Northern New York Agricultural Development Program
2023 Project Report

Whole-Farm Nitrogen Mass Balances and N_2O Emissions: Win-Win?

Project Leader:

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Collaborators:

Crop Consultants and Nutrient Management Planners: Mike Contessa, Eric Beaver, Champlain Valley Agronomics, Peru, NY. Miner Institute: Laura Klaiber, Allen Wilder, Chazy, NY. Cornell: Olivia Godber, Agustin Olivo, Ithaca, NY. 10 northern NY dairies.

Background:

For almost ten years now, farmers who participate in the annual whole-farm nutrient mass balance (NMB) assessment for nitrogen (N), phosphorus (P), and potassium (K) receive farm-specific annual reports that show how they compare to other farms and to feasible benchmarks ("Green Box", p. 2). The individual farm NMB report also includes trend figures (balances over time) and an "Opportunity Table" with key performance indicators (KPIs) that can be used to "trouble-shoot" (identify areas for improvement). More recently, farmers can also participate in the whole farm greenhouse gas (GHG) emissions assessment, using the Cool Farm Tool developed by the Cool Farm Alliance. This is an online tool used by many global corporations to estimate GHG emissions of farming systems, including dairy farms. The tool can also be used as a decision report tool by running scenarios. For this NNYADP-funded research project, we worked with four northern NY dairies to assess the relationship between whole farm N balances and whole-farm nitrous oxide (N_2O) emissions, adding to a larger dataset. The overall goal is to identify key drivers of whole-farm N balances and N_2O emissions.

Methods:

Four northern NY dairies shared up to four years (2019 – 2022) of data needed to run the the NMB and Cool Farm Tool GHG module. From this, we calculated their annual NMB and GHG footprint. By combining the data from these dairies with six more northern NY dairies and 65 other non-northern NY dairies who completed the whole farm NMB, of which 29 also completed the Cool Farm Tool GHG module, we have begun to identify the drivers, or KPIs, impacting the environmental footprint of these farms. Through what-if scenarios, we have started to evaluate drivers for differences in both NMBs and GHG emissions.

Results:

Whole-farm nutrient mass balance

In 2022, the weighted average N, P and K balances per acre and per cwt for dairies in northern NY were within the feasible range, with exception of the N balance per acre that exceeded the feasible range by just 2 lb N per acre (Table 1). The red dots in Figure 1 show where the northern NY farms operated, compared to the other NY farms in 2022.

Table 1: Nutrient mass balances for NNY, other NY farms, and feasible balances in 2022.

		Northern NY (n = 10)	Other NY (n = 65)	Feasible balances
		Balance per acre		
Nitrogen	Weighted mean balance (lb/acre)	107	122	> 0 and ≤ 105
	% of farms meeting feasible limits	50%	32%	
Phosphorus	Weighted mean balance (lb/acre)	9	11	> 0 and ≤ 12
	% of farms meeting feasible limits	70%	48%	
Potassium	Weighted mean balance (lb/acre)	35	45	> 0 and ≤ 37
	% of farms meeting feasible limits	80%	35%	
		Balance per cwt milk		
Nitrogen	Weighted mean balance (lb/cwt milk)	0.78	0.68	> 0 and ≤ 0.88
	% of farms meeting feasible limits	54%	57%	
Phosphorus	Weighted mean balance (lb/cwt milk)	0.07	0.03	> 0 and ≤ 0.11
	% of farms meeting feasible limits	65%	69%	
Potassium	Weighted mean balance (lb/cwt milk)	0.25	0.22	> 0 and ≤ 0.30
	% of farms meeting feasible limits	42%	45%	
		Optimal Operational Zone "Green Box"		
Nitrogen	% of farms meeting feasible limits	20%	26%	
Phosphorus	% of farms meeting feasible limits	70%	43%	
Potassium	% of farms meeting feasible limits	60%	34%	

