Long-term manure impact on soil nutrient status and surface water quality

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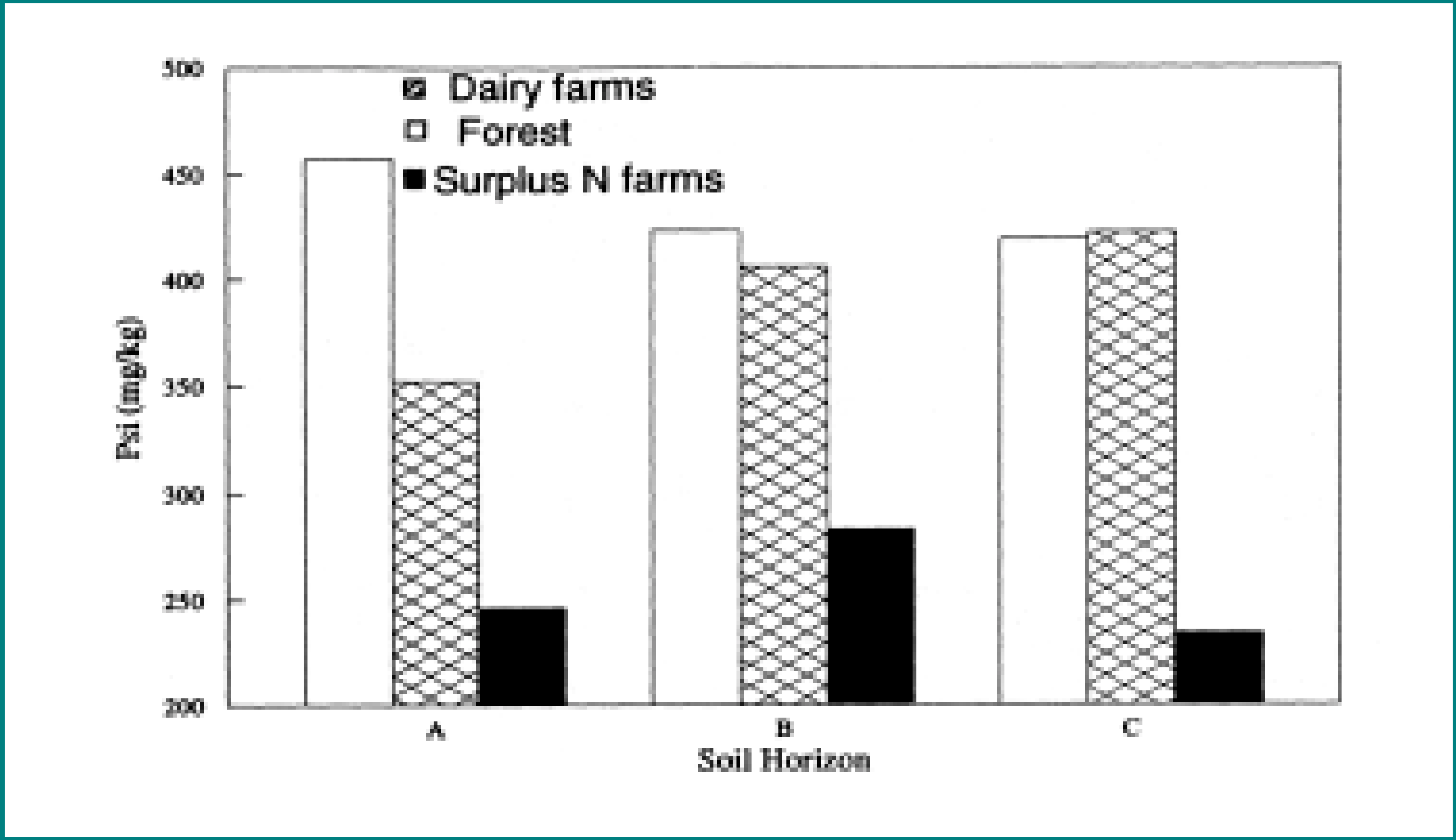
Manure impacts on soil P status

- P accumulates in soils when applied in excess of crop exports, especially in areas of high density of livestock confinement operations (Mozaffri and Sims, 1994, Simard et al. 1995)
- increases in soil-test P and degree of P saturation (Simard et al. 1995, Whalen and Chang, 2001)

