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Soil Phosphorus Losses in Surface Runoff and Tile Drainage as Related to P-Based Addition of Various Forms of Cattle Manure and Chemical Fertilizer

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Introduction

- Nitrogen-based manure application results in phosphorus (P) build-up in soils, due to the smaller N:P ratios in manures than those required by crops. Elevated levels of P in soils can cause increased P loss into surface water resource.
- Forms and contents of P in manure vary, depending on the type (i.e. swine, cattle, etc.) and form (i.e. liquid, solid), and thus the vulnerability to loss can differ.
- In the current Ontario P Site Index, of manure P 40% in the year of application and 80% in the following years are defaulted as available, regardless of types and forms.
- Manure P source coefficients are essentially required, if risk assessment of manure and soil P is to precisely reflect the reality of field conditions after application and if soil and manure P is to be efficiently managed to minimize losses to water resource, while satisfying crop needs for maximum production.

Objectives

- To evaluate whether liquid and solid cattle manures are different in the effects on soil P loss in both surface and sub-surface runoff in a clay loam soil of Ontario, Canada, under corn-soybean rotation, in comparison with chemical fertilizer
- To determine the cattle manure P source coefficients

Materials and methods

- **Soil:** Brookston clay loam (38% clay), GPCRC, Agriculture and Agri-Food Canada, Harrow, ON, Canada
- **Experiment duration:** 4 years, 2008-2012
- **Experimental design**
  - ✓ Liquid (LCM) and solid (SCM) cattle manure and chemical fertilizer (CF, as TSP), each of them added at 50 kg P ha^{-1}
  - ✓ Fertilizers N and K added to the CF treatment at or topped up in the cattle manure treatments to 200 kg N ha^{-1} available N and 100 kg K ha^{-1}, respectively
  - ✓ All nutrients added to the corn phase of a corn-soybean rotation
  - ✓ Reps: 2; Plot size: 0.1 ha each
- **Surface & Sub-surface (tile drainage) runoff water monitoring, sampling and P determination**
  - ✓ Flow volume monitoring and water sampling:
    - Continuous & year-round using auto-monitoring and sampling systems (Fig. 1)
    - Water samples collected with every 1000 L during growing season & every 3000 L during non-growing season
  - ✓ Water P analysis: dissolved reactive P (DRP), dissolved un-reactive P (not reported here), particulate P (PP), & total P
- **Manure P source coefficient (PSC) calculation**
  - ✓ PSC = 100*(soil P loss in manure treatment/soil P loss in chemical fertilizer P treatment)

Results

- **Surface runoff flow volume (Fig. 1A)**
  - ✓ Compared with CF (188mm), LCM (164mm) decreased, while SCM (322mm) increased, the mean value of annual flow volume.

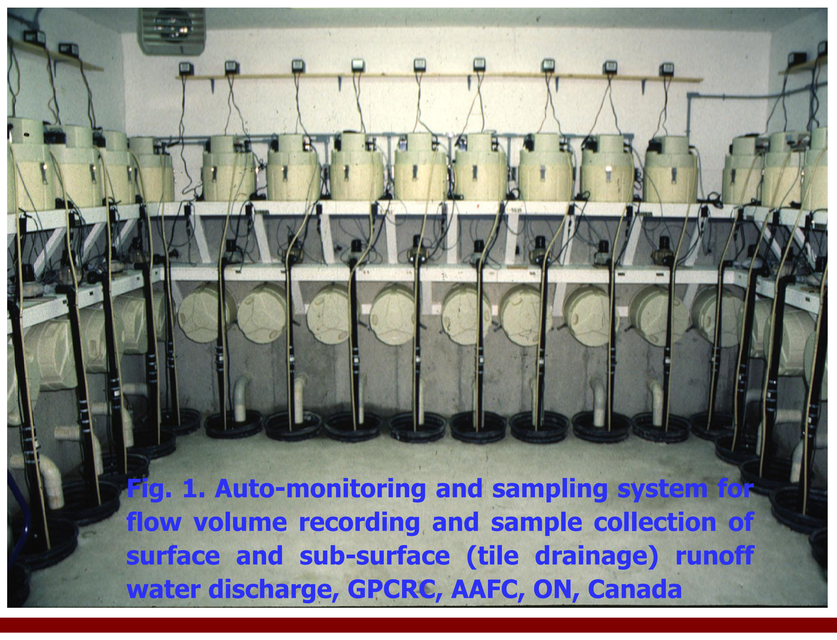

Fig. 1. Auto-monitoring and sampling system for flow volume recording and sample collection of surface and sub-surface (tile drainage) runoff water discharge, GPCRC, AAFC, ON, Canada