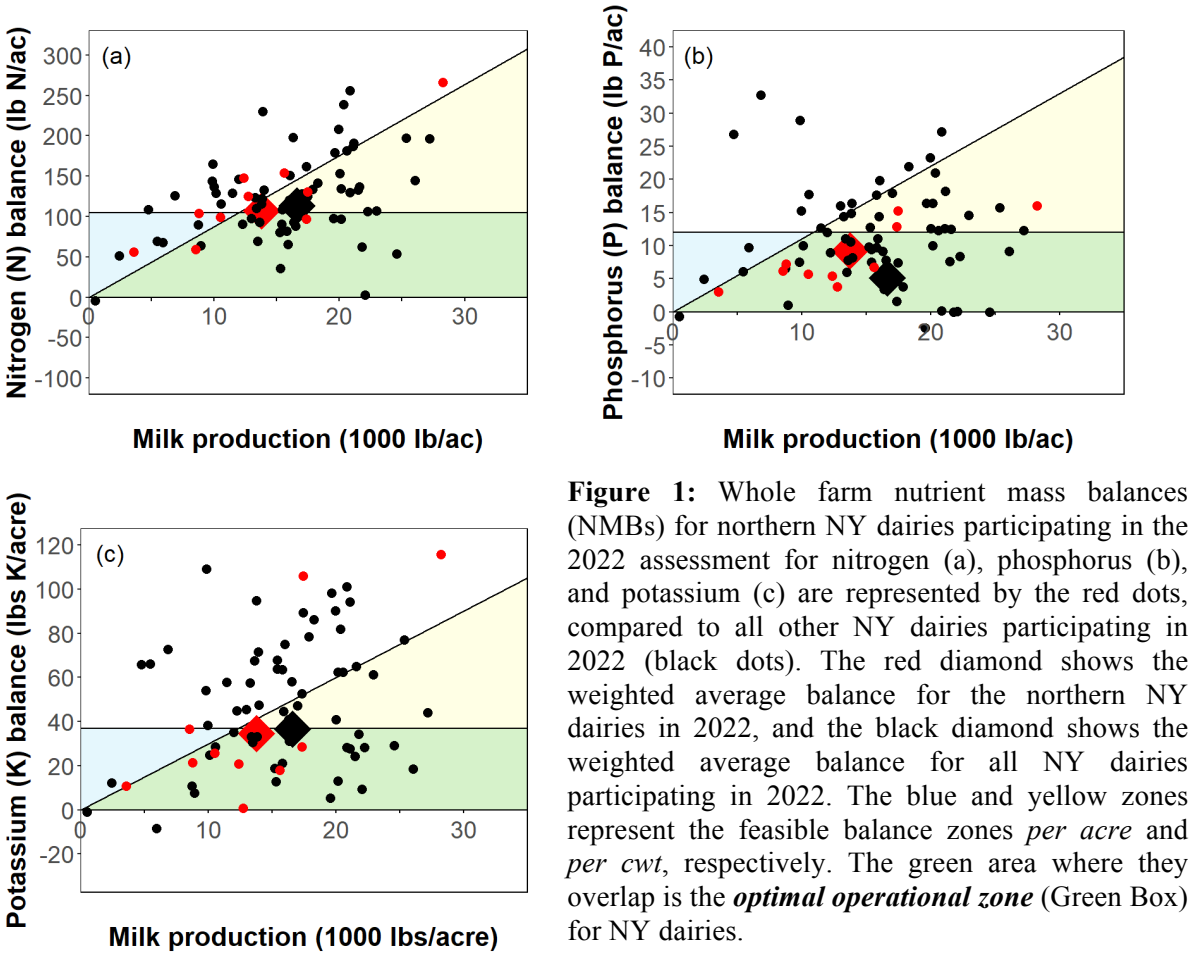

Figure 1: Whole farm nutrient mass balances (NMBs) for northern NY dairies participating in the 2022 assessment for nitrogen (a), phosphorus (b), and potassium (c) are represented by the red dots, compared to all other NY dairies participating in 2022 (black dots). The red diamond shows the weighted average balance for the northern NY dairies in 2022, and the black diamond shows the weighted average balance for all NY dairies participating in 2022. The blue and yellow zones represent the feasible balance zones *per acre* and *per cwt*, respectively. The green area where they overlap is the ***optimal operational zone*** (Green Box) for NY dairies.

