Effects of Long-Term Poultry Litter Application On Inorganic and Enzyme Hydrolyzable Phosphorus in Texas Blackland Vertisol

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Introduction

Animal manure has been known to be a beneficial soil amendment for many centuries. Poultry litter (PL), when used as a nutrient source for crop production, can supply all nutrients required for optimum plant growth. However, when used without an adequate management plan, manure can become detrimental to the environment, as runoff from improperly managed PL-amended land can contribute to surface water eutrophication.

Much of the P in PL exists in forms that are not immediately available for plant up; therefore, repeated or over-application of PL can lead to P-loading of soil. A better understanding of how manure impacts the different phosphorus (P) pools in the soil is needed to improve manure management plans and maintain environmental quality and production sustainability.

Objective

To determine the impact of long-term PL application and PL application rate on the distribution of P forms [inorganic (P_i), enzymatically hydrolyzable organic (P_e), non-hydrolyzable organic (P_{ne})] in a Texas Blackland Vertisol.

Materials and Methods

- A long-term (2000-2012) watershed-scale study was conducted where PL (turkey litter) at different rates or inorganic fertilizer were applied annually to cropped (fallow-corn-wheat rotation) and pasture (hayed or grazed) Texas Blackland Vertisol plots (Table 1). Further management information can be found in Harmel et al. (2009, 2011). Soil samples were collected in winter and sequentially extracted with a modified Hedley procedure, where soil was extracted with water (H_2O), 0.5 M sodium bicarbonate ($NaHCO_3$), 0.1 M sodium hydroxide (NaOH), and 1.0 M hydrochloric acid (HCl) (Waldrip-Dail et al., 2009).
- A fairly standardized designation is separation of extracted P into labile-P (H_2O- and 0.5 M $NaHCO_3$-P_i and P_o), moderately labile, Fe/Al-associated-P (0.1 M NaOH-P_i and P_o), and stable, Ca-associated-P (HCl-P_i and P_o), and residual-P fractions (Hedley et al. 1982; Cross and Schlesinger 1995; Negassa and Leinweber 2009).
- Enzyme hydrolysis of soil extracts were performed according to He and Honeycutt (2001) using acid phosphomonoesterase type I from wheat germ (E.C. 3.1.3.2), type IV-S from potato (E.C. 3.1.3.2), and nuclease P1 from *Penicillium citrinum* (E.C. 3.1.30.1).
- All analyses were conducted in triplicate and significance determined by single factor ANOVA.

Results and Discussion

- Repeated application of PL resulted in significant increases in total soil P content.
- These changes were largely due to increases in Ca-associated P (HCl-P_{ne}, Fig. 1d), and labile inorganic P adsorbed on crystalline surfaces ($NaHCO_3$-P_i, Fig. 1b).
- There were also small, but inconsistent, increases in moderately labile Al/Fe-associated enzyme hydrolyzable organic P (NaOH-P_e, Fig. 1c.).
- A similar trend in soil P changes was observed when PL was applied to pastureland at high rates (13.4 Mg/ha).
- In general, concentrations of all soil P forms were lower in pastureland than in cultivated plots.

Table 1. Annual fertilization and land use type.

Watershed	Annual PL rate	Average annual P rate	Land use type
	(Mg ha^{-1})	(kg ha^{-1})	
Y6 (Con)	0	0	Cultivated
Y13	4.5	126	Cultivated
Y10	6.7	188	Cultivated
W12	9.0	252	Cultivated
W13	11.2	314	Cultivated
Y8	13.4	376	Cultivated
SW12	0	0	Native pasture, hayed
SW17	0	0	Pasture, grazed
W10	6.7	188	Pasture, hayed and grazed
Y14	13.4	376	Pasture, hayed