Long-term manure addition reduces the soil P sorption capacity



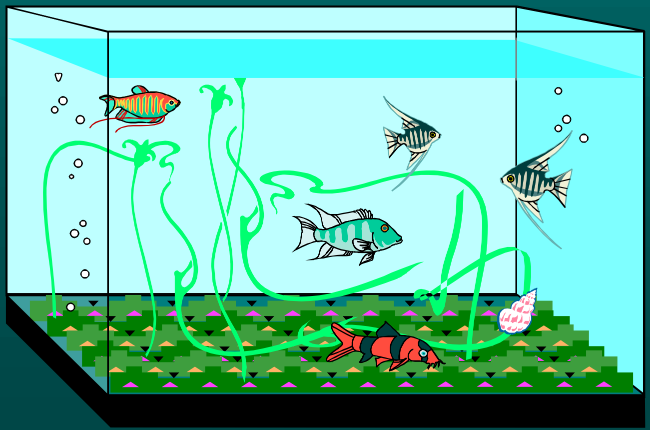
Significant contribution of soil P

- **Surface pathways (Sharpley et al. 2000)**

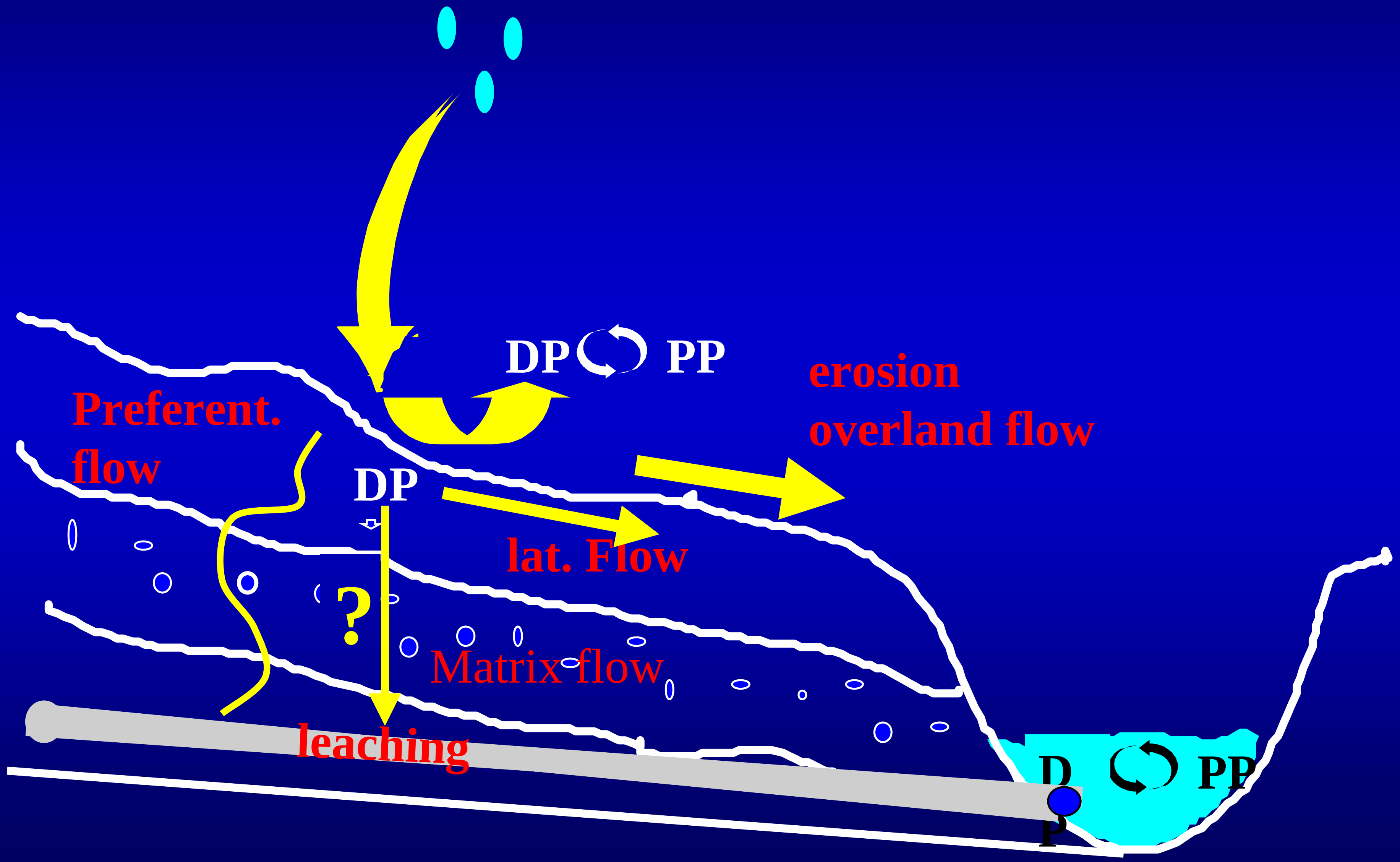
- **Subsurface pathways (Breeuwsma and Silva 1992)**

The result : eutrophication

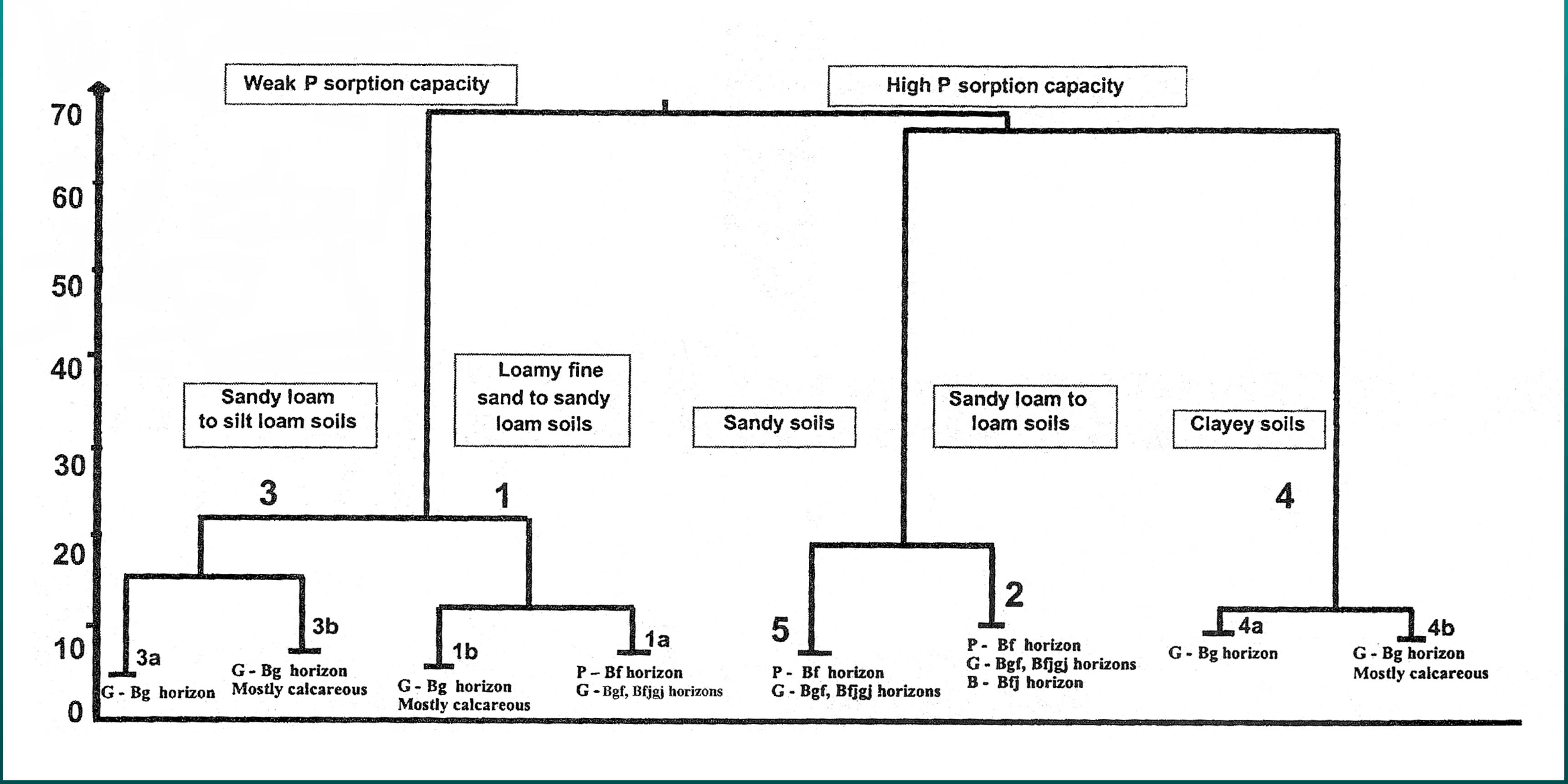
- Impaired water quality
- fisheries
- recreation
- farm industry
- drinking (USEPA 1996)