Table 2 presents indicators that contribute to the NMB and help predict the risk of exceeding feasible nutrient mass balances. The indicators in Table 2 do not show any major differences between the northern NY farms and other NY farms. As we saw in previous years, for both groups of farms, the average amount of nutrients imported in feed and N fertilizer is higher than the thresholds set to indicate a high risk of exceeding the feasible balances.

Table 2: Indicators to predict high risk of exceeding feasible balances.

Indicators to predict high risk of exceeding feasible balances				
Indicator		Weighted mean NNY farms (n = 10)	Weighted mean other NY farms (n = 65)	High risk of exceeding the feasible balances if
Animal density	animal units/acre	1.08	1.16	>1.00
Milk per cow	lb/cow/year	26,000	27,000	20,000
Homegrown feed	% of total feed DM	72%	65%	< 65%
Homegrown forage	% of total feed DM	70%	62%	-
N in purchased feed	lb N/acre	151	192	> 121
P in purchased feed	lb P/acre	21	26	> 20
K in purchased feed	lb K/acre	41	64	> 11
CP in all feed	%	14.9%	15.5%	> 17%
P in all feed	%	0.35%	0.36%	> 0.40%
Feed use	tons DM / AU	6.4	6.4	3.5 to 7.5
N fertilizer imports	lb N/acre	42	50	> 39
P fertilizer imports	lb P/acre	3	4	> 6
K fertilizer imports	lb K/acre	17	22	> 38
CP in homegrown feed	%	11.2%	11.3%	< 11.8%
Overall crop yield	tons DM/acre	4.9	4.8	-
% legume acres	%	31%	45%	-
Acres receiving manure	%	84%	74%	-

Whole-farm greenhouse gas inventory

Figure 2 shows the 2022 whole-farm GHG inventory for four of the northern NY dairies and an additional 29 NY dairies by source of emissions (left figure) and GHG (right figure). For all farms, enteric fermentation and associated methane (CH_4) were the major sources of GHG emissions, with important contributions by feed production and manure management for both N_2O and CH_4 emissions.

Through scenario analysis, we estimated the impact of beneficial management practices already taking place on the 33 farms (Figure 3). These include a combination of reduced tillage (59% of acres), the use of cover crops (44% of corn acres), covering liquid manure storages (five farms), and installing anaerobic digesters (nine farms). Uptake of these beneficial management practices is more feasible on some farms than others, due to factors such as land characteristics, existing infrastructure, and available financial capital. We therefore present the aggregated results for all dairies to indicate the progress already made collectively by a crosssection of dairies in NY. Figure 2 also shows the potential of these farms to further reduce their aggregated GHG inventory if all beneficial management practices could be implemented on all 33 farms.

Some potential mitigation strategies, such as the use of feed additives to reduce methane emissions from enteric fermentation, are still in the development stage, and a high level of

uncertainty still remains about their potential impact and regulation for use. These are therefore referred to as "speculative" opportunities at this point.

