Northern New York Agricultural Development Program
2024 Project Report

Linking Dairy Sustainability Metrics to Promote, Drive and Support Sustainability

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Collaborators:

- Crop Consultants and Nutrient Management Planners: Mike Contessa, Eric Beaver, Champlain Valley Agronomics
- Miner Institute: Laura Klaiber, Research Scientist; Allen Wilder, Forage Agronomist
- Campus Collaborators: Olivia Godber, Julianna Lee (NMSP)
- 8 Northern NY dairy farms.

Background:

For almost ten years and continuing, farmers who participate in the annual whole-farm nutrient mass balance (NMB) assessment for nitrogen (N), phosphorus (P), and potassium (K) have received farm-specific annual reports that show how they compare to other farms and to feasible benchmarks (*optimal operational zone "Green Box", Figure 1).* The individual farm NMB report also includes an "Opportunity Table" with key performance indicators (KPIs) that can be used to 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 entities to estimate the GHG emissions of farming systems, including dairy farms. The tool can also be used as a decision support tool by running scenarios. Both assessments combined give farmers an opportunity to assess their production efficiency, nutrient utilization, and greenhouse gas emission footprint.

Here we present data from 2019-2023 from eight northern NY dairies for nutrient balances calculated from the whole-farm NMB, and whole-farm GHG emissions estimated from the Cool Farm Tool (added to a larger statewide dataset).

In addition, a literature review of biodiversity indicator species, tools for biodiversity measurements, impacts of agriculture on biodiversity, and biodiversity conservation framework development was conducted. This literature review also included a landscape review of corporations connected to the dairy industry, for example dairy cooperatives, processors, or sustainability programs, and the effectiveness of any current activities related to biodiversity. The aim was to identify potentially relevant applications to a NY dairy biodiversity framework.

The overall goal of this effort is to link the individual sustainability metrics of nutrient use, GHG emissions and biodiversity to identify aligned KPIs and streamline sustainability objectives for dairy farms.

Methods:

Eight northern NY dairies shared up to five years (2019-2023) of data needed to run the the NMB assessment and Cool Farm Tool GHG module. From this, we calculated each dairy's annual NMB and GHG footprint. By combining the data from these dairies with 10 more northern NY dairies and 112 other non-northern NY dairies that completed the whole farm NMB between 2019 and 2023, of which 40 also completed the Cool Farm Tool GHG module, we have begun to identify the drivers (KPIs) impacting the environmental footprint of these farms. The biodiversity literature review was performed on the Web of Science search platform, and the landscape review through searching for publicly available online information.

Results:

Whole-farm nutrient mass balance

For 2019-2023, the weighted average P and K balances per acre and per cwt of milk for dairies in northern NY were within the feasible range, but the N balance per acre exceeded the feasible range by 20 lb N per acre and 0.03 lb N per cwt milk (Table 1). The red dots in Figure 1 show where the northern NY farms operated, compared to the other NY farms 2019-2023.

Table 1: Nutrient mass balances for NNY, other NY farms, and feasible balances 2019-2023.

		Northern NY (n = 15)	Other NY (n = 112)	Feasible balances
		Balance per acre		
Nitrogen	Weighted mean balance (lb/acre)	125	123	> 0 and ≤ 105
	% of farms meeting feasible limits	32%	36%	
Phosphorus	Weighted mean balance (lb/acre)	11	10	> 0 and ≤ 12
	% of farms meeting feasible limits	62%	52%	
Potassium	Weighted mean balance (lb/acre)	35	48	> 0 and ≤ 37
	% of farms meeting feasible limits	62%	36%	
		Balance per cwt milk		
Nitrogen	Weighted mean balance (lb/cwt milk)	0.91	0.75	> 0 and ≤ 0.88
	% of farms meeting feasible limits	36%	55%	
Phosphorus	Weighted mean balance (lb/cwt milk)	0.08	0.06	> 0 and ≤ 0.11
	% of farms meeting feasible limits	82%	72%	
Potassium	Weighted mean balance (lb/cwt milk)	0.25	0.29	> 0 and ≤ 0.30
	% of farms meeting feasible limits	58%	47%	
		Optimal Operational Zone "Green Box"		
Nitrogen	% of farms meeting feasible limits	14%	29%	
Phosphorus	% of farms meeting feasible limits	56%	47%	
Potassium	% of farms meeting feasible limits	46%	30%	