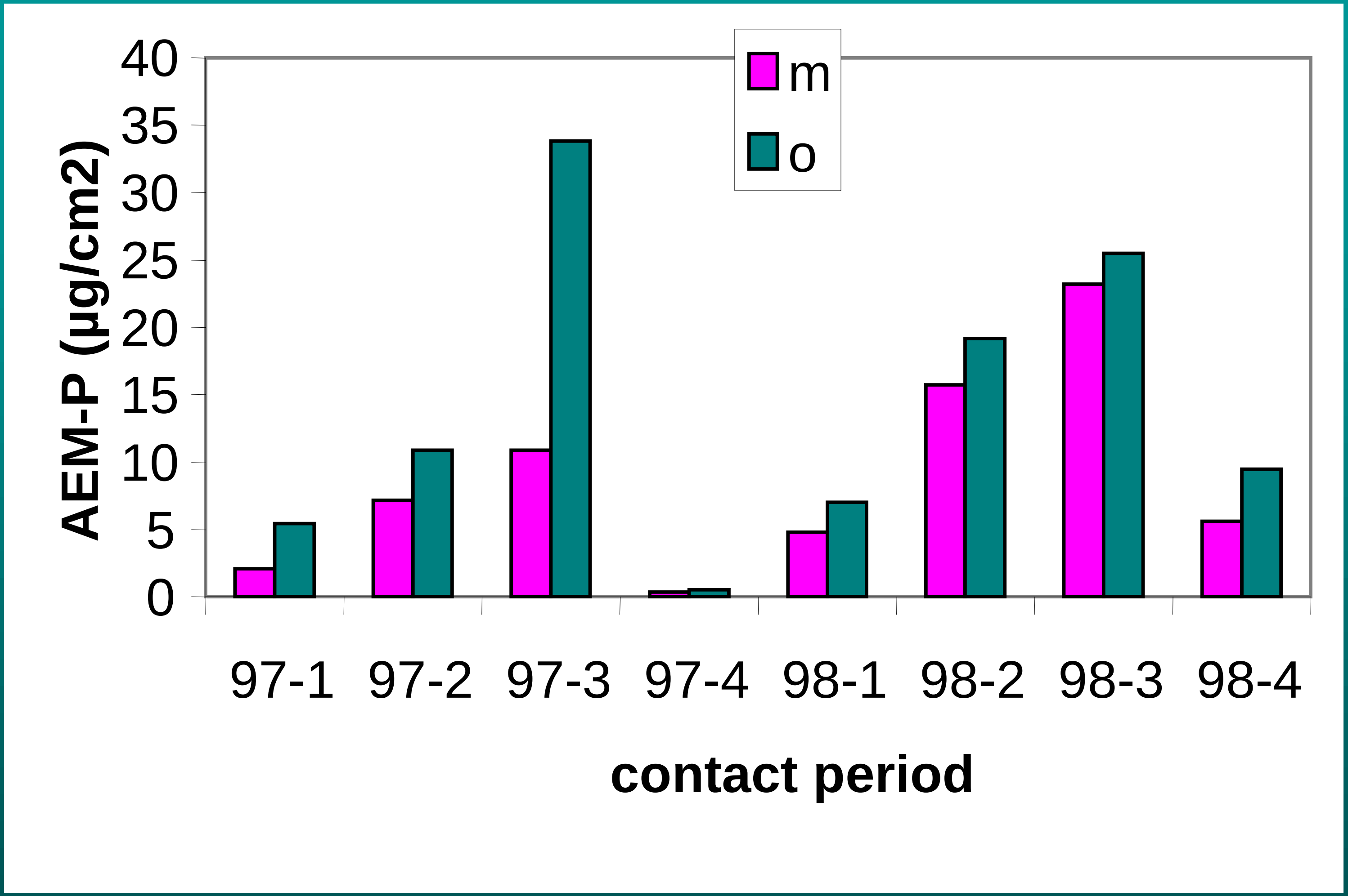


P transfer mechanisms



pH influences the reactivity of P with the solid phase



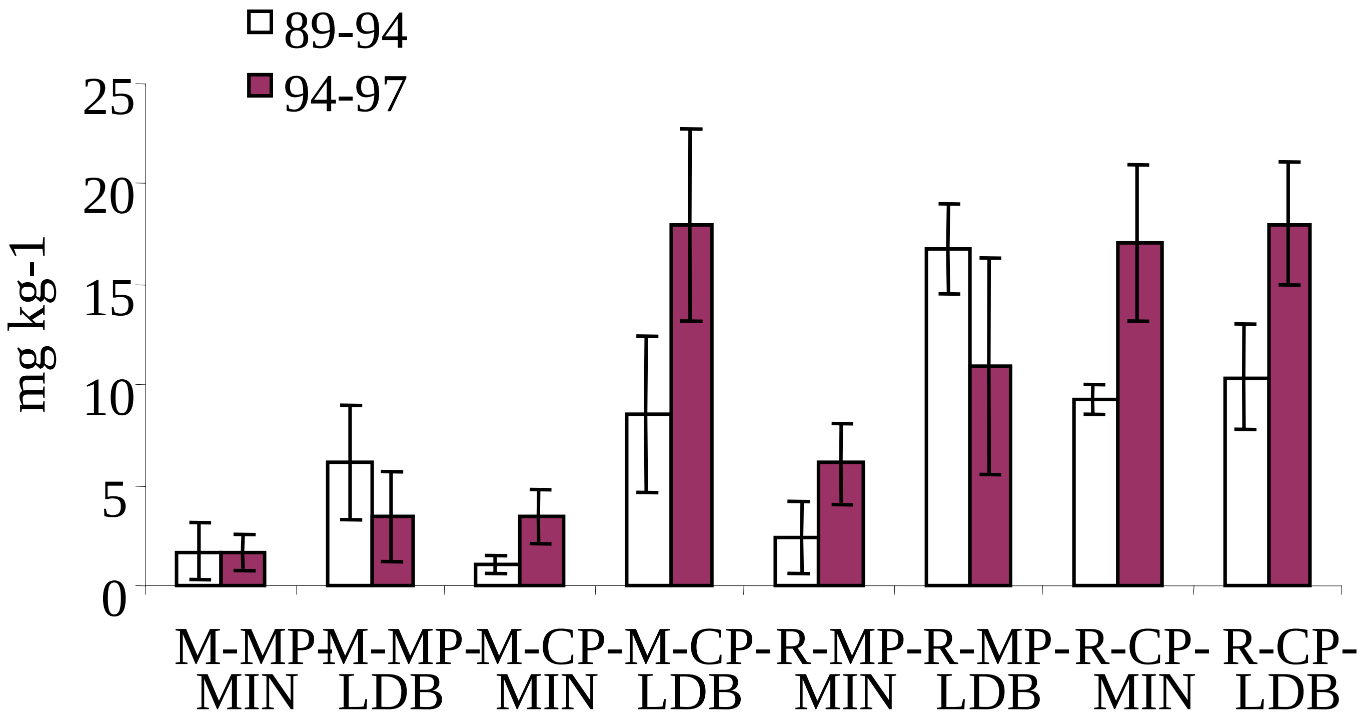


Impact of liquid hog manure (o) and mineral fertilizers (m) on the anion-exchange membrane P of a St-Urbain clay in 4 monthly contact periods in 1997 and 1998.

