U.S. MIDWEST DAIRY MANURE NUTRIENT OBSERVATIONS 2012-2022

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ABSTRACT

Dairy manure is a source of organic nutrients with variable manure characteristics. This analysis drew 2012-2022 data from ManureDB, the manure and organic amendment database developed by the University of Minnesota. Thousands of solid dairy and liquid dairy manure samples across 2012-2022 were evaluated for book value comparisons, temporal trends, and regional differences for total N, NH_4-N, P_2O_5, and K_2O analytes. The only significant trend detected in the Midwest (MW) region was a decreasing trend of P_2O_5 in solid dairy manure across 2012-2022. The analyte medians for the animal manure categories were compared to the MWPS (MidWest Plan Service) and ASABE (American Society of Agricultural and Biological Engineers) analyte book values when available. Data from ManureDB suggested that total N, P_2O_5, and K_2O was lower for solid dairy manures than ASABE summaries. When comparing the region, analyte, and year combinations, we found that the MW-NE regions exhibited a significant difference of 73% for solid dairy manure and 64% for liquid dairy manure, and the MW-SE region comparison demonstrated a significant difference of 84% for solid dairy and 100% for liquid dairy manure. Regional differences appeared to influence manure nutrient composition; however, the lack of consistent labeling regarding manure storages, bedding type and inclusion, and treatments complicated the ability to draw conclusions on these regional differences. ManureDB's growing database allows for improved snapshots of U.S. dairy manure, manure nutrient benchmarking, and an updated data source for agricultural and environmental modeling.

INTRODUCTION

The University of Minnesota created a manure and organic amendment nutrient database called ManureDB to aggregate manure nutrient characteristics. By 2025, ManureDB had over 550,000 samples across 1998-2025 (Bohl Bormann et al., 2025a). The database aggregates agricultural laboratory data across the U.S. and was first released to the public in 2023 with data attributed to specific regions across the US and spanning back to 1998. With many dairies located in the MW, dairy manure is a crop nutrient source utilized on nearby fields. These manure nutrients can vary greatly depending on animal housing, water utilization, animal type and genetics, climate, and manure treatment and storage. The goal of this study was to examine if concentrations of manure total nitrogen (N), phosphorus (P_2O_5), potassium (K_2O), and total N component, ammonium-N (NH_4-N) had significant trends, regional differences, and book value differences over the years 2012-2022 for MW liquid and solid dairy manure. This updated survey of manure characteristics can assist with farmer benchmarking, agricultural and environmental modelling, and manure management planning.

MATERIALS AND METHODS

The manure nutrient data for this analysis was pulled from ManureDB in February 2024 (Bohl Bormann et al., 2025a). Specific details on the ManureDB's design, data input and cleaning, and features can be found in Bohl Bormann et al. (2025b). The dairy manure samples were divided into liquid with <10% total solids and solid with >10% total solids categories. We focused on samples from the MW, which included IA, IL, IN, MI, MN, MO, OH, and WI for this study. For the 2012-2022 period there were >16,000 solid and >43,000 liquid MW dairy samples.

Because the data is not normally distributed medians, median absolute deviations (MAD), and relative median deviations (RMD) were calculated instead of means, standard deviations, and coefficient of variations. The MAD was calculated by finding the median of a data set, subtracting the median from each value in the dataset, and then finding the median from those calculations. The RMD was calculated by dividing MAD by median and multiplying by 100. The non-parametric Mann-Kendall trend test was used using the 'MannKendall' function in R (McLeod, 2022; R Core Team, 2023) to calculate test statistics and 2-sided p-values, identifying increasing, decreasing, or no significant trends. The non-parametric Mann-Whitney U test was selected to compare regions in the same year, for those regions with at least 500 samples within the 2012-2022 timeframe (MW, Northeast (NE), and Southeast (SE)) for four analytes (total N, NH_4-N, P_2O_5, and K_2O) using the wilcox_test and P.adjust functions from the R package 'coin' ((Hothorn et al., 2023; R Core Team, 2023).