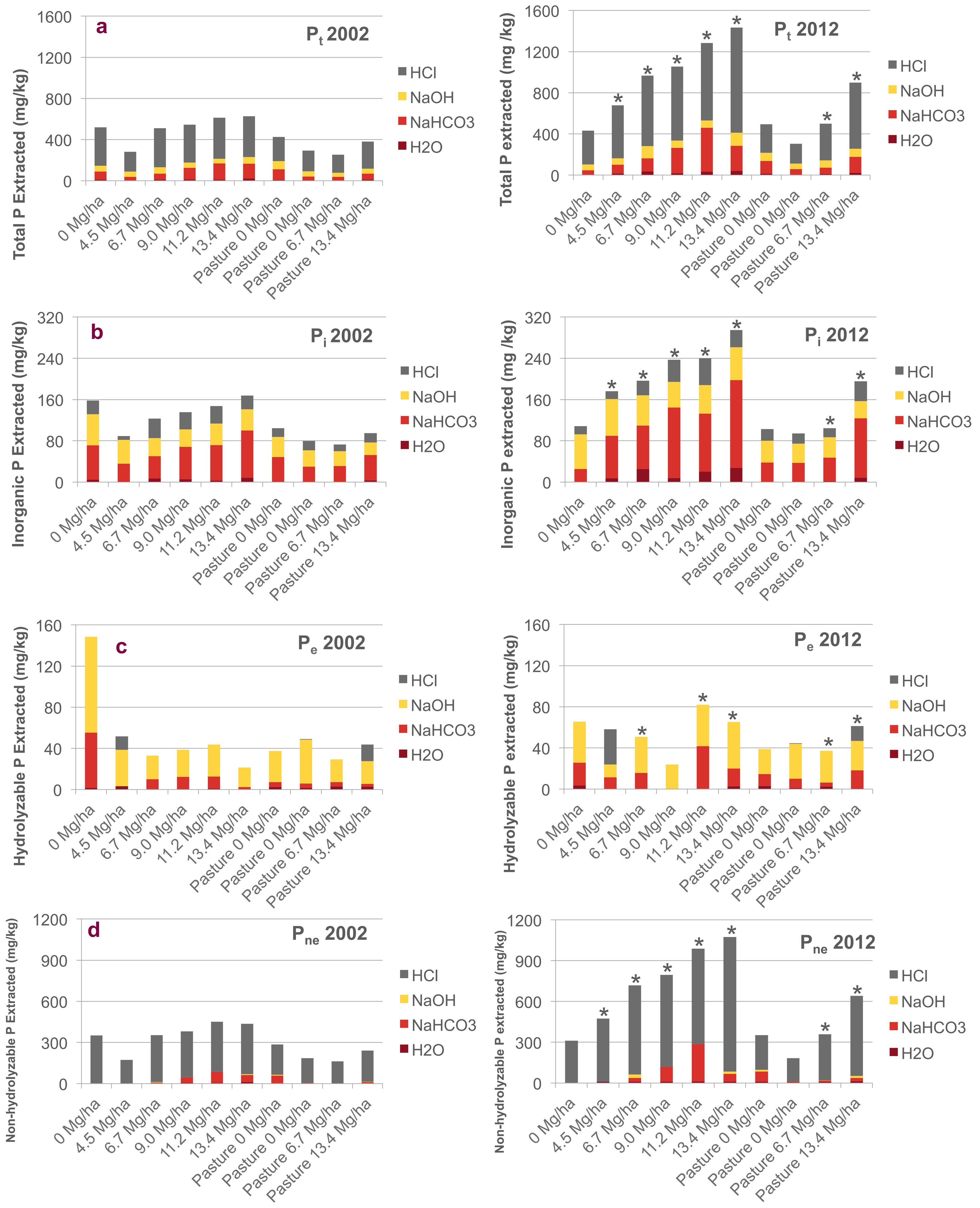

Figure 1. Average concentrations of total P (P_t) (a), P_i (b), P_e (c), and P_{ne} (d) determined from soil samples collected in 2002 (left) and 2012 (right) in cultivated and pasture soils. Water (H_2O), sodium bicarbonate ($NaHCO_3$), sodium hydroxide (NaOH), and hydrochloric acid (HCl). Asterisk (*) indicates a significant ($p<0.05$) increase in P levels between 2002 and 2012.

