies and farm diagnostics

	F1	F2	F3	F4	F5	F6	High likelihood of exceeding feasible balances if
	Nitrogen						
Balance (kg/ha)	44	133	91	156	173	299	> 118
Balance (kg/Mg milk)	8.2	11.6	7.0	8.1	9.9	13.7	> 8.8
Purchased feed N (kg/ha)	45	156	171	195	215	420	> 136
Fertilizer N (kg/ha)	30	47	29	74	48	13	> 44
Crop N exports (kg/ha)	3	0	0	0	4	0	< 1
Manure N exports (kg/ha)	0	0	35	0	0	43	< 1
Whole-farm N UE (%)	43	35	55	43	37	36	< 44
Feed N UE (milk, %)	17	21	19	24	21	16	< 20
Homegrown nutrients (% DM)	74	49	52	54	50	39	< 50
Crude protein in all feed (%)	12	14	15	15	18	18	> 17
CP in purchased feed N (%)	28	23	22	21	23	26	> 28
CP in homegrown feed (%)	10	10	12	12	14	26	< 11.8
	Phosphorus						
Balance (kg/ha)	6	8	2	21	22	13	> 13
Balance (kg/Mg milk)	1	0.7	0.2	1.1	1.3	0.6	> 1.1
Purchased feed P (kg/ha)	7	16	24	35	34	47	> 22
Fertilizer P (kg/ha)	3	2	0	8	6	2	7
Crop P exports (kg/ha)	0	0	0	0	1	0	< 1
Manure P exports (kg/ha)	0	0	7	0	0	13	< 1
Whole-farm P UE (%)	51	60	89	50	45	72	< 51
Feed P UE (milk, %)	16	24	23	26	26	23	< 25
Homegrown nutrients (% DM)	77	58	54	49	45	45	< 50
P in all feed (%)	0.34	0.33	0.35	0.38	0.40	0.35	> 0.50
P in purchased feed (%)	0.68	0.44	0.48	0.59	0.58	0.46	> 0.70
	Potassium						
Balance (kg/ha)	10	52	26	40	53	59	> 41
Balance (kg/Mg milk)	1.9	4.5	2.0	2.1	3.0	2.7	> 3.0
Purchased feed K (kg/ha)	12	30	44	64	52	96	> 43
Fertilizer K (kg/ha)	7	32	0	9	24	59	22
Crop K exports (kg/ha)	1	0	0	0	1	0	< 1
Manure K exports (kg/ha)	0	0	7	0	0	29	< 1
Whole-farm K UE (%)	50	37	61	44	36	52	< 39
Feed K UE (milk, %)	9	12	9	11	13	17	< 11
Homegrown nutrients (% DM)	88	79	81	77	76	53	-
K in all feed (%)	1.13	1.19	1.60	1.53	1.14	0.84	-
K in purchased feed (%)	1.19	0.08	0.91	1.09	0.90	0.93	-

Note. CP = crude protein; DM= dry matter; UE = use efficiency.

