



Northern New York Agricultural Development Program 2024-2025 Project Report

What If: Linking dairy sustainability metrics to promote, drive and support sustainability

Project Leader:

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Collaborators:

Crop Consultants: Mike Contessa and Eric Beaver (Champlain Valley Agronomics). Campus: Olivia Godber, Julianna Lee. Eighteen northern NY (NNY) dairies.

Background:

For nearly a decade, farmers participating in the annual whole-farm nutrient mass balance (NMB) assessment for nitrogen (N), phosphorus (P), and potassium (K) have received individualized reports that allow them to evaluate their performance relative to farm peers and to feasible benchmark ranges (the “Green Box”). Each farm-level NMB report also includes an “Opportunity Table” that summarizes key performance indicators (KPIs) to help identify potential areas for improvement. In more recent years, farmers have also had the option to complete a whole-farm greenhouse gas (GHG) emissions assessment using the Cool Farm Tool developed by the Cool Farm Alliance. This widely used online tool estimates GHG emissions for a range of agricultural systems, including dairy, and can also support scenario analysis for management decision-making. Taken together, these assessments enable farmers to evaluate production efficiency, nutrient use, and GHG emission footprints in an integrated way.

In this study, we present data from seventeen northern New York (NNY) dairy farms collected between 2019 and 2024, including whole-farm nutrient balances derived from the NMB and whole-farm GHG emissions estimated using the Cool Farm Tool, contributing to a broader statewide dataset. The overarching objective is to connect these complementary sustainability metrics (nutrient use and GHG emissions) to identify aligned KPIs and support more streamlined sustainability goals for dairy farms. Planned farmer meetings will be used to gather feedback on priority “what if” scenarios to be explored using the two assessment tools.

Methods:

Eighteen NNY dairy farms shared up to six years (2019-2024) of data needed to run the NMB and Cool Farm Tool GHG module (total NNY NMB assessments = 62, total NNY GHG assessments = 30). From this, we calculated their annual NMB and GHG footprint. These data were combined with those from another 125 other NY dairy farms who also completed the whole farm NMB between 2019 and 2024, of which 49 also completed the Cool Farm Tool GHG module (total other NY NMB assessments = 340, total other NY GHG assessments = 129). The drivers, or KPIs, impacting the environmental footprint of these farms were then identified, and “what if” scenarios run to identify potential beneficial management practices (BMPs) to mitigate GHGs. The common drivers of N balances and nitrous oxide (N₂O) emissions (a potent GHG) were explored in more detail in a dataset of 77 dairy farms, including nine located in NNY, with a focus on the potential impact of an increase in animal density in the region to meet the expected milk demand in coming years.

Results:

Whole-farm nutrient mass balance

For the 2024 calendar year, the weighted average N, P and K balances per acre and per cwt for dairies in NNY were within the feasible range (Table 2). The red dots in Figure 1 show where the NNY dairy farms operated, compared to the other NY dairy farms in 2024. The trend lines in Figure 3 show improvements made between 2019 and 2024 in all nutrient balances.

Table 2: Nutrient mass balances for NNY, other NY dairy farms, and feasible balances 2024.

		NNY (n = 14)	Other NY (n = 62)	Feasible balances
Balance per acre				
Nitrogen	Weighted mean balance (lb/acre)	105	109	> 0 and ≤ 105
	% of farms meeting feasible limits	50%	40%	
Phosphorus	Weighted mean balance (lb/acre)	7	6	> 0 and ≤ 12
	% of farms meeting feasible limits	86%	60%	
Potassium	Weighted mean balance (lb/acre)	28	42	> 0 and ≤ 37
	% of farms meeting feasible limits	57%	37%	
Balance per cwt milk				
Nitrogen	Weighted mean balance (lb/cwt milk)	0.84	0.65	> 0 and ≤ 0.88
	% of farms meeting feasible limits	43%	65%	
Phosphorus	Weighted mean balance (lb/cwt milk)	0.05	0.04	> 0 and ≤ 0.11
	% of farms meeting feasible limits	93%	76%	
Potassium	Weighted mean balance (lb/cwt milk)	0.23	0.25	> 0 and ≤ 0.30
	% of farms meeting feasible limits	57%	56%	
Optimal Operational Zone “Green Box”				
Nitrogen	% of farms meeting feasible limits	36%	29%	
Phosphorus	% of farms meeting feasible limits	79%	58%	
Potassium	% of farms meeting feasible limits	50%	35%	