Manure increase the proportion of labile P fractions (% of total P)

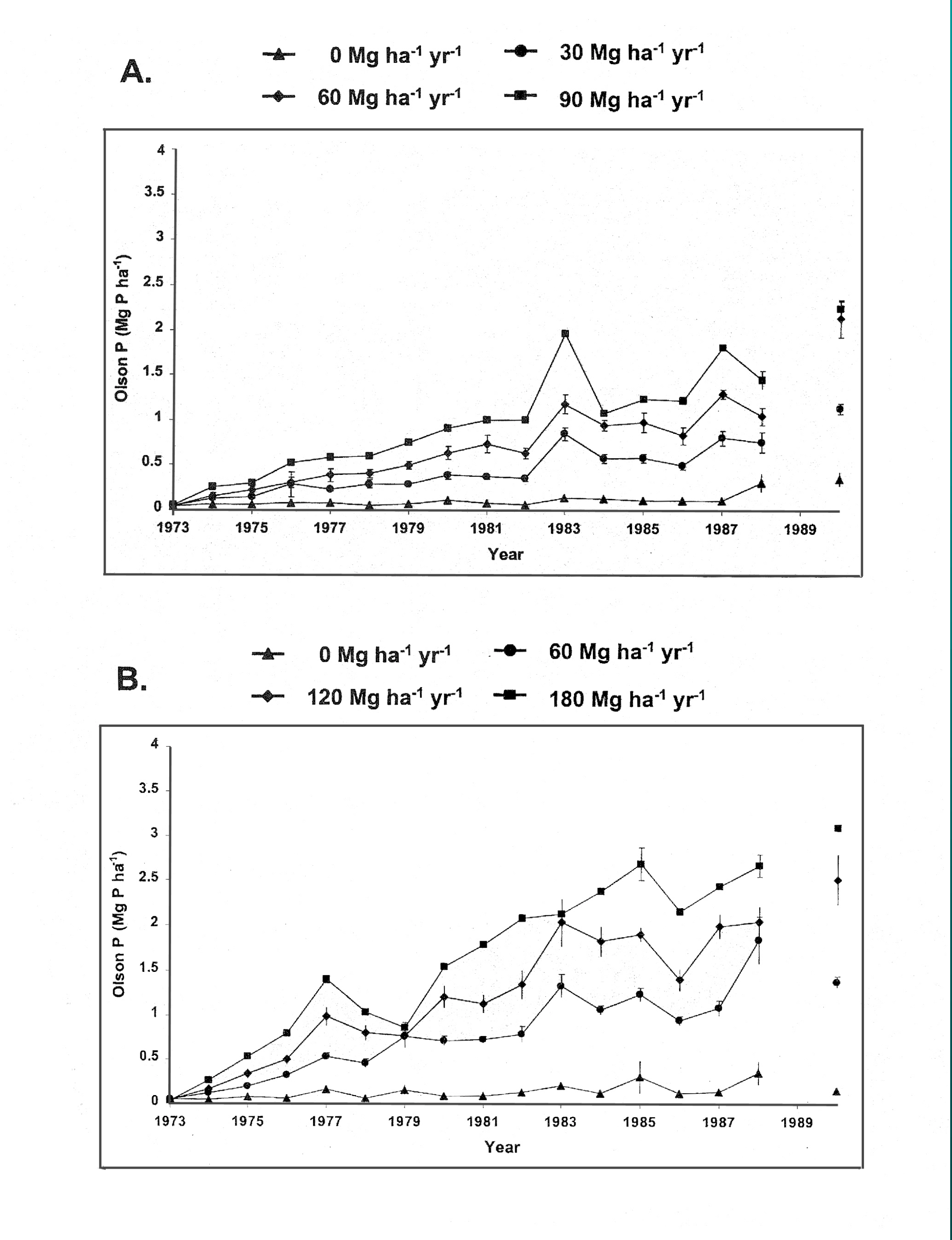
Rate of manure	Water soluble P	Labile Pi	Labile Po
0	7	16	25
30	13	42	6
60	14	46	4

Dormaar and Chang 1995



Change in labile P from 1989 to 1994 and from 1994 to 1997 (Zheng 2001)