For comparison to the previously published book values, we compared ManureDB analyte medians to the similar species manure type for the ASABE (ASABE, 2005) and MWPS (Lorimor et al., 2004) nutrient mean book values. Sometimes MWPS and ASABE had several values for a species to account for different life stages or manure storages. In those cases, the range of the highest and lowest analyte values for a species was compared to the ManureDB median and a percent difference was calculated by subtracting the ManureDB median from the closest book value number divided by the closest book value number, then multiplied by 100. The data file, R code, and output are found in Bohl Bormann et al., 2024a.

RESULTS AND DISCUSSION

ManureDB and Book Value Comparisons

We found differences between ManureDB and book values, although it is difficult to discern if these are due to changes in manure concentrations or greater quantities and locations now included. (Table 1 and Figure 3). The MW liquid dairy manure medians were less than MWPS means for total N, P_2O_5, and K_2O and greater for NH_4-N. The MW solid dairy manure medians were less than MWPS means for total N and NH_4-N and less than ASABE means for total N, P_2O_5, and K_2O.

Table 1. Descriptive statistics of as-received Midwest dairy manure sample characteristics in ManureDB, for 2012 to 2022.

Liquid dairy manure (<10% total solids)

Source/ Analyte	Median	MAD[b]	RMD[c]	25%[d]	75%[e]	Count
	lbs/1000 gal		**%**	lbs/1000 gal		
ManureDB Midwest Region[a]						
Total N	18.2	6.6	36%	13.3	22.5	43,346
NH_4-N	8.3	5.0	59%	4.8	11.7	21,318
P_2O_5	7.4	3.7	50%	4.8	9.8	43,278
K_2O	17.8	5.8	33%	14.0	21.7	43,365
MWPS[f]						
Total N	27-31					
NH_4-N	5-6					
P_2O_5	14-15					
K_2O	19-28					
ASABE[g]						
Total N	5.8, 25					2,707
NH_4-N	6.7, 11.7					2,707
P_2O_5	3.3, 25					2,707
K_2O	10.8, 40					2,707

Solid dairy manure (>10% total solids)

Source/ Analytes	Median	MAD[b]	RMD[c]	25%[d]	75%[e]	Count
	lbs/ton		**%**	lbs/ton		
ManureDB Midwest Region[a]						
Total N	8.2	4.2	51	6	12.2	16,338
NH_4-N	1.6	2.1	130	0.08	3	7,500
P_2O_5	3.5	2.1	59	2.4	5.9	16,332
K_2O	6.7	3.8	57	4.8	11.2	16,331
MWPS[f]						
Total N	9-10					
NH_4-N	2					
P_2O_5	3-4					
K_2O	5-7					
ASABE[h]						
Total N	10.6-14					666
NH_4-N						
P_2O_5	6-11.4					666
K_2O	9.6-16					666

[a]ManureDB (Bohl Bormann et al. 2025a); [b]median absolute deviation; [c]relative median deviation; [d]25th percentile; [e]75th percentile; [f]Dairy cow, heifer, calf, and herd range of means (Lorimor et al., 2004); [g]Dairy lagoon effluent, slurry means (ASABE, 2005), [h]Dairy scraped concrete, earthen lots means (ASABE, 2005).

