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Managing Phosphorus Balance on Virginia Dairy Farms

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Background

Virginia dairy farms can maintain milk production and improve their long-term sustainability by balancing their whole farm phosphorus imports and exports (measured here as lbs/ac P_2O_5). The annual phosphorus mass balance is the difference in the quantity of phosphorus imported onto the farm (such as purchased feed, fertilizer, etc.), and exported from the farm (such as crops, milk sold, etc.) during a year. If more phosphorus is imported than exported, this surplus phosphorus ends up in the soil through manure applications and can result in soil test phosphorus well above agronomic needs. Farmers can easily fix a negative phosphorus balance by purchasing phosphorus fertilizer or poultry litter, but a positive balance may be harder to address. Previous work in other states demonstrated that large positive phosphorus balances can be reduced over time through changes in farm management while still maintaining milk production (Cela et al. 2015). Our study evaluated the status of phosphorus balance on Virginia dairy farms and identified management risk factors associated with those farms that had excessive phosphorus.

Information on Participating Dairy Farms

Virginia dairy farms were invited to participate in the study through various types of contacts. In all, 58 dairy and mixed-operation dairy farms provided farm and phosphorus balance data. The phosphorus balance calculations were conducted in 2017, accounting for all phosphorus imports and exports that passed through the farm gate between Jan. 1 and Dec. 31 of that year. Farmers provided data on farm characteristics, such as acreage and animal numbers, as well as phosphorus imports and exports. Imports of phosphorus included in the calculations were feed purchased, fertilizers or animal manure and poultry litter, animals purchased, and bedding materials. Exports were milk sold, animals sold, crops sold, and animal manure exported off-farm. More detailed information on phosphorus measurements and other aspects of the study can be found in the journal article by Pearce and Maguire (2020). The participating dairy farms had a broad range in size, animal density, and productivity (table 1). After phosphorus balance calculations, all participating farmers were provided individualized reports that showed how they compared to the other dairy farms.

The greatest phosphorus import was through purchased feed (1 to 149 lbs/ac), followed by poultry litter generated on-farm (0.0 to 276 lbs/ac) and poultry litter imported (0.0 to 83.6 lbs/ac) (table 2). Other imports, like bedding materials, fertilizer, dairy manure, and animal purchases, averaged less than 3 lbs/ac combined. On the other hand, phosphorus tended to leave farms primarily through milk sold, especially on dairy farms that did not generate poultry litter. Milk-phosphorus exports ranged from 4.4 to 74.1 lbs/ac based on the land base and animal densities (table 2). Farms with poultry and more cropland exported as much as 276 lbs/ac of P_2O_5 in poultry litter and 54.3 lbs/ac in crop sold. The 14 dairy farms with poultry operations exported 52% of generated poultry litter, which was lower than a separate statewide assessment of 85% of generated poultry litter (Pearce and Maguire 2020). The lowest phosphorus export was through animals sold.

The median phosphorus balance of the 58 Virginia dairy farms was 25.4 lbs/ac which was similar to phosphorus surplus (26.3 lbs/ac) on 38 Danish dairies (Nielsen and Kristensen 2005). A positive phosphorus balance results when phosphorus imports exceed phosphorus exports. This study found that 79% of the participating Virginia farms had a positive phosphorus balance (greater than 0 lbs/ac), and these farms need to keep track of soil test phosphorus to minimize the environmental and regulatory impact.

Table 1. Descriptive statistics of selected characteristics for the 58 dairy, dairy and beef, dairy and poultry, and dairy, beef, and poultry farms surveyed for 2017 in Virginia.

	All farms (n = 58)			
Characteristic	Mean	Minimum	Median	Maximum
Mature dairy cows (n)	122	30	108	360
Total animal units* (AU)	251	73	226	811
Total land base (ac)	320	52	215	1,600
Manured land (%)	69	7	74	100
Animal density* (AU/ac)	1.1	0.3	0.9	2.7
Milk sold (lbs/cow/yr)	24,500	6,850	25,100	34,600
Milk sold (1000 lbs/ac)	12.2	1.9	9.5	32.4

* 1 Animal Unit = 1000 lbs animal weight (includes all dairy cows plus beef, but not poultry, as poultry litter is collected and often exported)

Table 2. Distribution of P_2O_5 imported onto and exported from 58 dairy and mixed-operation dairy farms in Virginia for 2017, separated into constituent parts.