Irrigation will impact on the change in soil test…

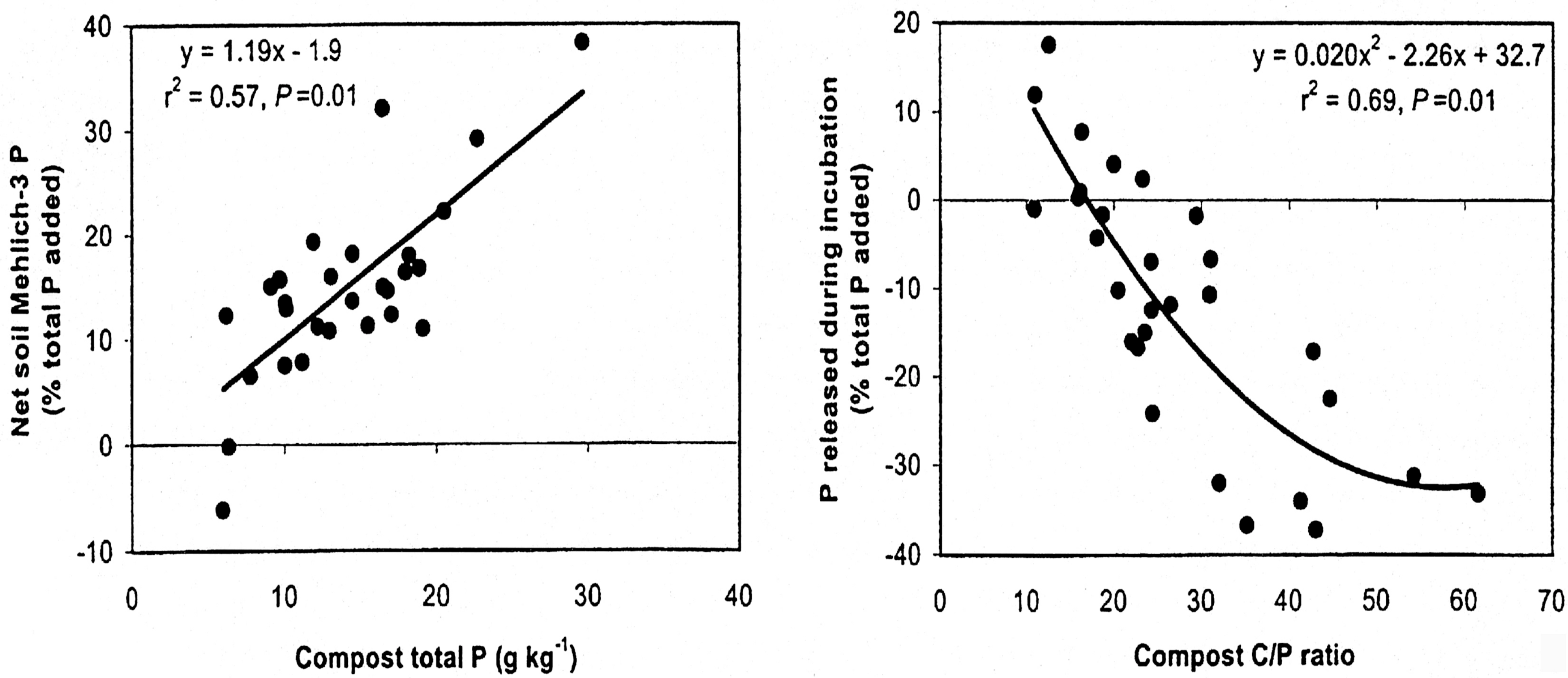


Whalen and Chang 2001

Manure Composition impact on the change in STP

- **Depends on the type of animal and manure mangement (Gagnon and Simard 2001)**
- **P leached was strongly correlated to manure and compost water soluble inorganic or organic P (Sharpley and Moyer, 2000)**

Compost and soil P



Gagnon and Simard 1999

Compost impact on STP (mg P kg^{-1})

Compost rate (Mg/ha)	0-20 cm	20-40 cm
0	48	39
14	52	41
28	59	47
42	65	53

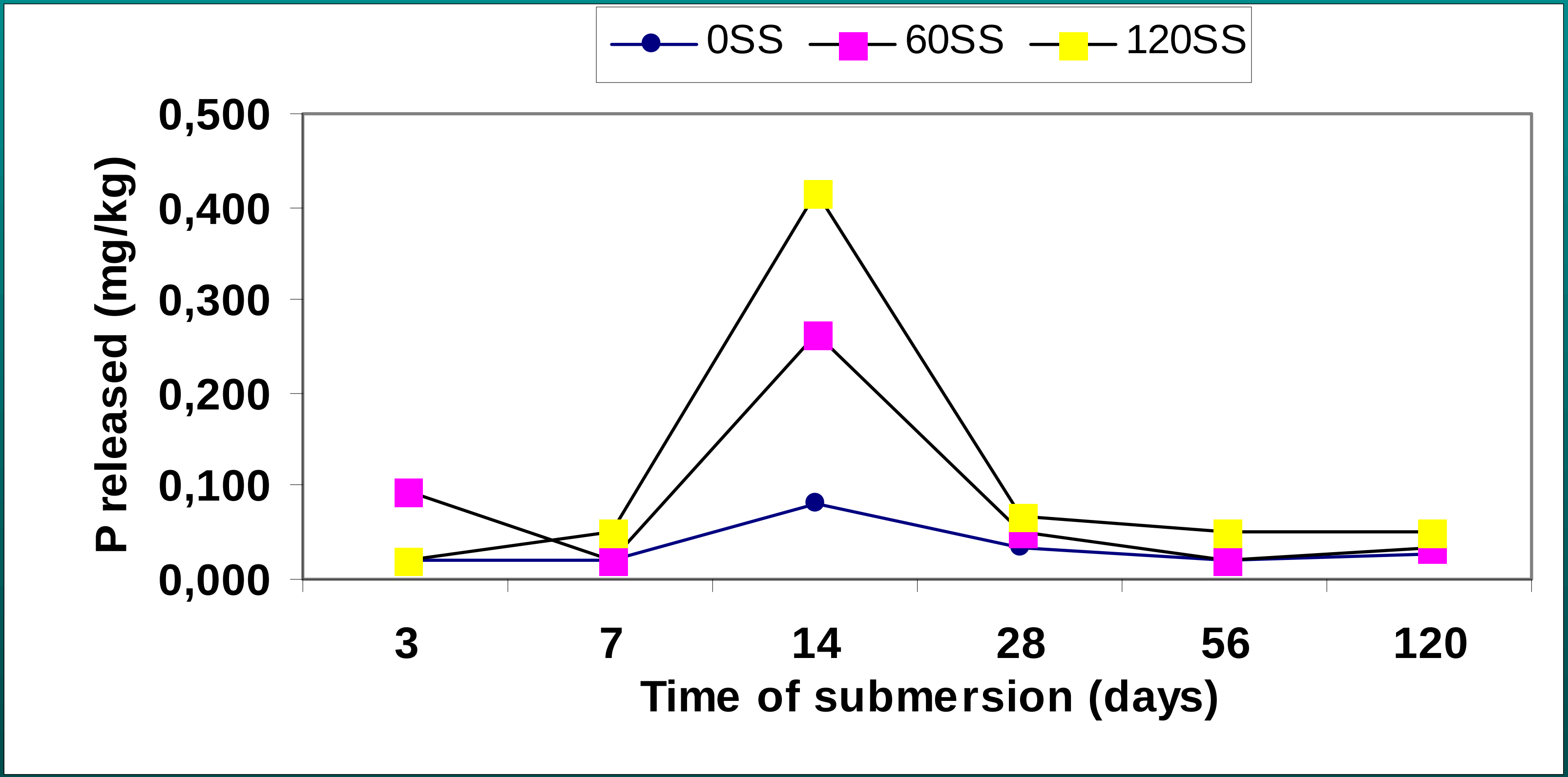
Baziramakenga et al. 2001

Linear correlation coefficients between the logarithm of the total P concentration in drainage water and the logarithm of some P attributes of soils from the Boyer Watershed, Province of Quebec, Canada.