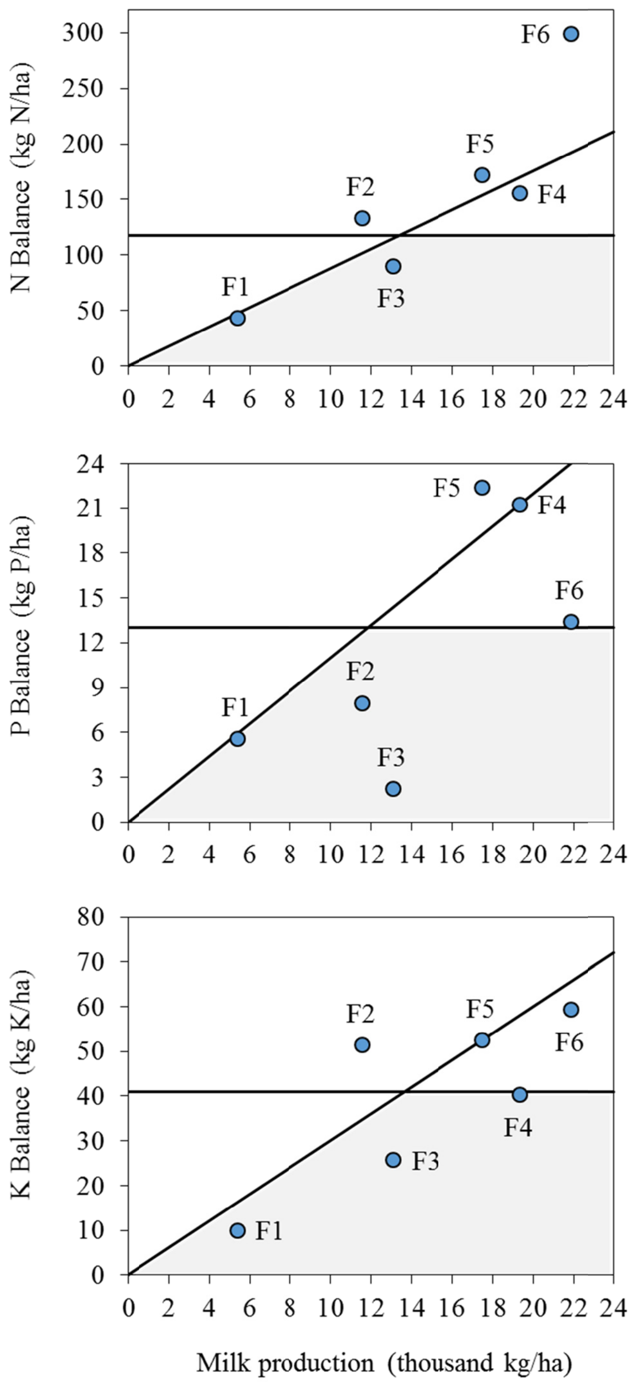

Figure 1. Nutrient mass balances (kg/ha) as a function of the milk production (kg/ha). The grey area indicates the optimal operational zone (i.e. feasible NMB per ha and per Mg of milk)

3.4 Farmer Responses Prior to and after Conducting an NMB with the Integrated System

Initial concerns by the farms about participating in the program could be divided into four categories: (1) time required to assemble information; (2) accuracy of the calculations and output; (3) the value of the results for the farm; and (4) confidentiality of the results.

3.4.1 Time Required

Participants reported a range of 2 to 10 hours to assemble their NMB input information prior to handing the information to the person that entered the data into the software (Table 4). The least amount of time, 2 to 3 hours, was needed when quantities of feed purchases and crop or manure sales were obtained from the farm's accounting software. The project facilitator spent on average another 9 hours interpreting farm information, reconciling nutrient analyses and entering data. Given these were the first nutrient balances the facilitator completed, it is reasonable to assume facilitator time will be lower for NMB assessments of farms in future years. All six case study farmers reinforced the importance of the facilitator to help complete the NMB and indicated that facilitators are important for future participation in NMB assessments.

3.4.2 Accuracy of the Calculations and Output

When the initial balances, based on input data supplied by the farm, were emailed with a request for review of the input data, farmers typically did not respond. A second review request was made during the farm meeting. This is when the farm began internalizing the workings of the balance, the calculations and implications. During the meeting with the project team and farm advisors, most of the farms identified some data entry issues, further emphasizing the importance of a review meeting with the farmer and farm advisors, especially for farmers who participate for the first time. Changes were made based on data review and additional farmer input. All six farmers felt confident in their farm's calculations as presented at the end of the assessment.

3.4.3 Value of the Results to the Farm

Five of the six farmers had low or no expectations about the benefits of a NMB assessment for their farm at the beginning of the project (Table 4). The sixth farmer had participated in NMB assessments in prior years and expected the balance to provide insight into their farm's nutrient use efficiency. Five of six farmers found it useful to compare their NMBs to the feasible benchmarks and optimum operational zone established in Cela et al. (2014) while one of the farmers replied he was "not sure" about the usefulness of the benchmarks (Table 4). Comparisons aided in interpreting the farm NMBs and identifying management changes that could improve farm nutrient use efficiencies over time. The survey results showed, however, that the farm meetings were essential to gaining a greater appreciation of the NMB assessment. In the meetings, farmers identified issues and asked many questions. The most dynamic meetings were those where one or more of the farm's consultants attended the meeting but all six farmers replied that the insights gained from the project were relevant to their farming operations, that the project made them think about changes in management that they could consider for the future:

"It makes you think of things in a different light or from a different perspective, than we normally look at things. Rather than think in either dollars and cents, or feed pounds, or feed pounds wasted, or what we are feeding, it makes you look at the bigger picture."