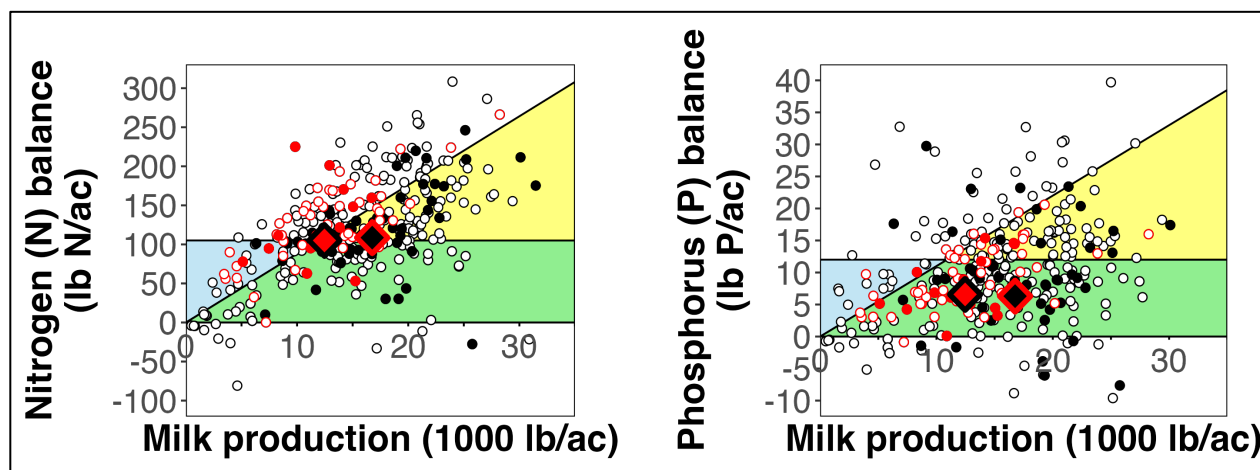


Figure 1: Whole farm N and P mass balances for 2024 for NNY dairy farms are represented by the solid red dots, compared to NNY dairy farms in the 2019 – 2023 (red circles), all other NY dairy farms in 2024 (solid black dots) and in 2019-2023 (black circles). The red diamond with black outline shows the weighted average balance for NNY dairy farms in 2024. The black diamond with red outline shows the weighted average balance for other NY dairies for 2024. The blue and yellow zones represent the feasible balance zones *per acre* and *per cwt*, respectively. The green area is the *optimal operational zone* (Green Box).

