Feasible Whole-Farm Nutrient Mass Balances

Balancing Nutrients on Dairy Farms

Dairy farmers can improve profitability and reduce their farm's environmental footprint by evaluating whole farm nutrient use efficiency and other key performance indicators (KPIs). The whole-farm nutrient mass balance (NMB) assessment tool can be used to derive these farm specific KPIs, identify possible areas of improvement, and track progress over time.

The NMB of a farm is the difference between the amounts of nitrogen (N), phosphorus (P), and potassium (K) imported as feed, fertilizer, animals, and other organic material (e.g. bedding, poultry manure, food waste, etc.), and nutrients exported via milk, animals, crops, and manure. This difference is then used to derive two main KPIs: NMB per tillable acre and NMB per hundredweight of milk exported.

The NMB per tillable acre KPI indicates if the farm has the potential to balance nutrients with crop requirements for its land base (an environmental efficiency indicator). The per hundredweight (cwt) of milk KPI indicates how efficiently nutrients are used to produce milk (production efficiency). Farms with a high NMB per cwt are using nutrients less efficiently than those with a lower NMB per cwt. Negative N balances may impact crop yield. Negative P or K balances may be desirable in the short-term if a farm has excessive soil test P and K levels, but such balances reflect soil mining and will reduce crop yields in the long term. Ideal NMBs are positive (>0) but not excessive as seen in Table 1.

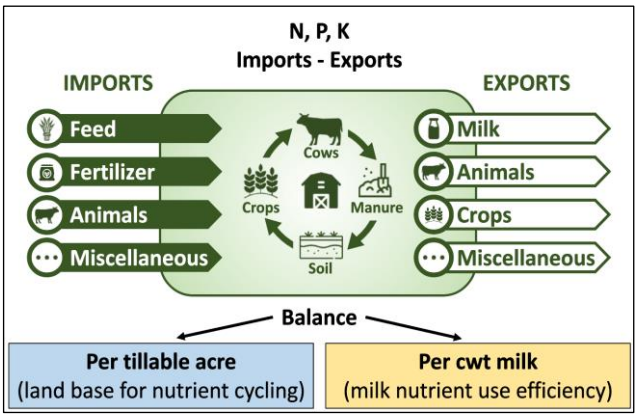


Figure 1. The NMB is the difference between the amounts of nitrogen (N), phosphorus (P), and potassium (K) imported onto and exported off the farm.

The first step to analyzing a farm's NMB is to collect information on nutrient imports and exports and entering this information into the NMB software (see Agronomy Factsheet 25 for details about the software and for access). The NMB software produces a report with NMB per acre, NMB per cwt, and some diagnostic indicators.

Distribution of NMBs for New York Dairies

New York dairy farms operate with a wide range of NMB per acre and per cwt. A study conducted in 2023 with 47 dairy farms showed ranges in NMB per acre from -66 to 323 lbs N/acre, from -11 to 37 lbs P/acre, and from -78 to 142 lbs K/acre. The NMBs per cwt ranged from -1.48 to 3.36 lbs N/cwt, from -0.03 to 0.40 lbs P/cwt, and from -1.73 to 1.08 lbs K/cwt.

Table 1: General mass balance values are shown and their desirability in the short and long term. Highlighted in red are undesirable due to an excess or mining of needed nutrients for crop growth.

Mass balance	Time period	Desirable/ Undesirable	Reason
Negative (Imp. < Exp.)	Short term	Desirable	If soil test P and K are high
	Long term	Undesirable	Soil P and K mining → yield losses
Surplus (Imp. > Exp.)	Short term	Desirable	Inefficiencies in plant and animal production
	Long term		
Large Surplus (Imp. >>> Exp.)	Short term	Undesirable	Higher risk of nutrient loss; soil P and K buildup
	Long term		Low nutrient use efficiency; economic losses