This is a good check on environmental stewardship and another way to find the proverbial "lowest stave in the barrel".

The surveys as well as comments during the meetings reinforced the expanded perspective farmers gained from reviewing their NMB with people knowledgeable about the NMB and operational benchmarks. Farmer survey responses reflected farmer interest in further evaluation of possible management changes following the assessment and team meetings (Table 4). Each of the six farmers indicated that they would like to repeat the assessment in future years. Some quotes from farmer feedback emphasized the value of the assessment and follow-up meeting:

"My N Balance surprised me, I didn't think it would be as high as it was. This reinforces that we must export more manure."

"I want to get a better handle on feed shrink and amounts of feed we move through the farm"

"I am thinking more about manure incorporation to capture more of the manure N and will begin looking into direct injection rather than using an airway."

"I have to spend some time considering how to lower the %N in my rations and continue pursuing manure application on growing crops."

All farmers responded that they were planning to make management changes after conducting the NMB and meeting with the team (Table 4). For example, F1 was planning to look more carefully at the ingredients that go into the cow mix while F2 said he is planning to improve data collection to get a better handle on feed shrinkage (storage). He also indicated he realized the value of accurate yield records and was interested in getting a yield monitor on the chopper. After doing a NMB, F3 said he needs to work on the feed efficiency and improve crop yields overall. F4 learned that they are having trouble building soil K and realized that his farm was losing more N than he had previously thought. He is now planning to incorporate more manure (direct injection) to capture more of the manure N and to reduce the need for inorganic N fertilizer. F5 said he need to lower the percentage of crude protein in the cow's ration. He is planning to apply more manure on growing crops, and wanted to look for options to increase both crops and milk production. F6 realized that he needed to get some manure back to the fields that supply the forage, even if these fields are not part of his own farm (manure exports). He is planning to evaluate ways to improve overall N and P use efficiency.

Table 4. Results of the survey conducted among six dairy farmers who collaborated in the whole farm nutrient mass balance study

	F1	F2	F3	F4	F5	F6
Would you have run the balance by yourself?	no	no	No	no	no	no
Any initial concerns about participating	none	time	time and energy	none	time	time and energy
Initial expectations	low	none	low, get feedback on fertilizer program	low	get insight	low, get feedback on fertilizer program
Time to gather data	8 hours	multiple hours	2 to 3 hours	10 hours	6 to 8 hours	2 to 3 hours
Comfortable with accuracy of inputs?	yes	yes	Yes	yes	yes	yes
Least accurate record?	purchased haylage	inventories, feed shrink	crop yields	manure incorporation	% dry matter on haylage	crop yields
Benefits of feasible NMBs and optimal operational zone	good	yes	very good	not sure	excellent	very good
Did you discuss your NMB with your:						
nutritionist	no	yes	Yes	yes	yes	yes
crop advisor	yes	yes	Yes	yes	yes	yes
Planning to make changes based on NMB results?	yes, check feeding program	yes, better records, yield monitor	yes, improve crop yields generally	yes, increase manure incorporation	yes, lower %N in ration, reduced tillage to increase soil health	yes, improve crop yields
Willingness to repeat NMB assessment in future years?	yes	yes	Yes	yes	yes	yes
Value of experience (out of 5):						
data collection itself	4	4	3	2	4	3
NMB reports	4	4	5	4.5	5	5
meeting as a group	5	5	5	4.5	3	5
NMB worth doing?	yes	yes	Yes	yes	yes	yes, but depends on the farmer

3.4.4 Confidentiality of the Results

Confidentiality of results was an issue identified at the start of the project by three of the six farms that participated. At the end of the process, this was no longer a concern. Three of the farms volunteered that the farm nutrient balances could become a positive communication tool for their farm and the dairy industry. As stated by one of the participants:

"I have the feeling that this can be part of our defense to the outside world to defend our existence. Does it have recognition by other conservation groups? That would be an imperative. Something like this could give us a better handle on what is happening over the TDML [total daily maximum load] *approach."*