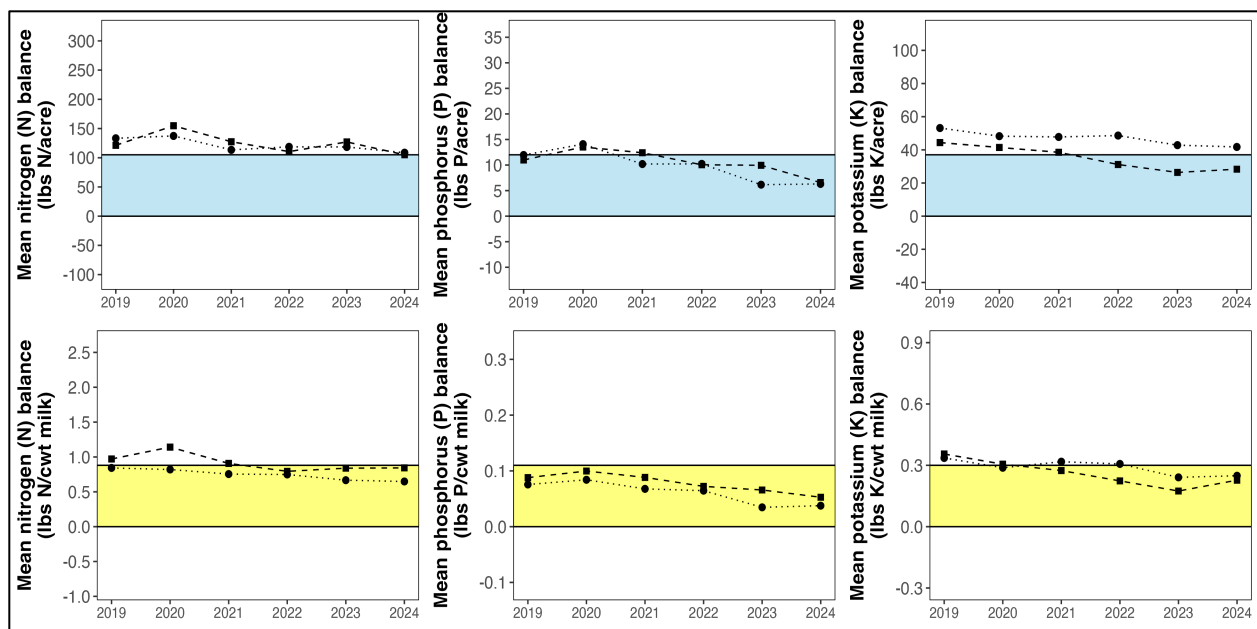


Figure 2: Whole farm nutrient mass balances (NMBs) for NNY dairy farms (dashed lines, square points) and other NY dairy farms (dotted lines, circle points) in the 2019-2024 assessments for N, P, and K. The blue and yellow zones represent the feasible balance zones *per acre* and *per cwt*, respectively.

The KPIs (Table 3) show nutrients imported in feed was below the threshold set to indicate a high risk of exceeding feasible balances for N, P and K in the northern NY dairy farms in 2024, and above the threshold for all three nutrients imported in feed for other NY dairy farms.

Table 3. Weighted average of key performance indicators (KPIs) to predict high risk of exceeding feasible balances in NY dairy farms in 2024.

KPI		Weighted mean NNY farms (n = 15)	Weighted mean other NY farms (n = 47)	High risk of exceeding the feasible balances if
Animal density	AU/acre	0.93	1.18	>1.00
Milk per cow	lb/cow/year	27,000	28,000	20,000
Homegrown feed	% of total feed DM	76%	71%	< 65%
Homegrown forage	% of total feed DM	100%	97%	-
N in purchased feed	lb N/acre	117	170	> 121
P in purchased feed	lb P/acre	16	24	> 20
K in purchased feed	lb K/acre	31	56	> 38
CP in all feed	%	14.9%	14.3%	> 17%
P in all feed	%	0.34%	0.33%	> 0.40%
Feed use	Tons DM / AU			3.5 to 7.5
N fertilizer imports	lb N/acre	68	62	> 39
P fertilizer imports	lb P/acre	4	4	> 6
K fertilizer imports	lb K/acre	22	29	> 38
CP in homegrown feed	%	11.4%	11.0%	< 11.8%
Overall crop yield	Tons DM/acre	4.5	5.8	-
% legume acres	%	36%	40%	-
Acres receiving manure	%	82%	75%	-

The difference could be driven by the lower weighted average animal density of the NNY dairy farms in the dataset: 1.0 AU/acre in 2024 for the northern NY farms versus above 1.2 AU/acre for the other NY dairy farms. For both groups, the average amount of nutrients imported in N fertilizer was higher than the threshold set to indicate a high risk of exceeding feasible balances.