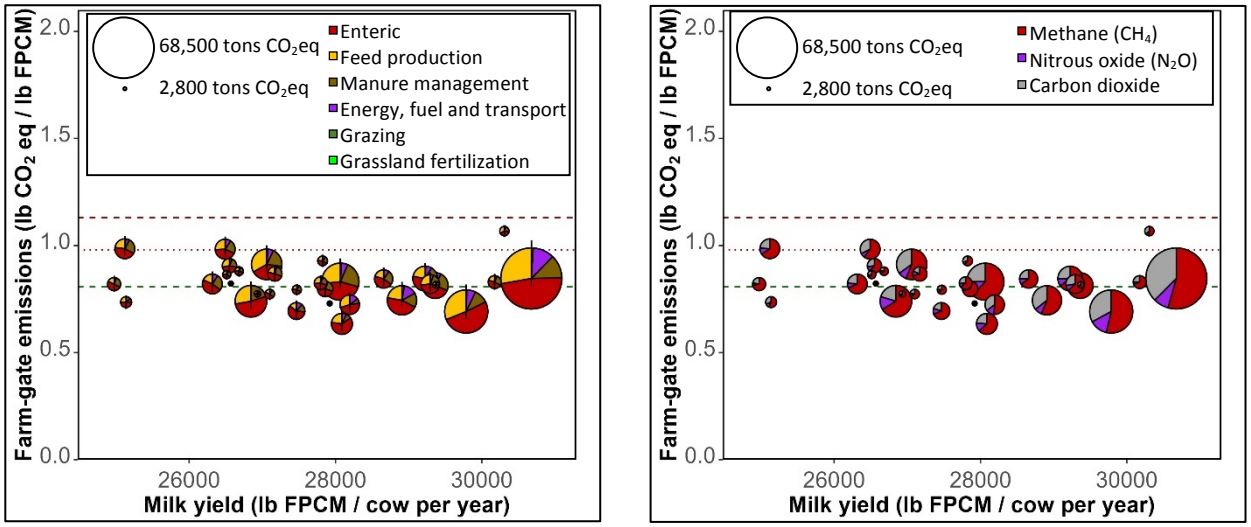

Figure 2: The sources of greenhouse gases (GHGs) in carbon dioxide equivalents (CO_2eq; left figure) and GHG (in CO_2eq; right figure) contributing to whole-farm GHG inventories, per lb of fat and protein corrected milk (FPCM; vertical axis), and lb FPCM per cow per year (horizontal axis). The size of the pie chart represents the total emissions of that dairy. The 2022 weighted average GHG emissions of all NY farms is shown by the green dashed line **(0.81 lb CO_2eq per lb FPCM)**, the average North American dairy GHG emissions is shown by the dashed red line (1.13 lb CO_2eq per lb FPCM, 2015 baseline; FAO 2022), and the average Northeast US dairy GHG emissions is shown by the dotted red line (0.98 lb CO_2eq per lb FPCM, 2017 baseline; Rotz et al. 2021). Data for 33 NY dairy farms.