Horizon/layer	P_w	P_{M3}	P_{si}
0-5 cm	0.61**	0.32	0.32
5-20 cm	0.43*	0.06	0.06
20-40 cm	0.34*	-0.30	-0.30
40-60 cm	0.34*	-0.28	-0.28
60-80 cm	0.54*	-0.20	-0.20

SIMARD and BEAUCHEMIN 2001

Flooding impact on manure amended soils



Marsan and Simard 1996

Degree of soil P saturation (DSPS)

- **DPSS (%)= (desorbed P / P sorption capacity X 100**
- **Pox/(Feox+Alox) ratio in mmol/kg (van der Zee and van Reimsdijk, 1988)**
- **PM3/Xm (Sharpley 1995)**
- **PM3/AlM3 Giroux et Tran (1996)**

Indicators of Risk of Water Contamination by P

- Modification of the PI index (Lemunyon and Gilbert 1993)
- Adaptations in Canada (Bolinder et al. 1998, OMAFRA)

Use

- "*This index is intended as a tool for field personnel to easily identify agricultural areas or practices that have the greatest potential to export P and allow farmers more flexibility in developing remedial strategies*" (Sharpley and Tunney, 2000)

"These indexes integrate agronomic soil test P and other criteria that quantify erosion, surface runoff as well as P fertilizer and/or organic P source application rate, timing and methods in a simple, weighted matrix system to identify soils, landforms, and management practices with the potential for unfavourable impacts on water bodies because of P losses from agricultural soils"
(Sims et al. 2000).

IROWC-P

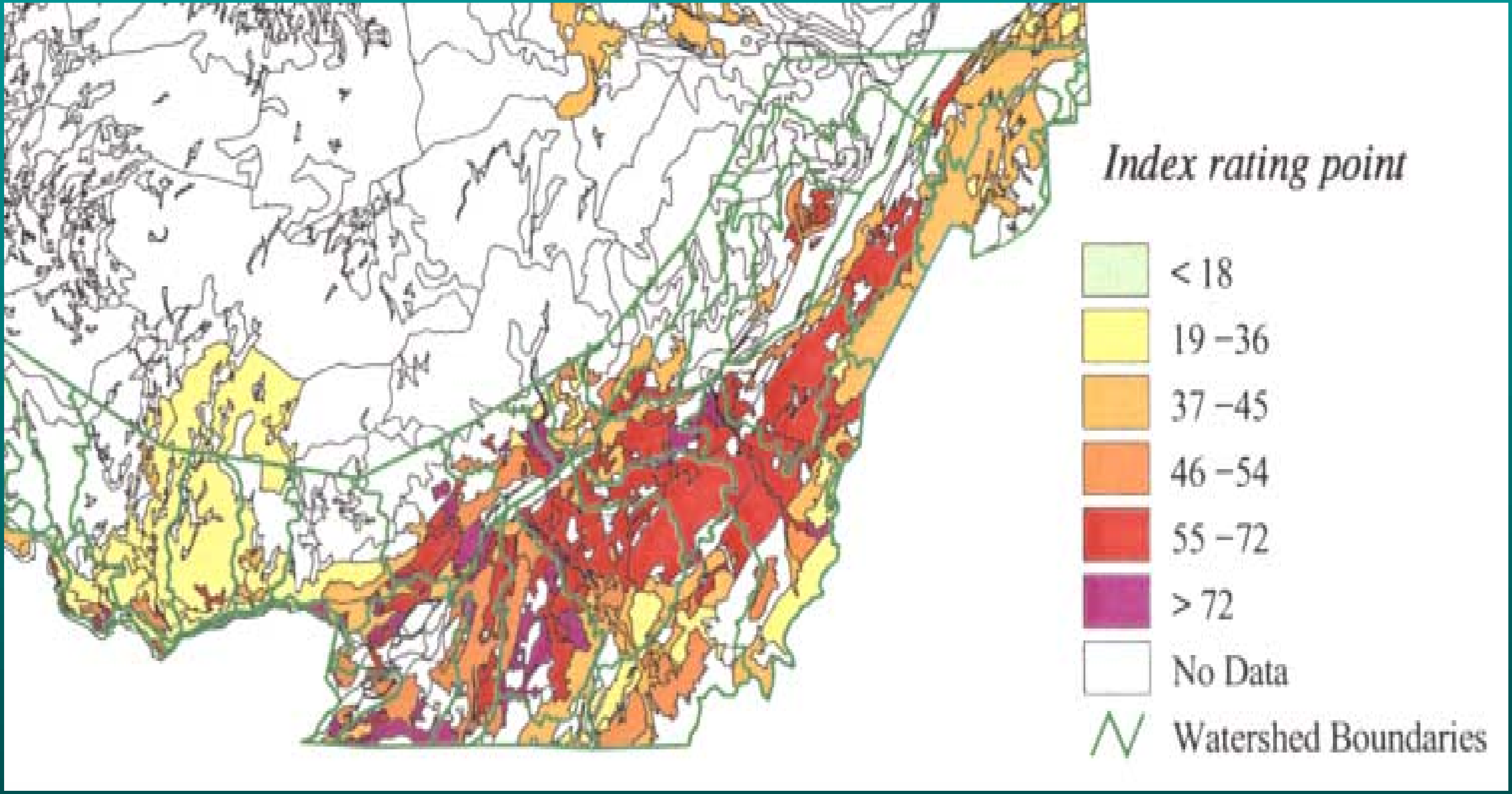
- Soil erosion (1.0)
- Runoff potential (2.5)
- P saturation (2.0)
- P soil test (2.5)
- Crop Residues (1.0)
- Manure P added (2.0)
- Fertilizer P added (1.0)

Adapted PI (IROWC-P)

Phosphorus transfer rating (value)