Whole-farm greenhouse gas inventory

At the whole farm level, the 2024 weighted average net GHG emission intensity was 0.79 lb CO₂eq / lb FPCM for the NNY dairy farms (Figure 3). These emissions are net emissions and include potential removals through carbon sequestration. When potential carbon sequestration is removed, the weighted average gross GHG emission intensity was **0.80 lb CO₂eq / lb FPCM** for the NNY dairy farms.

In 2024, beneficial management practices (BMPs) that reduced GHGs on the NNY dairy farms included continuous reduced or no-tillage (42% of corn silage acres), the use of cover crops (44% of corn silage acres), and installing anaerobic digesters (five farms). Implementation of these BMPs have resulted in a 13% lower GHG emission intensity on these farms, compared to a scenario with all farms having uncovered liquid manure storage without separation or a digester, and full tillage field management with no cover crops (Figure 4). If no feed was homegrown and all forages were to be purchased, GHG emission intensity could be as much as 34% higher than estimated for 2024. Furthermore, if all farms were to move to no-till and 100% cover cropped with their field management without any compromise to crop yields, in addition to all farms investing in manure separation with cover and flare systems, or an anaerobic digester if animal units are sufficient, plus a feed additive to reduce methane emissions, an additional 23% reduction from the scenario with no BMPs could be achieved. Uptake of these BMPs is more feasible on some farms than others, due to factors such as land characteristics, existing infrastructure, and available financial capital, in addition to wide variation in the efficacy of some mitigation options, such as feed additives.

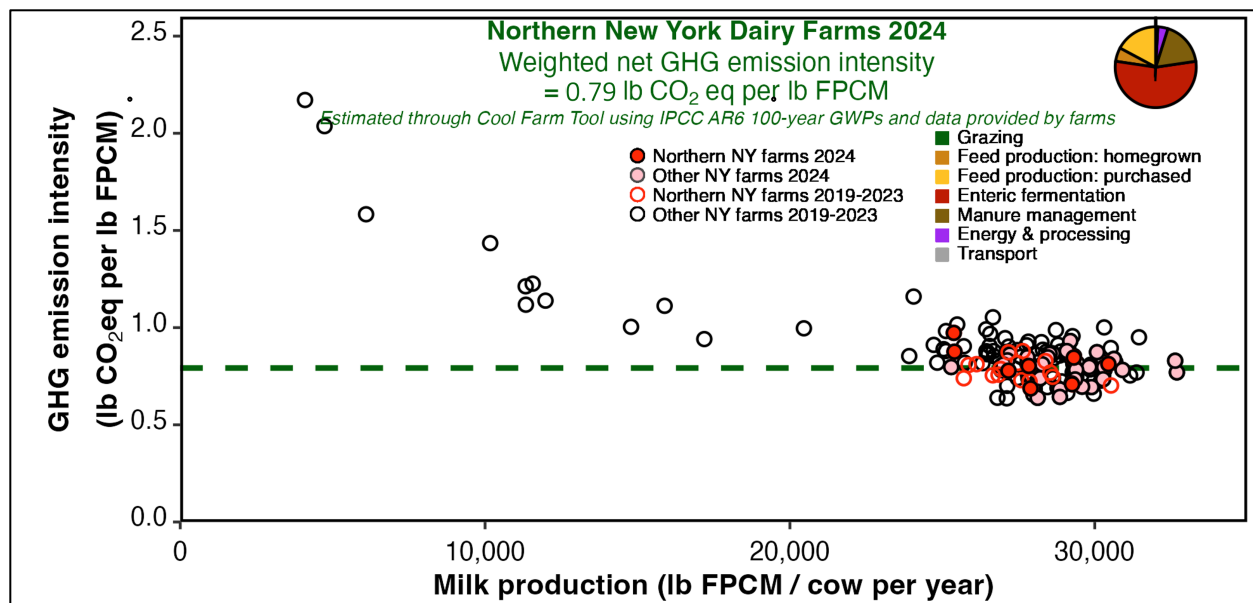


Figure 3: The net greenhouse gas (GHG) emission intensity in carbon dioxide equivalents (CO₂eq) per lb of fat and protein corrected milk (FPCM; vertical axis), and lb FPCM produced per cow per year (horizontal axis) for NNY dairy farms and other NY dairy farms in 2024, and from 2019-2023. The weighted average net GHG emissions of the NNY dairy farms is the green dashed line.