	All farms (n = 58)			
Characteristic	Mean	Minimum	Median	Maximum
Imports, lbs/ac				
Feed	48.4	1.0	38.1	149
Poultry litter, generated	24.7	0.0	0.0	276
Poultry litter, imported	7.7	0.0	0.0	83.6
Misc, bedding	1.4	0.0	0.6	12.5
Fertilizer	0.8	0.0	0.0	21.7
Dairy manure	0.2	0.0	0.0	11.1
Animals purchased	0.2	0.0	0.0	3.2
Total	83.4	13.7	71.2	370
Exports, lbs/ac				
Milk	28.0	4.4	21.7	74.1
Poultry litter	14.8	0.0	0.0	276
Crop	4.7	0.0	0.0	54.3
Animals sold	4.6	1.1	3.7	12.0
Dairy manure	5.1	0.0	0.0	55.7
Total	57.2	5.5	41.2	341
Total P_2O_5 Balance, lbs/ac	26.2	-63.2	25.4	200

Defining a Zone of Operation for Phosphorus Balance and Phosphorus Use Efficiency

To establish reasonable guidelines for phosphorus balance targets, this study's authors drew upon an approach demonstrated in the state of New York (Cela et al. 2015). An upper phosphorus mass balance was set so that 75% of dairy farms fall below that phosphorus surplus per acre, with the idea that if 75% of farms can do this, then all farms should find it achievable. Because farms should not operate long-term with negative phosphorus balances, another bounding guideline was set along the bottom of the zone at 0 lbs/ac. Another guideline focused on phosphorus balances related to milk production, a measure of efficiency. That target was set so that 50% of dairy farms produced milk below a certain phosphorus balance per 1,000 lbs of milk.

In Virginia, the 17 farms within the sustainable zone (shaded region in figures 1 and 2) were able to both efficiently produce milk and manage phosphorus balances. In this study, 75% of the farms operated with a phosphorus balance of less than 38.3 lbs/ac, as indicated by farms falling below the horizontal dashed line in the figures. Though more sustainable than the top 25% of farms, operating at 38.3 lbs/ac can still increase Mehlich 1 soil test phosphorus by about 2 ppm (4 lbs/ac) annually in the soils of this region (Maguire, Mullins, and Brosius 2008). Farms like the one marked in figure 1 as "H" (200 lbs/ac) should drastically reduce phosphorus imports or increase phosphorus exports, and farms with a negative phosphorus balance, like the one marked as "L" (-21 lbs/ac), should monitor soil test