Site characteristic (weight)	Very low (1)	Low (2)	Medium (4)	High (8)	Very high (16)
Soil erosion (1)	< 500	500-2000	2000-6000	6000-15000	> 15000
Runoff potential (2.5)	Very low	Low	Moderate	High	Very high
P saturation (2.0)	0-25%	2.5-5%	5-10%	10-20%	> 25%
P soil test (2.5)	< 60	60-150	150-250	250-500	> 500
Annual P balance					
Crop residue (1.0)	< 2%	2-5%	5-20%	20-50%	> 50%
Manure (2.0)	< 50%	50-100%	100-150%	150-200%	> 200%
Fertilizer (1.0)	< 50%	50-100%	100-150%	150-200%	> 200%
Site vulnerability	12-18	19-36	37-72	73-144	145-192

IROWC-P 1991



Bolinder et al. 1998

The Quebec Index (MEFQ 1998)

- Risk of preferential flow (3)
- Total P balance (3)
- Manure type and incorporation mode (7)

Risk of preferential flow

Texture	(1,5)	sandy loam	loam, silt loam	Clay loam, silty clay loam	medium sandy loam, clay	Coarse sands, heavy clay
Distance between tile drains (m)	(1,5)	nil	> 35	25-35	15-25	< 15

Risk associated with manure

Application period	Incorporated	Tillage before the application	Solid manure or mineral fertilizer[1]	Liquid manure (< 10 % dry matter)[1,2]
Pre-seeding[3]	low	low	high	medium
In the growing season	very low	very low	medium	high
Post-harvest in late fall	medium	medium	very high	very high

Other factors

- Soil drainage class
- soil texture, presence of a calcareous substratum
- potential for cracking
- mean high water tables
- depth to tile drain lines
- distance to a waterbody

The 12 February 1998 compromize

P-M3 (kg/ha)	0-60	61-150	151-250	251-500	>500
1998	N	N	N	N	N
2003	N	N	S<10:N S>10:P +40	S<20:P +20 S>20:P	P
2008	N	N	S<10:P +40 S>10:P +20	S<10:P +20 S>10:P	P-20
IRP	v. Low	Low	Medium	High	v. High

The Ontario Index

	LOW	MEDIUM	HIGH	VERY HIGH	EXTREME
1. Soil Erosion (USLE in t/ha/year)	< 12 2	12 - 25 4	25 - 37 8	> 37 16	
2. Water Runoff Class (slope and soil texture)	< 0.5% loam 1	0.5-2.0% loam 2	2-5% clay loam 4	> 5% clay 8	
3. Soil test P (Olsen, mg/L)	< 15 2	15-30 4	31-60 8	61-100 16	> 100 32
4. Fertilizer P_2O_5 application rate (kg/ha)	< 25 0.5	25-50 1	50-75 2	> 75 4	
5. Fertilizer placement	band-applied 1.5	incorporated < 2 weeks 3	incorporated > 2 weeks 6	not incorporated 12	
6. Manure P_2O_5 application rate (kg/ha)	< 12 0.5	12-36 1	36-60 2	> 60 4	
7. Manure/Biosolid Application Method	injected in season	incorporated in < 5 days	pretillage, crop residue, or standing crop	bare soil; not incorporated	
	1.5	3	6	12	

P guidelines in NMAN2000

	Distance to Watercourse (m)			
P Index	< 3	3-30	30-60	> 60
< 30	0	CR	CR+78	CR+78
30-50	0	CR	CR	CR+78
>50	0	0	CR	CR

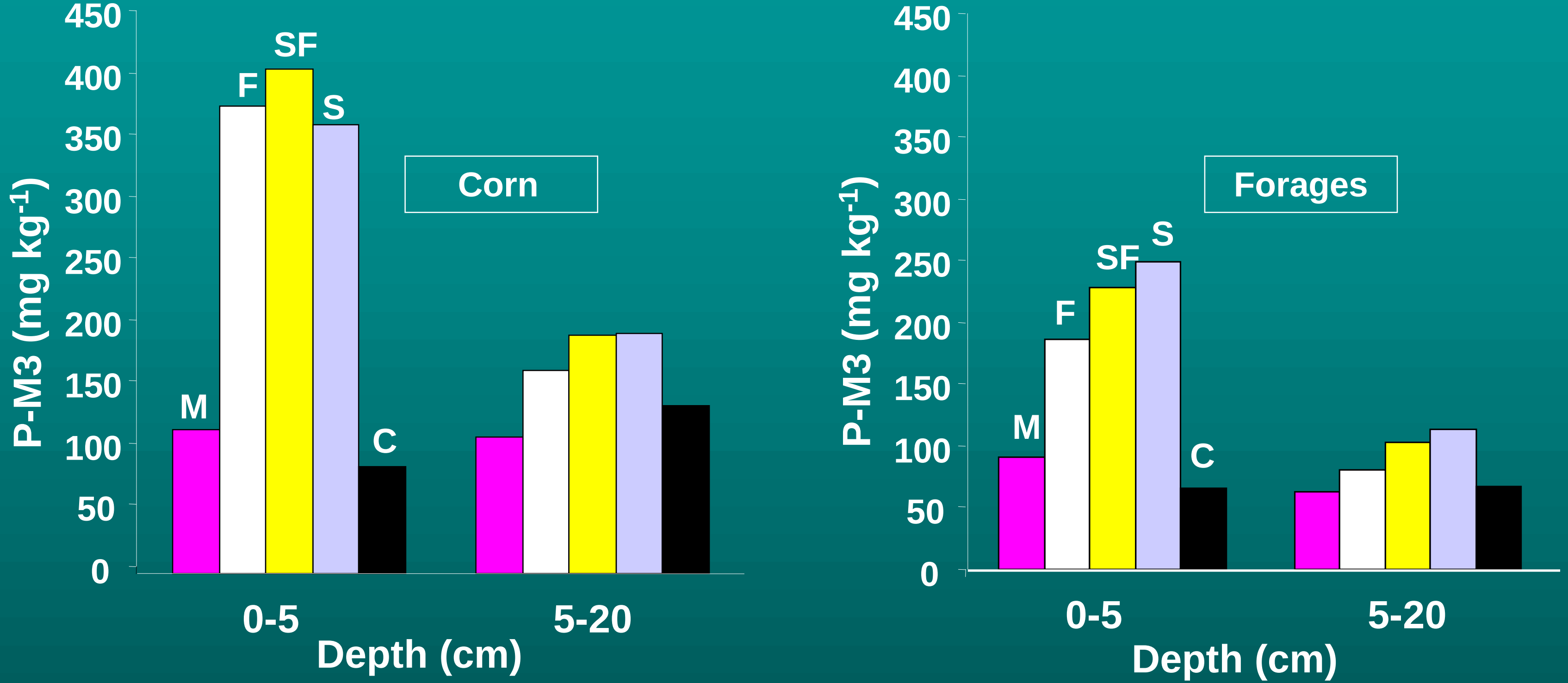
P index at the watershed scale

- *PI = (erosion rating x runoff rating x return period rating) x sum of (source characteristic x weight)*
  - *(Gburek et al. 2000, Heathwaite et al. 2000)*