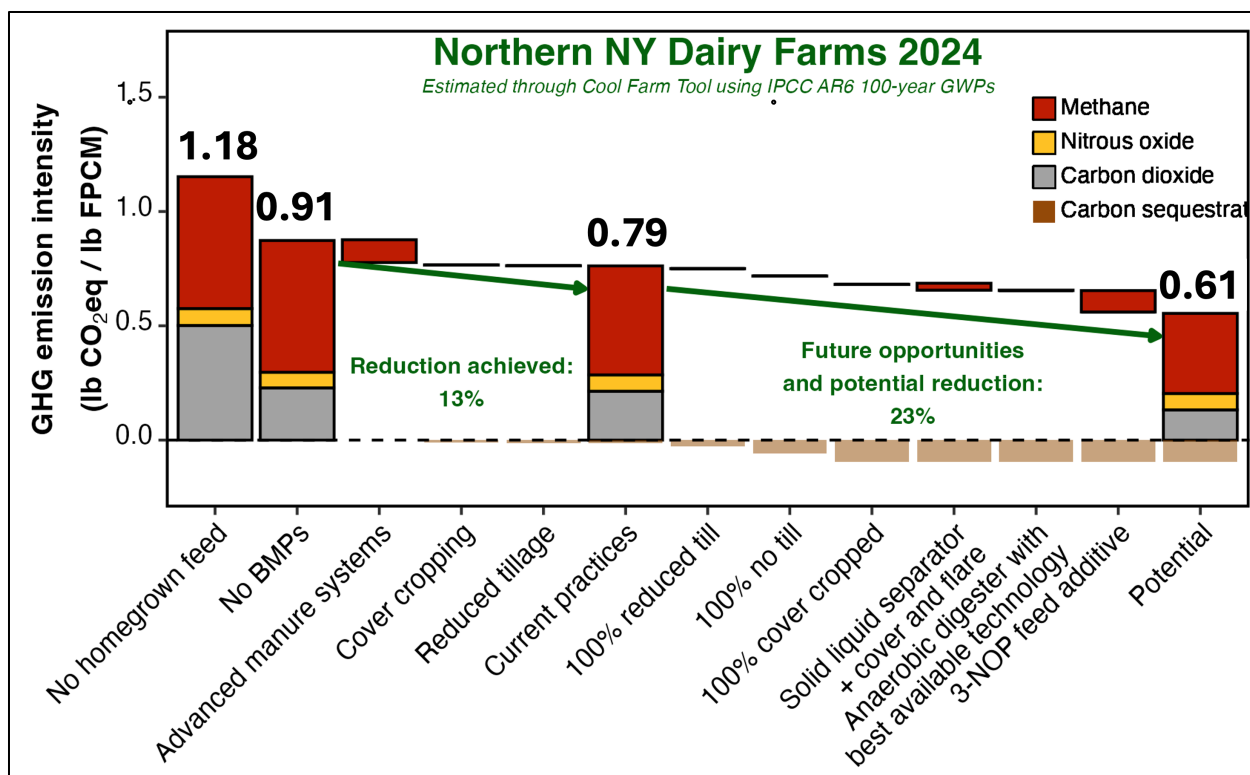


Figure 4: The current weighted net greenhouse gas (GHG) emission intensity in carbon dioxide equivalents (CO₂eq) per lb of fat and protein corrected milk (FPCM), for NNY dairy farms in 2024, the reduction achieved through beneficial management practices in place on these farms, and the future opportunities and associated potential reductions in GHG emission intensity with 100% uptake of available field and manure management practices, in addition to use of the feed additive 3-NOP (Bovear).