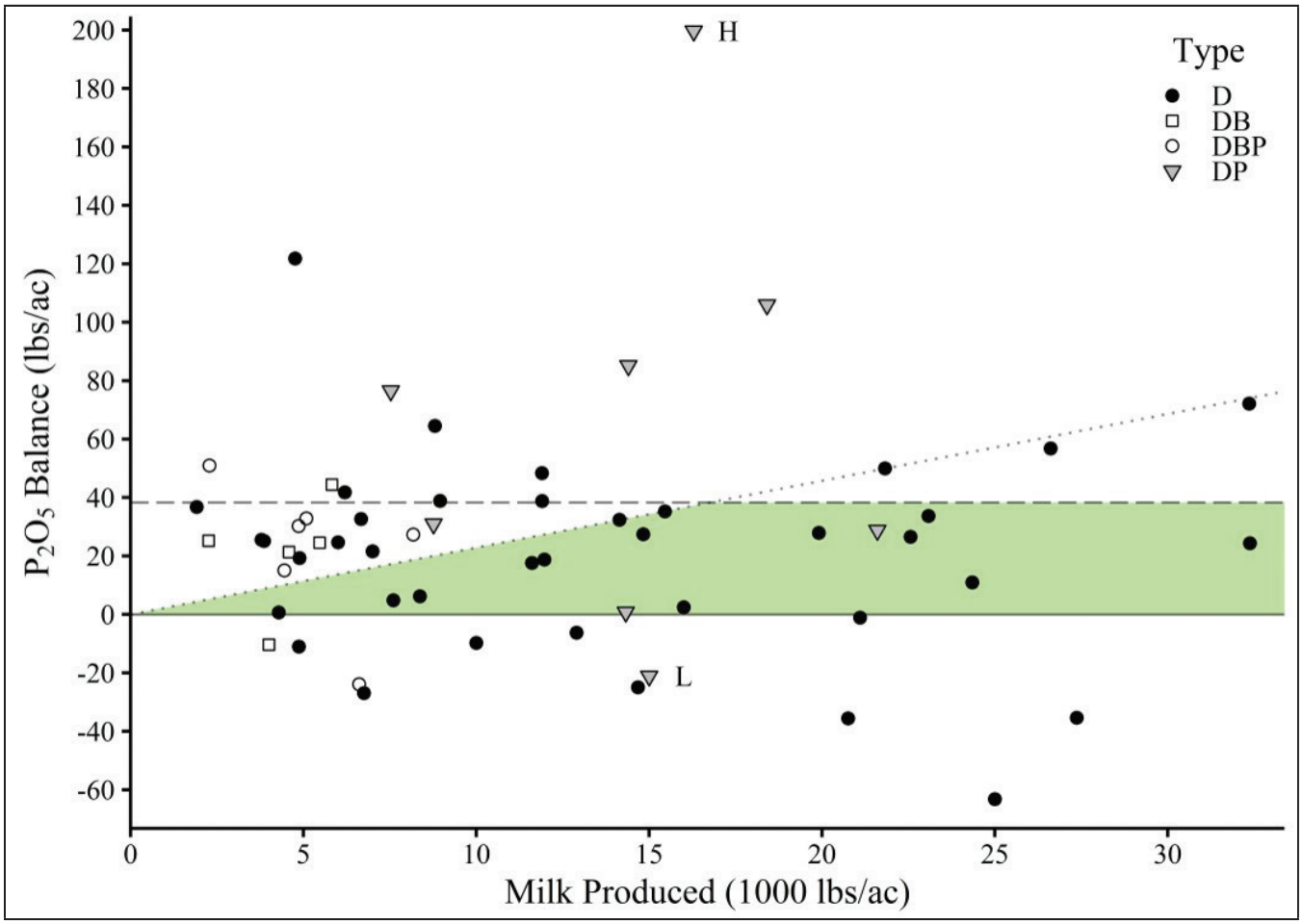

Figure1. Each point represents one of the 58 Virginia dairy and mixed dairy farms in the study. Farm types are: D = dairy operation, DB = mixed operation of dairy and beef, DBP = mixed operation of dairy, poultry, and beef, and DP = mixed operation of dairy and poultry. The shaded region bounded by the three lines represents the phosphorus balance zone of operation for minimized phosphorus balance and efficient phosphorus use. P_2O_5 balance (lbs/ac) is compared with milk production intensity (1,000 lbs/ac). Two farms with similar characteristics (land base, dairy herd size, and milk production, both with poultry production) have been marked "H" and "L" for their high and low phosphorus balances.

phosphorus to avoid limiting yields in the long run. The average phosphorus use efficiency of Virginia dairy farms was 2.2 lbs of surplus phosphorus per 1,000 lbs-milk (figure 1). As there was no correlation between farm phosphorus balance and milk production, farms can improve phosphorus use efficiency without affecting milk production. phosphorus to avoid limiting yields in the long run.

When looking at farm type, the eight mixed-operation dairy and poultry farms (DP) had the greatest median phosphorus balance of 53.6 lbs/ac followed by the six mixed-operation dairy, poultry and beef farms (DBP) with a median phosphorus balance of 28.8 lbs/ac. The mean phosphorus balance for all farms was 25.4 lbs/ac (figure 1).

Dairy farms with poultry (DP and DBP) falling above the feasible operation zone did not export poultry litter. Farms can export excess poultry litter to reduce phosphorus import.

Overall, 22 out of the 58 farms applied poultry litter and had a mean phosphorus balance of 47.8 lbs/ac, which was well above median phosphorus balance of 25.4 lbs/ac for all of the farms in the study (figure 2). Of the 11 farms with the highest farm phosphorus balance and below-average milk production, nine applied poultry litter. Some farms were able to use poultry litter without having an excessive phosphorus balance, but these tended to have more cropland and were able to grow more of their own feed and therefore import less phosphorus in feed. The high phosphorus content in poultry litter makes it the largest risk factor for phosphorus imbalance in this study. Other factors, like animal density and use of dried distiller's grains (DDGs), were not direct risk factors for Virginia dairy farms.