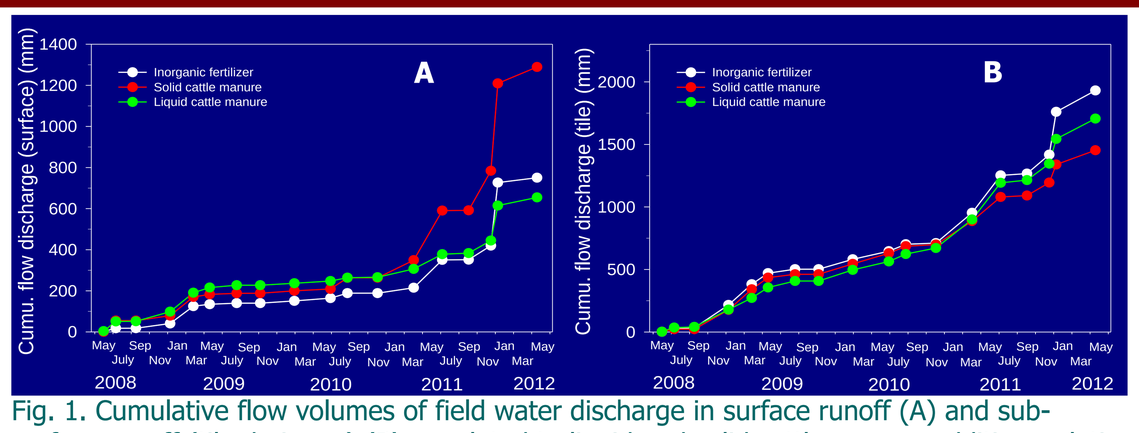

Fig. 1. Cumulative flow volumes of field water discharge in surface runoff (A) and sub-surface runoff (tile drainage) (B) as related to liquid and solid cattle manure addition, relative to chemical fertilizer, in a clay loam soil, ON, Canada, over a 4-year period, 2008-2012.