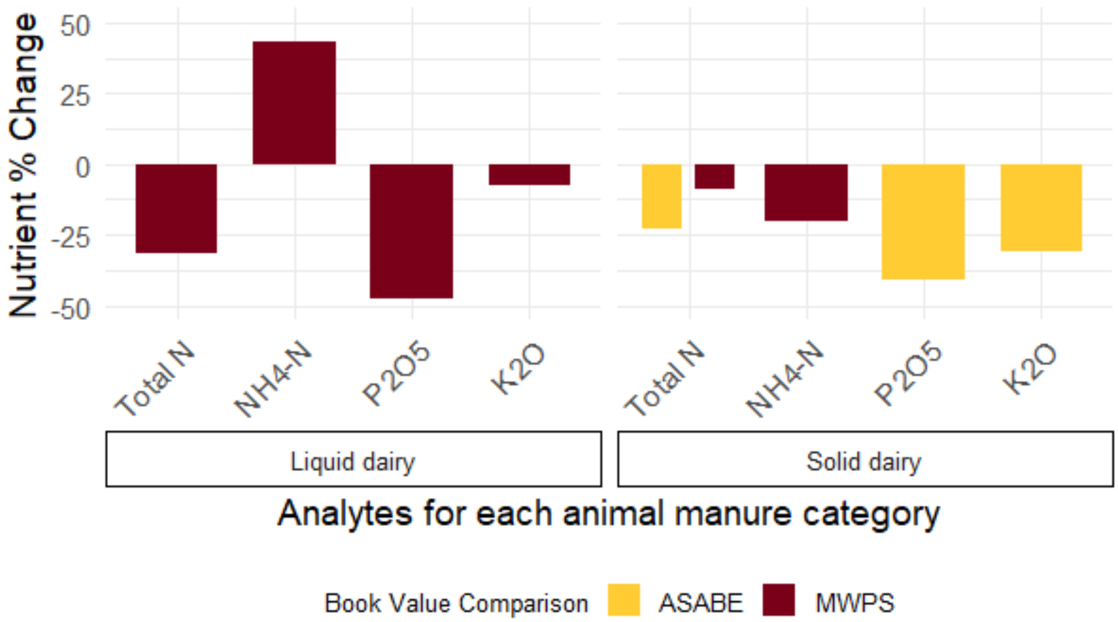

Figure 3. Percent change of manure characteristics (total N, NH_4-N, P_2O_5, and K_2O) from book values (ASABE and MWPS) for Midwest region liquid and solid dairy manure categories from 2012-2022.

Regional Nutrient Comparisons

Regional differences were noticeable in both liquid and solid dairy manure nutrient concentrations (Table 2, Figures 4 and 5) with regions significantly different for more than half of the years for all the analytes. The MW-SE comparison had more years significantly different than the MW-NE comparison for both liquid and solid dairy manure.

Table 2. The percentage of years between 2012-2022 with significant differences between regions for N, NH_4-N, P_2O_5, and K_2O comparisons. Liquid (<10% total solids) and solid (>10% total solids) dairy manures were reported separately.

	Liquid dairy manure		Solid dairy manure	
Analyte	MW-NE	MW-SE	MW-NE	MW-SE
	% of years significantly different			
Total N	64	100	64	91
NH_4-N	73	100	82	100
P_2O_5	55	100	73	100
K_2O	64	100	73	45