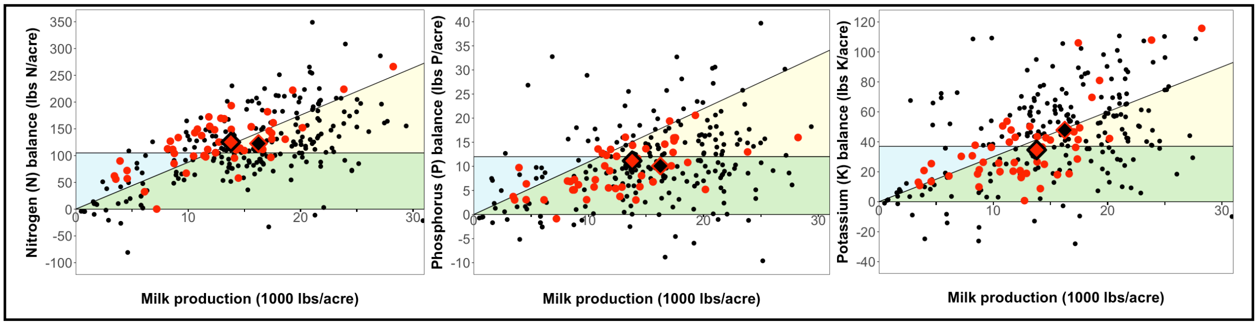

Figure 1: Whole farm nutrient mass balances (NMBs) for northern NY dairies in the 2019-2023 assessments for N (a), P (b), and K (c) are represented by the red dots, compared to all other NY dairies in 2019-2023 (black dots). The red diamond shows the weighted average balance for the northern NY dairies in 2019-2023, and the black diamond shows the weighted average balance for all NY dairies participating in 2019-2023. 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.

The KPIs in Table 2 did not show any major differences between the northern NY farms and other NY farms. For both groups, the average amount of nutrients imported in feed and N fertilizer was higher than the thresholds set to indicate a high risk of exceeding feasible balances.

Table 2. Key performance indicators (KPIs) to predict high risk of exceeding feasible balances.

KPI		Weighted mean NNY farms (n = 15)	Weighted mean other NY farms (n = 112)	High risk of exceeding the feasible balances if
Animal density	AU/acre	1.04	1.15	>1.00
Milk per cow	lb/cow/year	27,000	28,000	20,000
Homegrown feed	% of total feed DM	70%	65%	< 65%
Homegrown forage	% of total feed DM	66%	64%	-
N in purchased feed	lb N/acre	158	190	> 121
P in purchased feed	lb P/acre	21	26	> 20
K in purchased feed	lb K/acre	39	61	> 11
CP in all feed	%	15.5%	15.5%	> 17%
P in all feed	%	0.35%	0.36%	> 0.40%
Feed use	Tons DM / AU	6.3	6.3	3.5 to 7.5
N fertilizer imports	lb N/acre	51	52	> 39
P fertilizer imports	lb P/acre	5	4	> 6
K fertilizer imports	lb K/acre	20	26	> 38
CP in homegrown feed	%	11.3%	11.3%	< 11.8%
Overall crop yield	Tons DM/acre	4.6	4.7	-
% legume acres	%	33%	39%	-
Acres receiving manure	%	69%	75%	-

Whole-farm greenhouse gas inventory

At the whole farm level, the weighted average net GHG emission intensity was 0.81 lb CO_2eq/lb FPCM (fat and protein corrected milk) for the participating NNY dairy farms, and 0.82 lb CO_2eq/lb FPCM for the other NY dairy farms (Figure 2). 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 **0.82 lb CO_2eq/lb FPCM** for the northern NY dairy farms, and 0.86 lb CO_2eq / lb FPCM for the other NY dairy farms. At the crop production level, the weighted GHG emissions and potential sequestration for alfalfa-grass and corn silage production on three northern NY dairy farms (left) and 34 other NY (right) dairy farms in 2023 were estimated (Figure 3). The GHG emission intensity is presented per ton of dry matter produced to indicate the emission intensity of homegrown feed production. This assessment was done separately given the important role of homegrown forage production for dairy sustainability in NY.