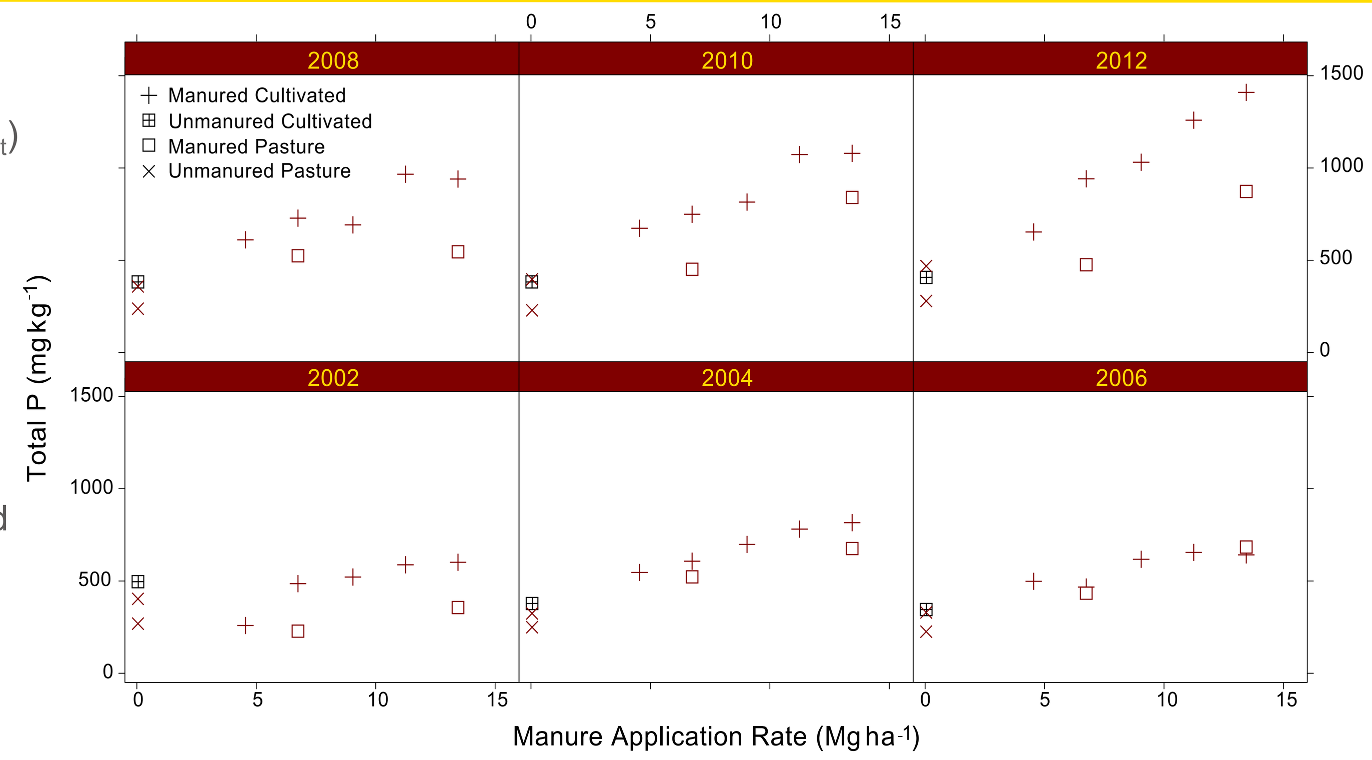

Figure 2. Average increase in total P (P_t) determined from soil samples collected from 2002 to 2012 extracted with water (H_2O), sodium bicarbonate ($NaHCO_3$), sodium hydroxide (NaOH), and hydrochloric acid (HCl) of Texas Blackland Vertisol.

Table 2. Comparison of change in average concentrations (standard error) of forms of enzymatically hydrolyzable P [phosphomonoesters (monoester), deoxoribonucleic acid (DNA), phytate].

Treatment	Monoester-P	DNA-P	Phytate-P
	mg kg^{-1}		
Unmanured Cultivated 2002	41.28 (6.12)	37.70 (5.33)	69.49 (20.82)
Unmanured Cultivated 2012	37.21 (10.01)	7.22 (4.70)	21.06 (5.31)
Manured Cultivated 2002	22.69 (2.62)	11.00 (2.39)	4.01 (1.61)
Manured Cultivated 2002	36.54 (3.74)	10.23 (2.72)	9.21 (2.10)
Unmanured Pasture 2002	23.86 (4.31)	9.88 (2.29)	9.63 (1.61)
Unmanured Pasture 2012	18.86 (1.66)	7.56 (1.15)	15.24 (2.81)
Manured Pasture 2002	14.92 (1.51)	5.88 (1.35)	15.67 (5.23)
Manured Pasture 2012	24.44 (2.38)	7.27 (0.92)	17.55 (3.51)

Results and Discussion (cont.)

- When PL was applied at the same rate, both P_t and P_{ne} forms of soil P were more prone to accumulate in cultivated soils than in pastureland (Figs. 1a, b, and d), which suggests that cropland has more potential to serve as a source of legacy P than manured pastureland.
- In general the increase in P_e was due to an increase in the NaOH soluble P_e; however, there were a couple of manured plots that also showed an increase in $NaHCO_3$ and HCl soluble P_e (Figure 1c).
- The observed increase in P_e with PL application was due to an increase in the concentration of phosphomonoesters, which were 61% and 64% higher in PL-amended cultivated and pasture soils, respectively, than soil from plots that did not receive PL (Table 2).
- The DNA concentration in soil (cropped and pasture) was not influenced by PL application (Table 2).
- While PL application increased concentrations of phytate in soil from cultivated plots over 2-fold, this same effect was not observed in pasture soils (Table 2).

Conclusions

- The results of this research showed that repeated application of PL resulted in a steady increase in soil P levels throughout the years.
- Most of the increase in soil P levels was a direct result of increased labile inorganic P and stable, Ca-associated, non-hydrolyzable organic P.
- Mismanagement of PL in both cropped and pasture systems can lead to accumulation of P that is not plant available and presents risks to surface waters in the event of runoff of soluble or particulate-associated P.

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