4. Summary and Conclusion

The NMB was programmed into the Fields & Crops Manager program and used to calculate the balance for six case study farms. Accounting software that is managed to track quantities of purchases was the best source of data on farm imports and exports. Feed imports were the most complex information to collect because of the high frequency of purchases and large number of different products typically purchased. Where accounting software was not used to track quantities of purchases and sales, a feeding management system could provide totals of purchased feeds fed through the year providing the feeding management system was operational throughout the year. Animal information was reliably available through the farms' cow management software while crop record systems were not kept completely enough to be useful for NMB assessment. Despite hesitation about participating at the start of the project, all six farmers concluded in the final survey that (1) the NMB assessment was worth the effort required to collect the information; (2) farm meetings that were attended by farm advisors (planner, nutritionist, NMB facilitator, etc.) greatly improved the value of the NMB assessment; and (3) use of the "optimum operational zone" as a NMB target to strive for was essential for better understanding of the NMB and identification of management alternatives. Farms related that the NMB information offers a unique whole farm view of their operation and gave every indication they will refer to that view when making management decision in the future. We conclude that successful adoption of the NMB assessments requires minimizing the amount of farmer time necessary to complete the assessment and maximizing the farm's understanding of the NMB results through farmer meetings. Year-round recording of quantities of purchases in the farm's accounting software as invoices are entered, and working with a knowledgeable NMB facilitator, are keys to successful adoption.

Acknowledgements

We thank the six New York dairy farmers who participated in this study and gave us their feedback on the process and findings.

References

Albrecht, G. L., Ketterings, Q. M., Czymmek, K. J., Van Amburgh, M., & Fox, D. G. (2006). Whole Farm Nutrient Management: Capstone course on environmental management of dairy farms. *Journal of Natural Resources and Life Science Education (Renamed Natural Science Education), 35*, 12-23. http://dx.doi.org/10.2134/jnrlse2006.0140

Cela, S., Ketterings, Q. M., Czymmek, K. J., Soberon, M., & Rasmussen, C. N. (2014). Characterization of N, P, and K mass balances of dairy farms in New York State. *Journal of Dairy Science, 97*, 7614-7632. http://dx.doi.org/10.3168/jds.2014-8467

Cela, S., Ketterings, Q. M., Czymmek, K. J., Soberon, M., & Rasmussen, C. N. (2015). Long-term trends of nitrogen and phosphorus mass balances on New York dairy farms. *Journal of Dairy Science, 98*, 7052-7070. http://dx.doi.org/10.3168/jds.2015-9776

Cela, S., Ketterings, Q. M., Soberon, M., Rasmussen, C. N., & Czymmek, K. J. (2016). Upper Susquehanna watershed and New York state improvements in nitrogen and phosphorus mass balances of dairy farms. *Journal of Soil and Water Conservation* (In Press).

Daatselaar, H. G., Reijs, J. R., Oenema, J., Doornewaard, G. J., & Aarts, H. F. M. (2015). Variation in nitrogen use efficiencies on Dutch dairy farms. *Journal of the Science of Food and Agriculture, 95*(15), 3055-3058. http://dx.doi.org/10.1002/jsfa.7250

Ketterings, Q. M. (2014). Extension and knowledge transfer; adaptive management approaches for timely impact. *Journal of Agricultural Science, Cambridge, 152*(S1), 57-64. http://dx.doi.org/10.1017/S002185961300066X

Long, E., & Ketterings, Q. M. (2016). Factors of yield resilience under changing weather evidenced by a 14-years record of corn-hay yield in a 1000-cow dairy farm. *Agronomy for Sustainable Development, 36*, 16. http://dx.doi.org/10.1007/s13593-016-0349-y

Soberon, M. A., Cela, S., Ketterings, Q. M., Rasmussen, C. N., & Czymmek, K. J. (2015). Changes in nutrient mass balances over time and related drivers for 54 New York dairy farms. *Journal of Dairy Science, 98*, 5313-5329. http://dx.doi.org/10.3168/jds.2014-9236

Soberon, M. A., Ketterings, Q. M., Rasmussen, C. N., & Czymmek, K. J. (2013). Whole farm nutrient balance calculator for New York dairy farms. *Natural Science Education, 42*, 57-67. http://dx.doi.org/10.4195/nse.2012.0020

USDA-NASS. (2014). Milk cows and production final estimates 2008-2014. *Statistical Bulletin 1036*.