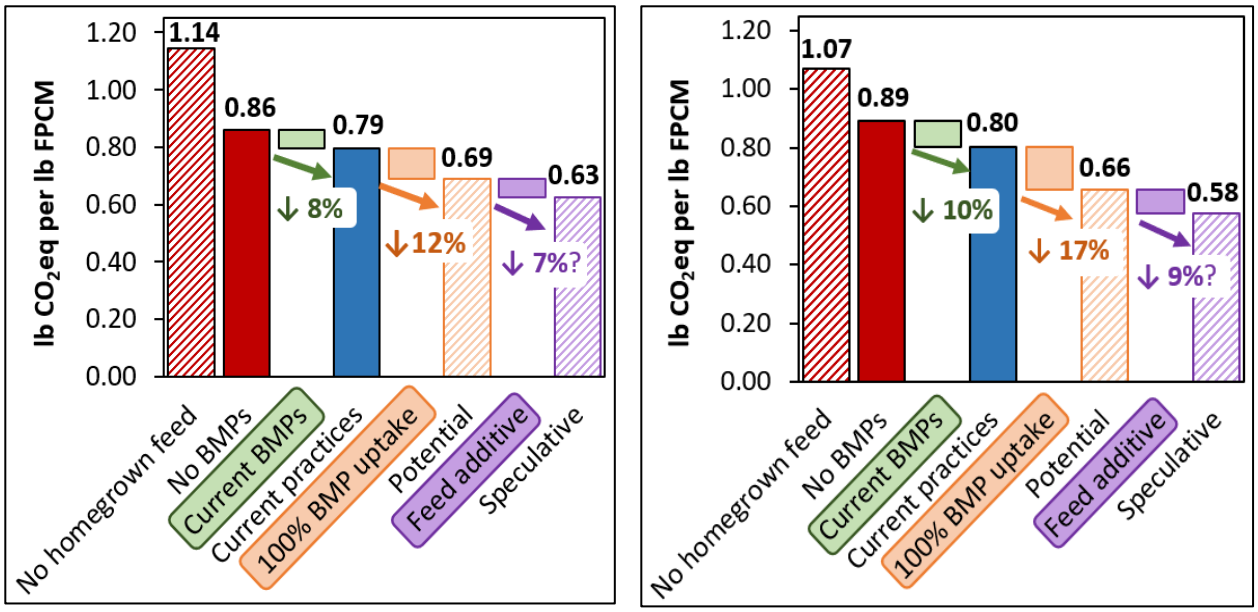

Figure 3: The progress made through implementation of beneficial management practices (BMPs) to reduce the greenhouse gas (GHG) emission intensity (lb CO_2eq per lb fat and protein corrected milk; FPCM) of the four NNY dairies (left) and another 29 NY dairies (right), and potential future reductions that could be made through additional beneficial management practices.

Relationship between whole-farm N balances and nitrous oxide (N_2O) emissions

Figure 4 shows the relationship between annual whole-farm N balances and N_2O emissions for 46 NY dairies, including 10 northern NY dairies between 2019 and 2022. Work is currently identifying potential drivers of the two balances, such as animal density, manure management system, manure and fertilizer application, and animal feeding practices.

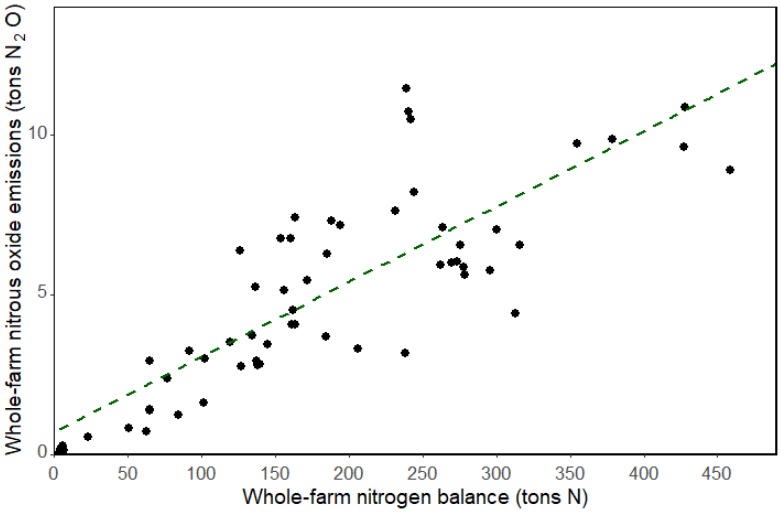

Figure 4: The relationship between whole-farm N balances and nitrous oxide (N_2O) emissions on 10 northern NY and 36 non-northern NY farms; some farms have provided data for multiple years and are represented more than once.

Extension activities

An extension article was written for Progressive Dairy (March 2024 issue). In addition, an oral presentation was given at the 2023 Cornell Nutrition Conference, the January 2024 meeting of the NMSP External Advisory Committee, and for Field Crop Extension Educators during the Ag Inservice annual gathering in November 2023. Oral presentations are scheduled for March 2024 at the Northeast Dairy Management Conference and at NNYADP research update meetings scheduled for March 13, 2024, at Miner Institute and March 20, 2024, in Lowville, NY.

Conclusions/Outcomes/Impacts:

Farms engaged in this project contributed relevant scenarios for "what-if" evaluations. Farm NMBs show drivers for balances for N and P and possible opportunities to reallocate nutrients for greater nutrient use efficiency. Potential impact of beneficial management practices on GHG inventories has been quantified. Ongoing work aims to use the whole-farm N balances to estimate the whole-farm nitrous oxide (N_2O) emissions, a potent and important GHG for dairies. Work is also ongoing to evaluate the impact of by- and waste-product use on dairy rations on whole farm NMBs and GHG footprints.