Conclusions/Outcomes/Impacts:

Many of the KPIs for GHG emission intensity were related to animal density, such as the percent of homegrown feed production, and the need to import nutrients in feed. Reducing feed purchases could not only benefit the GHG emission intensity of farms, but would also contribute to improvements in whole farm N and P balances, and farm economics. Other KPIs include crop yields and feeding intensity. Detailed understanding of the impact of homegrown forage digestibility and the potential trade-offs between GHG emission intensity of different GHG sources needs to be prioritized. As many of the KPIs drive both farm-gate N and P balances and GHG emission intensity, common mitigation practices could be developed for multiple aspects of dairy sustainability. As milk demand in NY increases, higher animal densities are expected. Continuing to optimize efficiency of both crop and milk production will be essential, as will the development of manure export relationships with cash crop farmers, and new manure treatment technologies to help with the responsible recycling of manure nutrients.

Outreach:

Agronomy fact sheet:

- Factsheet #131: Above-ground biodiversity.
<http://nmsp.cals.cornell.edu/publications/factsheets/factsheet131.pdf>
- Factsheet #132: Animal density.
<http://nmsp.cals.cornell.edu/publications/factsheets/factsheet132.pdf>

Journal Articles

- Godber, O.F., Czymmek, K.J., van Amburgh, M.E. & Ketterings, Q.M. (2025). Farm-Gate greenhouse gas emission intensity for medium to large New York dairy farms. Journal of Dairy Science. doi: [10.3168/jds.2024-25874](https://doi.org/10.3168/jds.2024-25874)

Extension articles (includes northern NY balances):

- Godber, O.F., Czymmek, K.J., Amburgh, M.E. & Ketterings, Q.M. (2025). New York Dairies Show the Way to Reduce Greenhouse Gas Emissions. What's Cropping Up?

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/>

Statewide extension talks also attended by northern NY farmers and farm advisors:

- Godber, O.F., Auer, A., Lee, J., Ray, K. & Ketterings, Q.M. (2025) Dairy Sustainability Indicators: Enhancing sustainability in dairy farms. NMSP Lunchtime Webinar Series.
- Auer, A., Lee, J. & Ketterings, Q.M. (2025) Nutrient Management Spear Program: Dairy Key Performance Indicators Update. Agriculture, Food and Environmental Systems In-service, Ithaca, New York, USA. November 2025.
- Ketterings, Q.M., J.C. Ramos Sanchez, K. Workman, S. Srinivasagan, M. Marcaida, O. Godber (2025). NY On-Farm Research Partnership. Aurora Farm Field Day. Aurora, NY. July 24, 2025.
- Olivo, A., and Q.M. Ketterings (2025). Adaptive Nitrogen Management. Northeast Region Certified Crop Advisor Annual Conference. Syracuse, NY. December 10, 2025.

Student Engagement

- A group of undergraduate student interns visited northern NY in August 2025 to engage with two northern NY dairy farmers, collaborators at the Miner Institute, and crop advisors and planners from Champlain Valley Agronomics.

Next Steps:

We will continue the work with dairies in northern New York to assess the relationship between nutrient balances calculated from the whole-farm NMB, whole-farm GHG emissions estimated from the Cool Farm Tool, and biodiversity. The growing database will help identification of additional beneficial management practices that have a positive impact on the widest range of dairy farm sustainability credentials for the farms. This work will 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, contact:

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Photo: The NMSP and PRO-DAIRY partners meets with Eric Beaver of Champlain Valley Agronomics, Chazy, New York, to learn about their insights in agriculture and environmental management in northern New York and participation in Northern New York Agricultural Development Program-sponsored projects. Photo by Q.M. Ketterings.