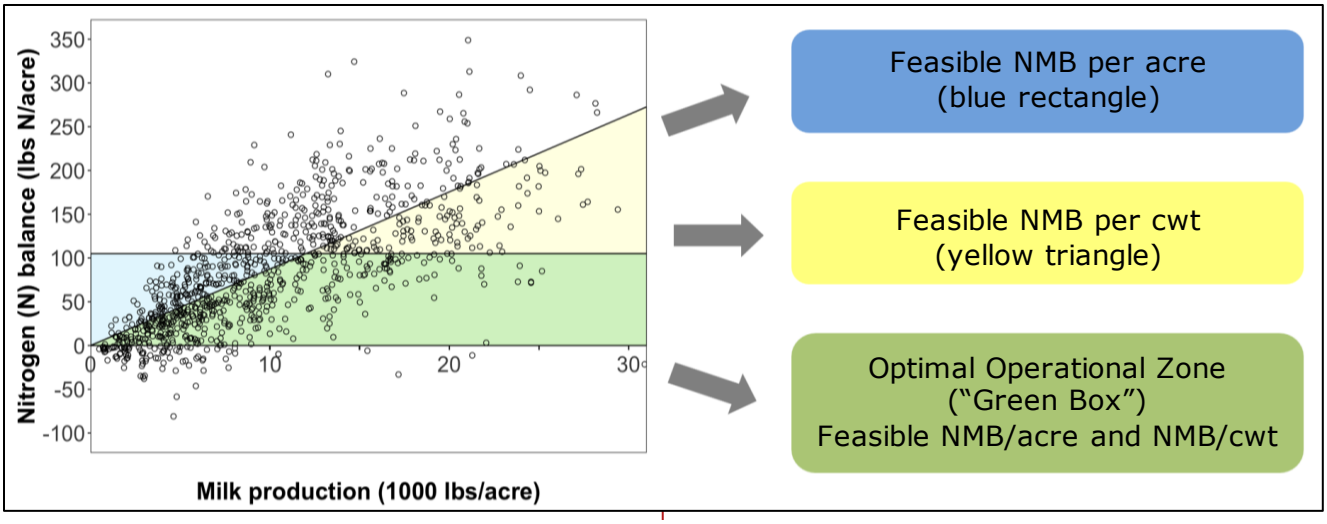


Figure 2: The nitrogen feasible balance per acre (blue), feasible balance per cwt milk (yellow) and the optimal operational zone (green) for dairy farms in New York (each circle is a farm year).

Optimum Operational Zone

A feasible NMB is defined as a balance that allows dairy farms to be economically profitable and environmentally sustainable. Feasible balances (i.e. ranges to strive to be within for a farm) have been derived for N, P, and K balances per acre and per cwt based on data from New York dairies (Table 2).

Table 2: Feasible nitrogen, phosphorus and potassium balances for New York dairy farms on a per acre and a per cwt milk basis.

	Do I have the land-base to cycle manure?	*Am I efficiently producing milk?*
Nutrient	lb per acre	lb of per cwt milk
Nitrogen	> 0 and ⩽ 105	> 0 and ⩽ 0.88
Phosphorus	> 0 and ⩽ 12	> 0 and ⩽ 0.11
Potassium	> 0 and ⩽ 37	> 0 and ⩽ 0.30

As an example, a farm that has an NMB of 10 lbs P/acre meets the feasible balances per acre while one with an NMB of 20 lbs P/acre is outside the limits. Farms that exceed the feasible balances have opportunities to improve over time. The per acre and the per cwt NMBs can be combined to define the *optimal operational zone* ("green box"), where a farm meets the feasible balances per acre and per cwt (Figure 2). The ideal situation for a farm is to be in the "green box". A farm that exceeds the feasible balance per acre but meets the feasible balance per cwt is efficiently producing milk but limited in its land-base. A farm that meets the feasible balances per acre but not the balance per cwt has sufficient land-base but opportunities to gain efficiency.

Summary

A whole farm NMB is the difference between imported and exported N, P, and K expressed per acre and per cwt of milk produced. Ideal balances are positive (>0) but not excessive. Farmers with NMBs in the optimal operational zone ("green box") are producing milk with high efficiencies and a relatively low risk of contributing nutrients to the environment.

Additional Resources

- Nutrient Management Spear Program Agronomy Fact Sheets #25: Whole Farm Nutrient Mass Balance; #128: Reading a Whole-Farm Nutrient Mass Balance Report: http://nmsp.cals.cornell.edu/guidelines/factsheets.html
- For help assessing a NMB and interpreting the results, contact Quirine Ketterings, Nutrient Management Spear Program, 323 Morrison Hall, Cornell University 14853.

Disclaimer

This fact sheet reflects the current (and past) authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this fact sheet does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of discharge levels from agricultural land.

For more information

Cornell University
Cooperative Extension

Nutrient Management Spear Program
http://nmsp.cals.cornell.edu

Julianna Lee, Olivia Godber, and Quirine Ketterings
(Sebastian Cela, Melanie Soberon, Caroline Rasmussen, and Karl Czymmek)

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