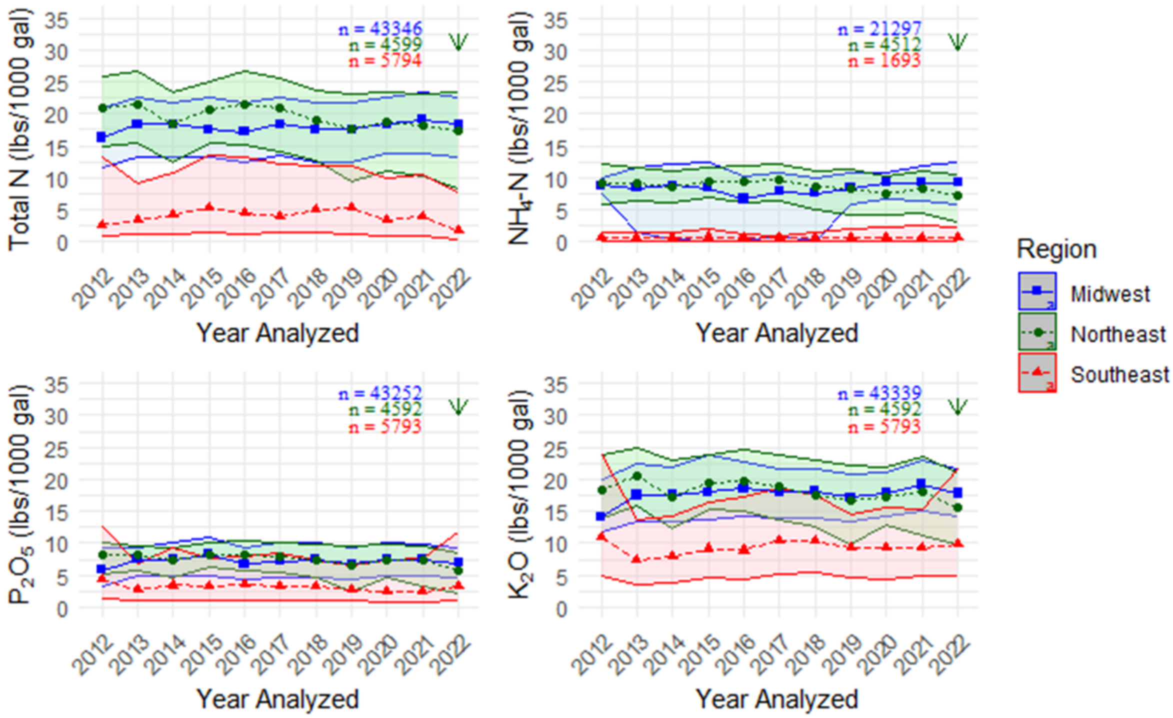

Figure 4. Liquid dairy manure total N, NH_4-N, P_2O_5, and K_2O medians from 2012-2022 for the Midwest, Northeast, and Southeast regions. Only regions with at least 500 samples and samples for each year were included in this analysis. ↓Indicates a significant decreasing trend, which was only found for the northeast region.

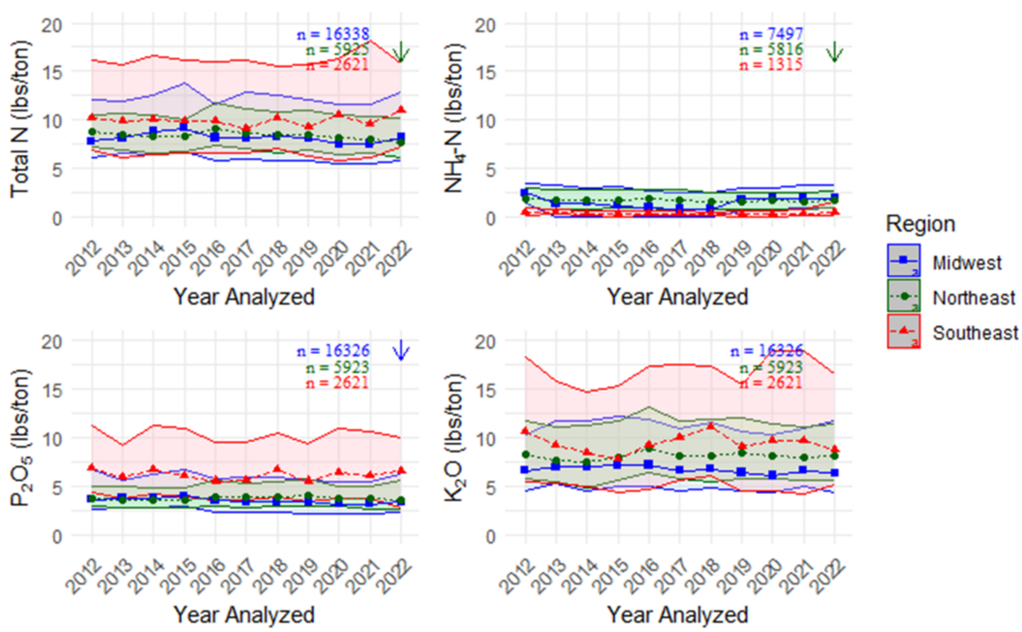

Figure 5. Solid dairy manure total N, NH4-N, P2O5, and K2O medians from 2012-2022 for the Midwest, Northeast, and Southeast regions. Only regions with at least 500 samples and samples for each year were included in this analysis. ↓Indicates a significant decreasing trend and the color of the arrow matches the color of the region.

Midwest Dairy Nutrient Trends

Solid dairy manure had the only significant MW nutrient trend with a decreasing P_2O_5 trend (Figure 5). While this trend was likely too small to impact agronomic nutrient management planning, it will be helpful to monitor as the database continues to add data annually. The MW liquid dairy manure did not have any significant trends over this period.

Future Plans

Work is underway to evaluate other manure sample metadata in addition to region such as total solids, storage type, animal type, manure type, and bedding type for updating the ASABE Manure Production and Characteristics standard ASAE D384.2. The ManureDB team will continue to incorporate new data from past and new collaborators into ManureDB, improve the website and its features, and archive data annually in the USDA National Agricultural Library's Ag Data Commons (Bohl Bormann et al. 2024b). On farm manure sampling is still strongly encouraged as manure nutrient concentrations vary greatly.

ACKNOWLEDGEMENTS

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