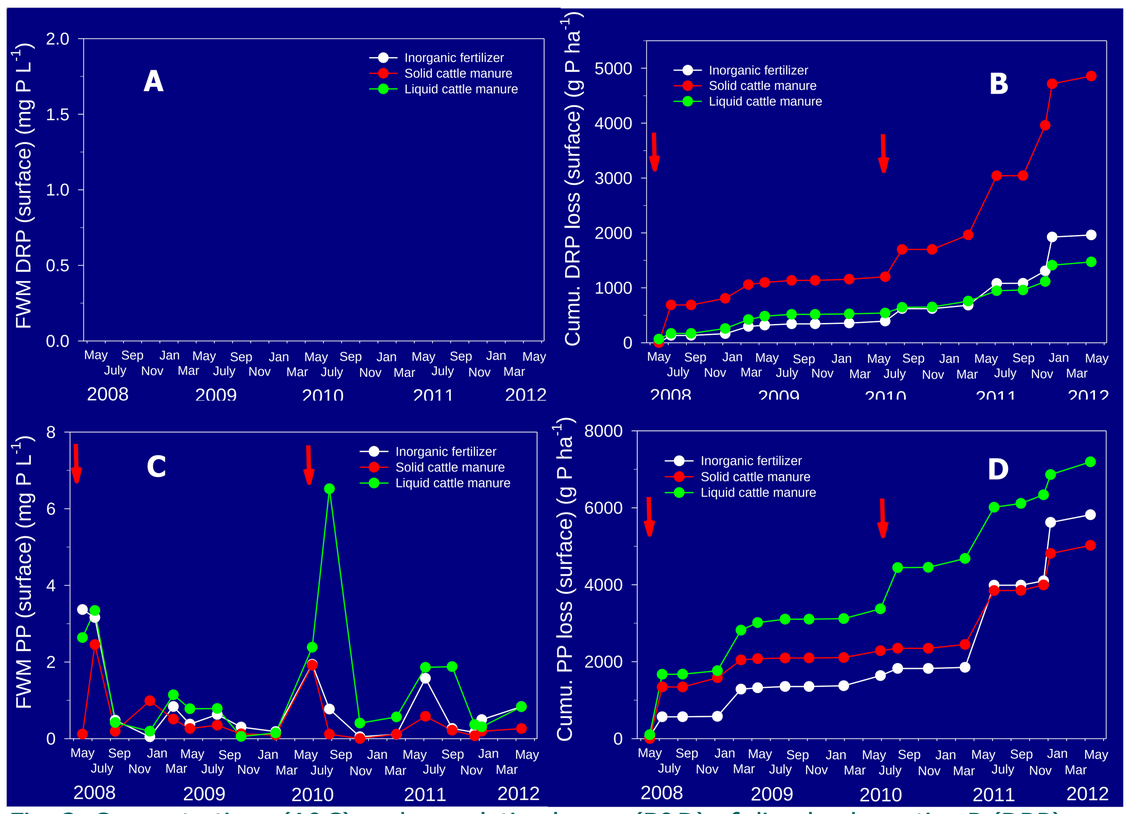

Fig. 2. Concentrations (A&C) and cumulative losses (B&D) of dissolved reactive P (DRP) (A&B) and particulate P (PP) (C&D) in surface runoff water as related to liquid and solid cattle manure addition, relative to chemical fertilizer, in a clay loam soil, ON, Canada, 2008-2012. The arrows indicate the time when the manure/fertilizer was applied.

Results (cont'd)

- **Soil P loss in surface runoff water discharge**
  - ✓ Flow volume weighted mean of P concentration (FWM) over the 4-yr period (Fig. 2, A&C)

    Compared with CF,
    - both LCM and SCM increased the FWMs of DRP;
    - LCM increased, while SCM decreased, FWM of PP and TP.
  - ✓ Soil P loss (Fig. 2, B&D, Table 1)

    Compared with CF,
    - LCM decreased the averaged anural loss (AAPL) of DRP by 25%, but increased the AAPLs of PP and TP by 114 and 11%, respectively;
    - SCM increased the AAPLs of DRP, by 147%, and TP, by 30%, although it decreased the AAPL of PP, by 13.7%.

Table 1. Four-year means of annual flow volume (AFV, mm), annual P loss (APL, g ha^{-1} yr^{-1}), and % of APL in either surface or sub-surface runoff water discharge over total soil P loss (i.e. the sum of surface and sub-surface) (% SPL) as related to addition of chemical fertilizer (CF) and liquid (LCM) and solid (SCM) cattle manure in a clay loam soil, ON, Canada

Pathway	P source	AFV	APL			% SPL		
			DRP	PP	TP	DRP	PP	TP
Surface	CF	187.6	491	1455	1972	34.4	38.2	37.0
	LCM	163.7	368	1799	2194	34.7	54.1	48.9
	SCM	322.3	1214	1256	2573	57.7	64.9	61.3
Sub-surface (tile)	CF	482.8	934	2351	3360	65.5	61.8	63.0
	LCM	426.7	693	1525	2291	65.3	45.9	51.1
	SCM	363.4	888	679	1623	42.3	35.1	38.7

Results (cont'd)

- **Sub-surface (tile) flow volume (Fig. 1B)**
  - ✓ Compared with CF, both LCM and SCM decreased the mean values of annual flow volume.
- **Soil P loss in sub-surface runoff water discharge**
  - ✓ FWM over the 4-yr period (Fig. 3, A&C)

    Similar to surface runoff, compared with CF,
    - both LCM and SCM increased the FWMs of DRP;
    - LCM increased the FWMs of PP and TP, while SCM decreased the FWMs of PP and TP.
  - ✓ Soil P loss (Fig. 3, B&D, Table 1)

    Compared with CF,
    - both LCM and SCM decreased the AAPL of TP through the reductions of DRP and PP, predominately due to the reduced flow volumes;
    - the reduction of AAPL was further enhanced with SCM, mainly in PP.
- **Soil total P loss (STPL) (surface + tile) and pathway partitioning (Table 1)**
  - ✓ STPL was reduced with both LCM and SCM, relative to CF.
  - ✓ Sub-surface runoff accounted for 35 to 66% of the STPL.
- **Manure P source coefficient (PSC)**
  - ✓ The PSCs were 74% for LCM and 147% for SCM, if calculated based on DRP loss.
  - ✓ The PSCs were 84 and 79% for LCM and SCM, respectively, if calculated based on TP loss.