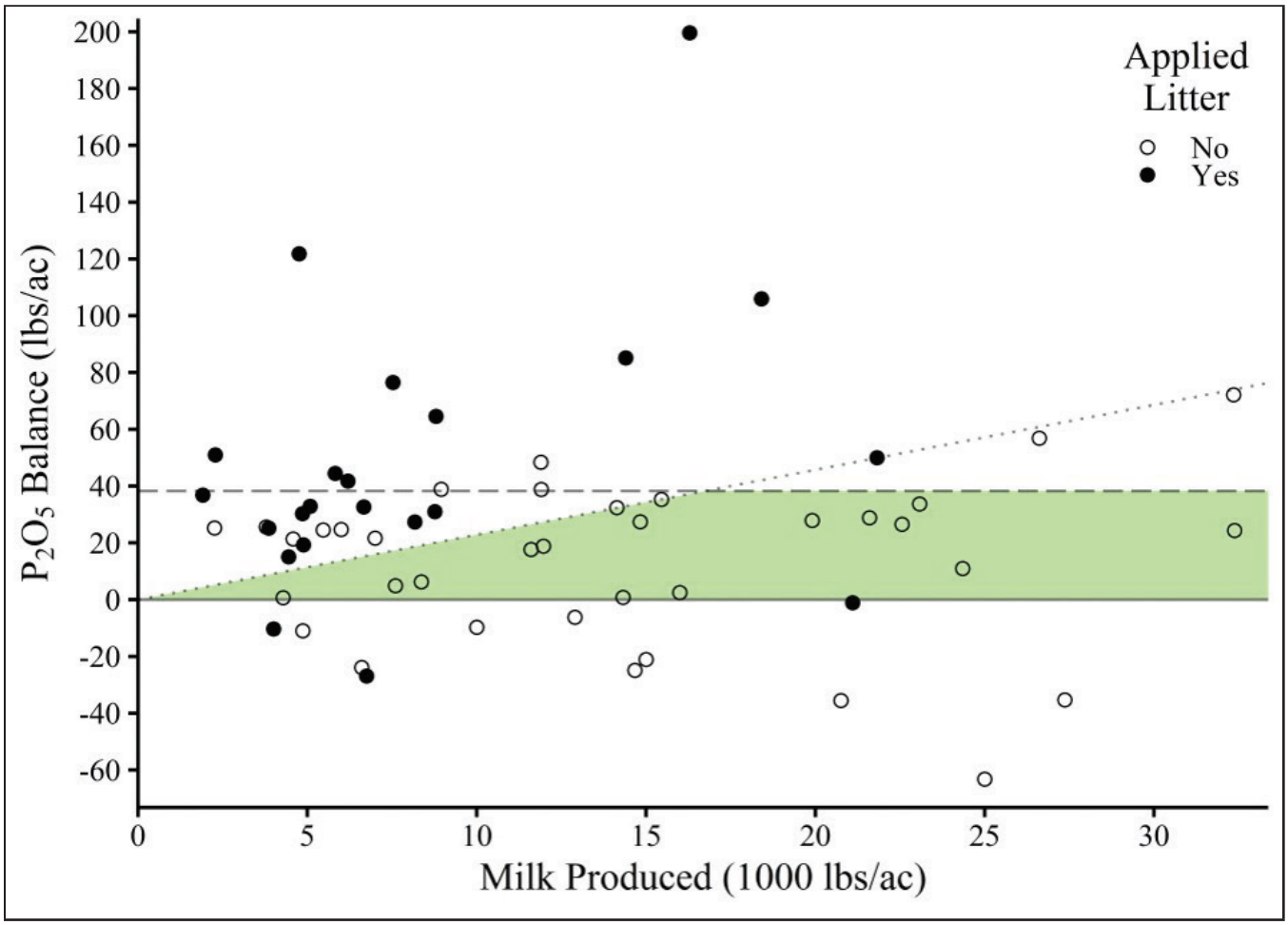

Figure 2. Each point represents one of the 58 Virginia dairy and mixed dairy farms in the study. The shaded region bounded by the three lines represents the phosphorus balance zone of operation for minimized phosphorus balance and efficient phosphorus use. P_2O_5 balance (lbs/ac) is compared with milk production intensity (1,000 lbs/ac). Dairy farms with a net import of poultry litter (n = 22) are highlighted.

Conclusions on Phosphorus Management on a Farm

There was no direct link between phosphorus balance and milk production, and therefore some Virginia dairy farmers efficiently balanced phosphorus without affecting the production of milk. Farms that fall outside the feasible zone of operation can improve phosphorus balance by changing management practices with the help of the indicators in table 2. There were two clear risk factors for surplus phosphorus balance: 1) excess use of poultry litter, and 2) excess phosphorus imported in purchased feed. While poultry litter is a good fertilizer in many situations, excess phosphorus balances can be minimized by avoiding regular use of poultry litter and exporting generated poultry litter from mixed dairy and poultry farms. Likewise, farmers with a phosphorus deficit could assist by importing poultry litter from local farms with excess phosphorus. It is also important to optimize homegrown feed production and follow precision feeding practices with purchased feeds. Overall, farms can increase their phosphorus use efficiency for long-term sustainability while maintaining milk production by minimizing risk factors associated with increasing soil test phosphorus concentrations.

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