Outreach:

Agronomy fact sheet: Factsheet #85: Feasible Whole-Farm Nutrient Mass. This factsheet is currently being updated by an undergraduate intern working on this project.

Extension articles: Godber, O.F. and Ketterings, Q.M. (2023). What is the value of your dairy farm's environmental footprint? PRO-DAIRY's The Manager. March 2024 issue.

Software tools used in the project:

- Whole-farm NMB. http://nmsp.cals.cornell.edu/software/Cornell_NMB_1.0.exe
- Cool Farm Tool. https://app.coolfarmtool.org/

Extension talks already delivered or to be given in March:

- Godber, O.F. and Ketterings, Q.M. (2023). Dairy Environmental Footprints: Marketing Data to Promote, Drive and Support Sustainability. Cornell Nutrition Conference 2023. East Syracuse, NY. October 19, 2023.

- Czymmek, K., Ray, L., Van Amburgh, M., Ketterings, Q.M., and Godber, O. (2024). Dairy Farming & Greenhouse Gas Emissions: A Discussion of Climate Smart Challenges & Opportunities. Northeast Dairy Management Conference, Syracuse, NY. March 6, 2024.
- Workman, K., Ketterings, Q.M. and Godber, O. (2024). The Value of Dairy Environmental Footprints for Your Farm and the New York Dairy Industry. Northeast Dairy Management Conference, Syracuse, NY. March 7, 2024.
- Ketterings, Q.M. (2024). Connecting the Dots: Dairy Sustainability, Value of Manure, Yield Stability Zones. NNYADP Research Update Meetings in Chazy, NY. March 13, and in Lowville, NY, March 20, 2024)

Student Engagement: A group of undergraduate student interns visited northern NY in August 2023 to engage with CCE educators, two northern NY dairy farms, collaborators at the Miner Institute, and crop advisors and planners from Champlain Valley Agronomics.

Training: Whole farm NMB training was given to a northern NY consulting firm in spring 2023.

Next Steps:

We continue the work with the five northern NY dairies, their staff and advisors to add NMB and GHG inventory data for the **2023** calendar year, in addition to a biodiversity assessment. We aim to identify additional beneficial management practices, and develop recommendations for use of tools or specific KPIs that can be utilized by farmers to obtain a most robust and comprehensive sustainability assessment with data readily available to them, and to accurately monitor impact of management changes on progress over time. As a much larger dataset is needed to identify drivers, we will continue to combine the datasets from northern NY with the data other non-northern NY dairies. Findings will help identification of beneficial management practices that have a positive impact on the widest range of dairy farm sustainability credentials for the farms as possible. This will help to develop an integrated sustainability metric and contribute to a roadmap for continuous improvement, reporting requirements of co-operatives and retailers, and communication of current environmental achievements and future progress, while keeping a focus on dairy economic sustainability as a key pillar of sustainability.

Acknowledgments:

We thank the farmers participating in the project for sharing data and providing valuable feedback on findings and scenarios to evaluate.

For Further Information:

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Photos:

Upper left: The 2023 NMSP summer intern cohort and staff touring The Miner Institute with Champlain Agronomics staff. Photo credit: Quirine Ketterings.

Upper right: The 2023 NMSP summer intern cohort and staff hearing about manure management practices at the Miner Institute with forage agronomist Allen Wilder. Photo credit: Quirine Ketterings.

Center left: The 2023 NMSP summer intern cohort and staff visiting edge-of-field research sites at the Miner Institute with research scientist Laura Klaiber. Photo credit: Quirine Ketterings.

Lower left: The 2023 NMSP summer intern cohort and staff touring Adirondack Farms to learn about their anaerobic digester. Photo credit: Quirine Ketterings.