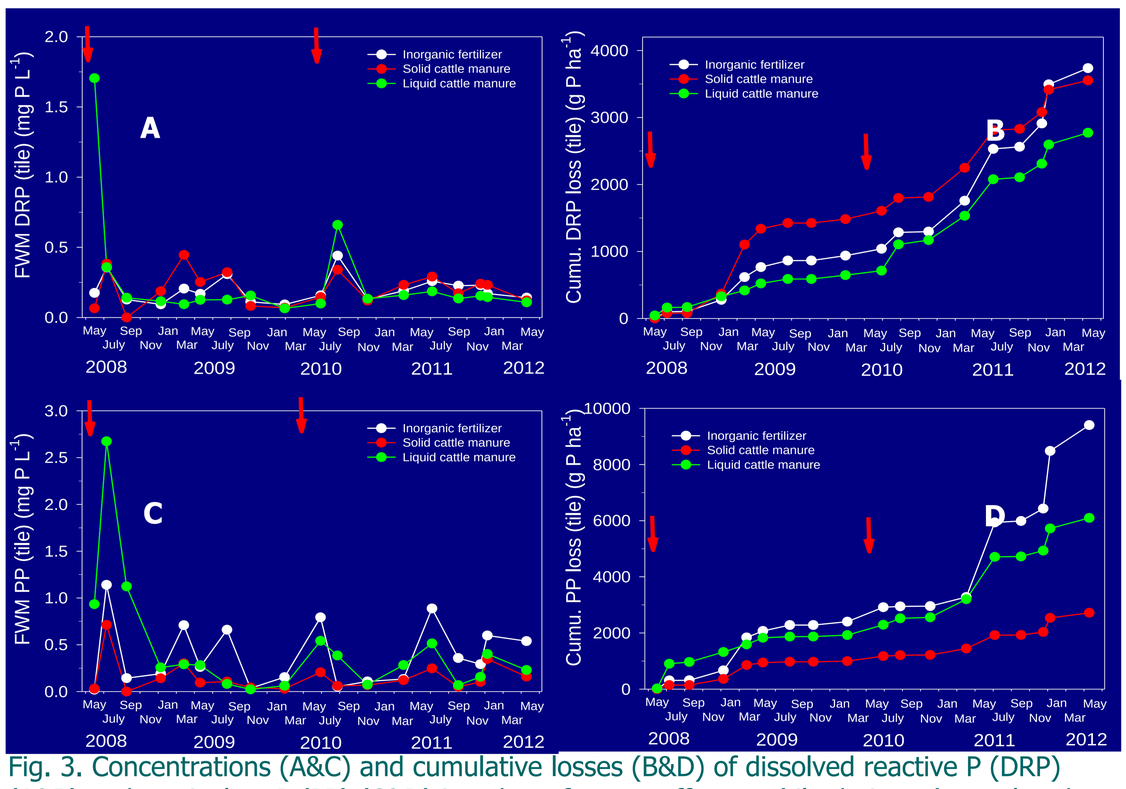

Fig. 3. Concentrations (A&C) and cumulative losses (B&D) of dissolved reactive P (DRP) (A&B) and particulate P (PP) (C&D) in sub-surface runoff water (tile drainage) as related liquid and solid cattle manure addition, relative to chemical fertilizer, in a clay loam soil, ON, Canada, 2008-2012. The arrows indicate the time when the manure/fertilizer was applied.

Conclusions

- Compared with CF,
  - ✓ P added in LCM at the same rate decreased soil DRP, PP and TP losses;
  - ✓ P added in SCM also decreased PP and TP losses, although it increased DRP loss.
- Sub-surface runoff was a mayor pathway for soil P loss.
- PSCs varied with the form of cattle manure and the form of P in field discharge water.
  - ✓ PSCs for LCM was 74%, if based on DRP loss, and 84%, if based TP loss.
  - ✓ PSCs for SCM was 147%, if based on DRP loss, and 79%, if based on TP loss.

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