In 2023, practices that reduced GHGs on the participating northern NY dairy farms included reduced tillage (48% of acres), the use of cover crops (59% of corn acres), covering liquid manure storages (two farms), and installing anaerobic digesters (seven farms). Uptake of these practices is more feasible on some farms than others, due to factors such as land characteristics, existing infrastructure, and available financial capital. Our statewide evaluation of 2022 data for 36 medium to large NY dairy farms (including five northern NY dairy farms) found that methane was the biggest contributing gas (60% of total emissions), mostly from enteric fermentation (45% of total emissions). Manure management was a major driver of emissions and homegrown feed production, heifer-to-cow ratio and feed consumption intensity also impacted emissions. High quality homegrown feed, nutrient management and manure treatment lowered emissions.

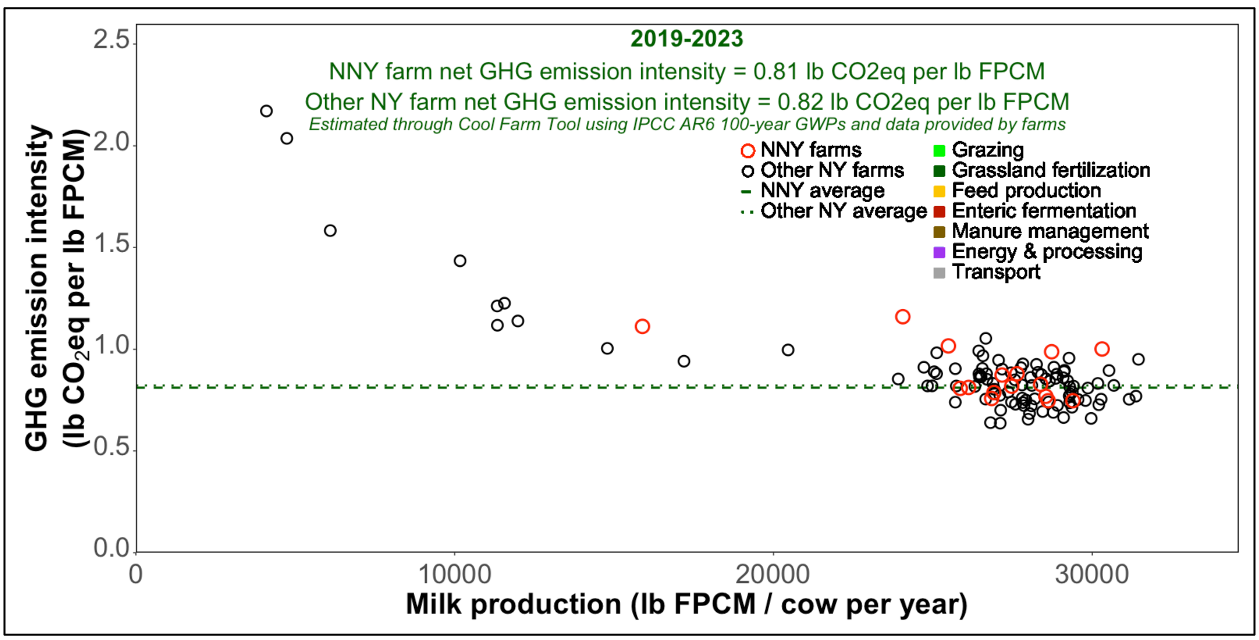

Figure 2: The net greenhouse gas (GHG) emission intensity in carbon dioxide equivalents (CO_2eq) per lb of fat and protein corrected milk (FPCM; vertical axis), and lb FPCM produced per cow per year (horizontal axis) for eight NNY dairy farms (red points) and 40 other NY dairy farms (black points) between 2019 and 2023. The weighted average net GHG emissions of the northern NY farms is shown by the green dashed line **(0.81 lb CO_2eq per lb FPCM)**, and for the other NY dairy farms by the dotted green line (0.82 lb CO_2eq per lb FPCM).

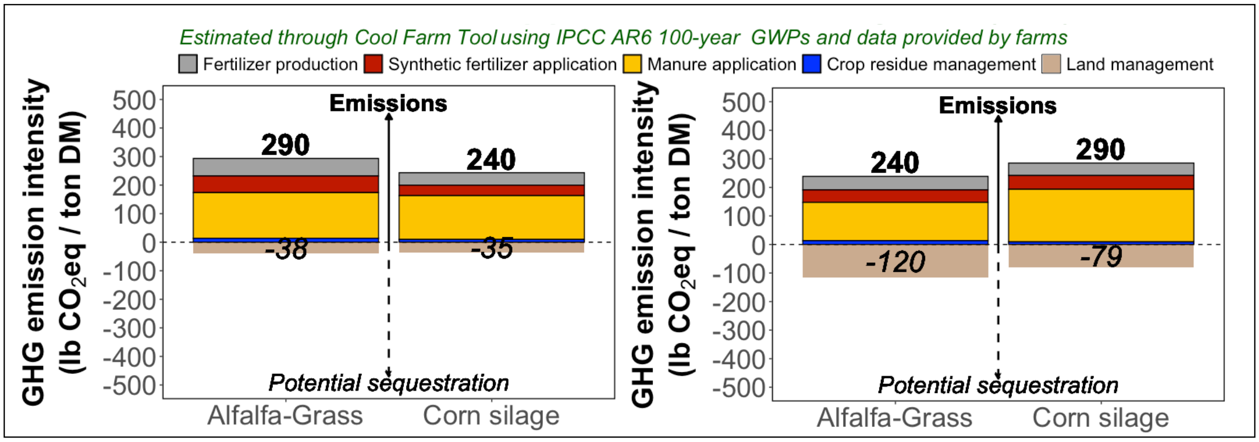

Figure 3: The sources of greenhouse gases (GHGs) and GHG emission intensity in lb of carbon dioxide equivalents (CO_2eq) per ton of alfalfa-grass or corn silage produced for northern NY dairy farms (a) and other NY dairy farms (b). The contribution of different sources of GHG emissions are indicated as positive numbers, and the amount of potential sequestration achieved through reduced tillage and/or cover cropping are shown as negative numbers. The net (overall) emissions are the difference between these two numbers.

Biodiversity

The literature and landscape review showed that KPIs for biodiversity can be categorized as structural diversity, habitat diversity and biotic diversity (Figure 4). However, no clear indicators have emerged from this work yet. Many companies are looking to include some assessment of biodiversity and this work will need to continue in future years.

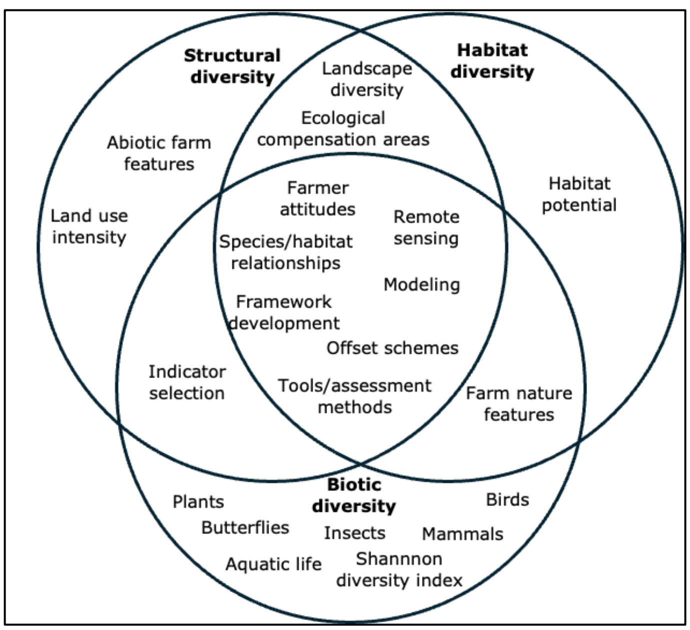

Figure 4: The key performance indicators (KPIs) identified for biodiversity in the literature and landscape review.

Conclusions:

The biodiversity literature review showed three types of indicators: structural, habitat,and biotic diversity. While no clear indicators have emerged from this work yet, many companies are looking to include some assessment of biodiversity and this work will need to continue. Many of the KPIs for GHG emission intensity were related to homegrown feed production and manure system. Reducing fertilizer and 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 improve farm economics. Other KPIs include heifer to cow ratio and herd feed consumption 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.

Outreach:

Events attended by NNY farmers and farm advisors

- NMSP External Advisory Committee, July 2024, NNY participants in attendance.
- Statewide Field Crop Extension Educators Meeting, Ag In-Service Gathering, Cornell University, November 2024.
- 2024 Cornell Nutrition Conference, Syracuse, NY: Dairy farming & greenhouse gas emissions: How do we get started?, Czymmek, K., Godber, O.F., Ray, L., Workman, K. Van Amburgh, M. October 23, 2024.
- PRODAIRY Spring 2024 Dairy Greenhouse Gas Webinar Series: Quantifying nutrient balances and greenhouse gas emissions from your dairy, Godber, O., Q.M. Ketterings, March 15, 2024, Zoom.
- 2024 NNYADP Research Update Meeting. Miner Institute, Chazy NY: Connecting the Dots: Dairy Sustainability, Value of Manure, Yield Stability Zones, Ketterings, Q.M., March 13, 2024.

Agronomy factsheets:

- Factsheet #25: Whole-Farm Nutrient Mass Balances Software (updated). http://nmsp.cals.cornell.edu/publications/factsheets/factsheet25.pdf.
- Factsheet #85: Feasible Whole-Farm Nutrient Mass Balances (updated). http://nmsp.cals.cornell.edu/publications/factsheets/factsheet85.pdf.
- Factsheet #128: Reading a Whole-Farm Nutrient Mass Balance Report (new) http://nmsp.cals.cornell.edu/publications/factsheets/factsheet128.pdf.

Extension articles (including northern NY balances):

- Godber, O.F., K. Workman, K., Reed, and Q.M. Ketterings (2024). New York state, regional and county level nitrogen and phosphorus balances for harvested cropland. What's Cropping Up? blog. July 2024, https://blogs.cornell.edu/whatscroppingup/2024/07/30/new-york-state-regional-and-county-level-nitrogen-and-phosphorus-balances-for-harvested-cropland/.

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/.

Student Engagement/Training

- August 2024 project team visit to engage with two northern NY dairy farms, collaborators at the Miner Institute, and Champlain Valley Agronomics staff.

- Nutrient mass balance training for intern working at NNY consulting firm, summer 2024.

Next Steps:

We will continue the work with the eight northern New York dairy farms, their farm staff and advisors 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 potential. Our goal is to use a minimum of three years of data to account for year-to-year variability. We aim to utilize the Cornell Net Carbohydrate and Protein System to explore opportunities related to the feeding practices of dairy cows that cannot currently be modeled in Cool Farm Tool. Furthermore, expected developments in the Cool Farm Tool will allow us to quantify a wider range of manure management practices at the treatment, storage, and application stages. Findings 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 as possible. This will help to further 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:

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For More Information:

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Photos:

Photo 1, left: NMSP team and interns visited Miner Institute and Champlain Valley Agronomics to learn about agriculture and dairy sustainability. Photo: Miner Institute

Photo 2, right: Jon Rulfs of Adirondack Farms and Eric Beaver of Champlain Valley Agronomics talk with the NMSP team and interns about the importance of nutrient management and applied research, including whole farm assessments. Photo: Quirine Ketterings