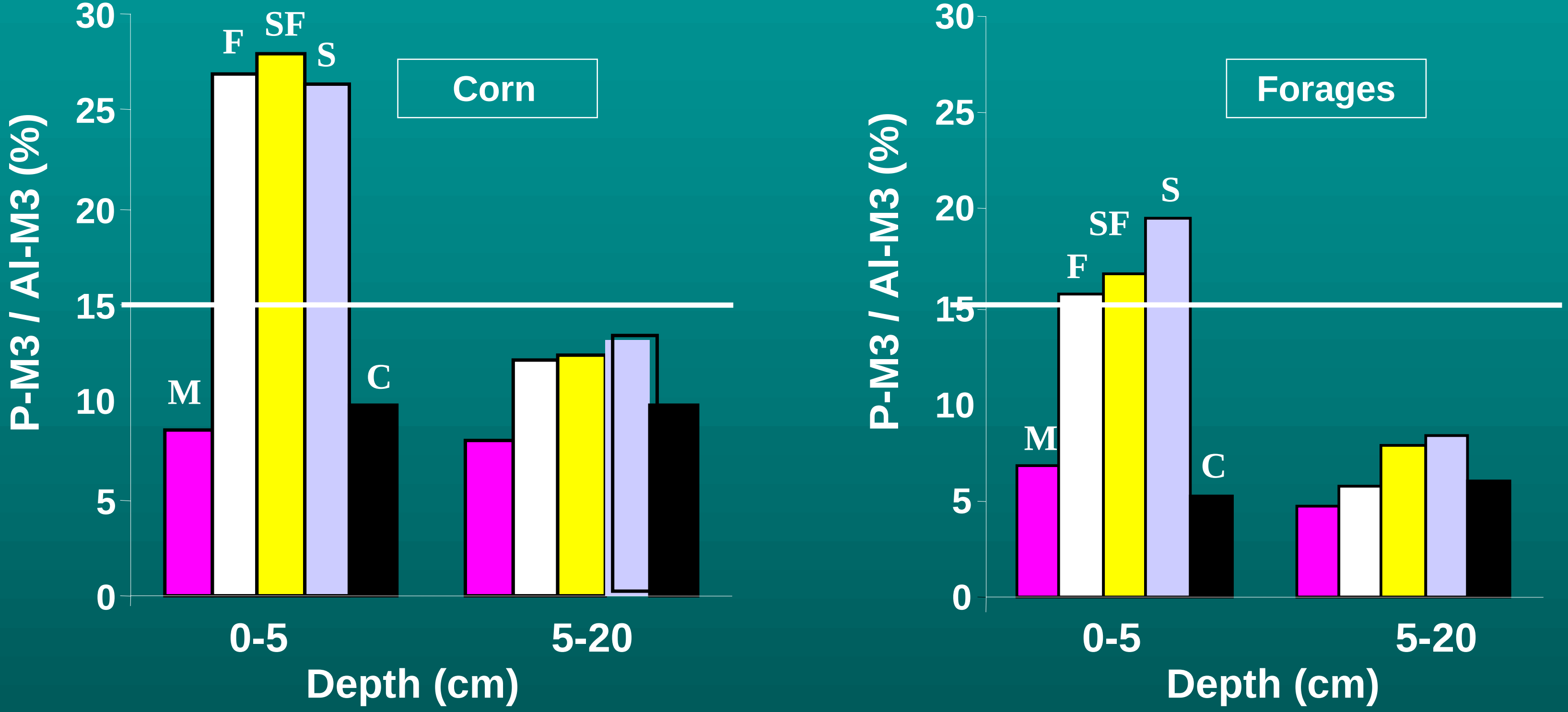
Application of Manure and P Losses in Surface Runoff and Drainage Water: a case study

- Coaticook silt loam (Humic Gleysol)
- 5,3 % OM, 81 mg/kg M3P
- inorganic fertilizers (IF)
- IF + HLM (360 kg N/ha)
- all spring or fall and split-applications
- silage corn or timothy-red clover

The Lennoxville liquid manure project



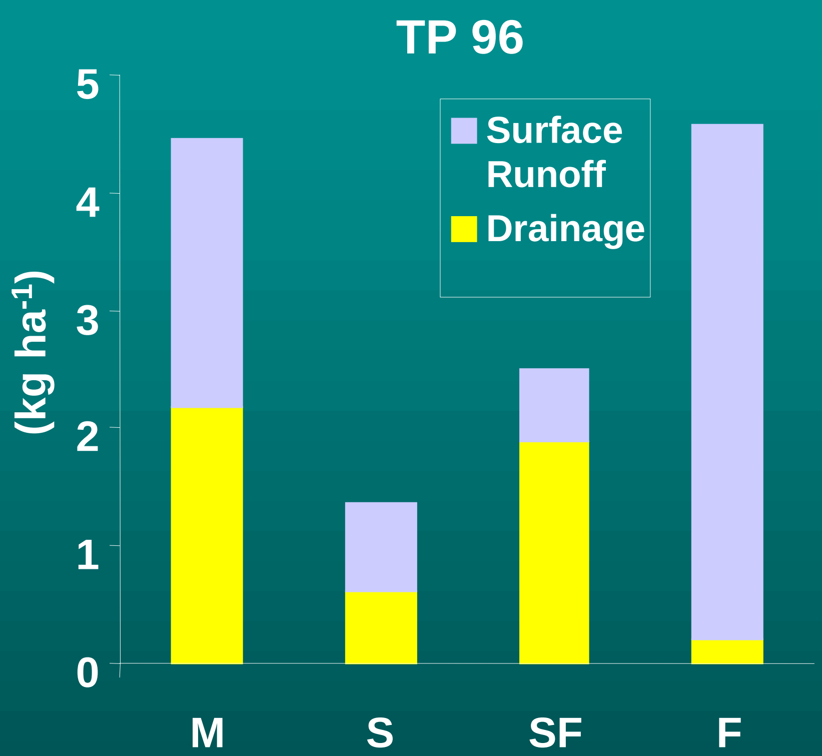
Mehlich-3 extractable P contents from the 0-5 cm and 5-20 cm layer of a Coaticook silt loam as affected by nutrient source and timing of manure application (Simard et al. 2000).

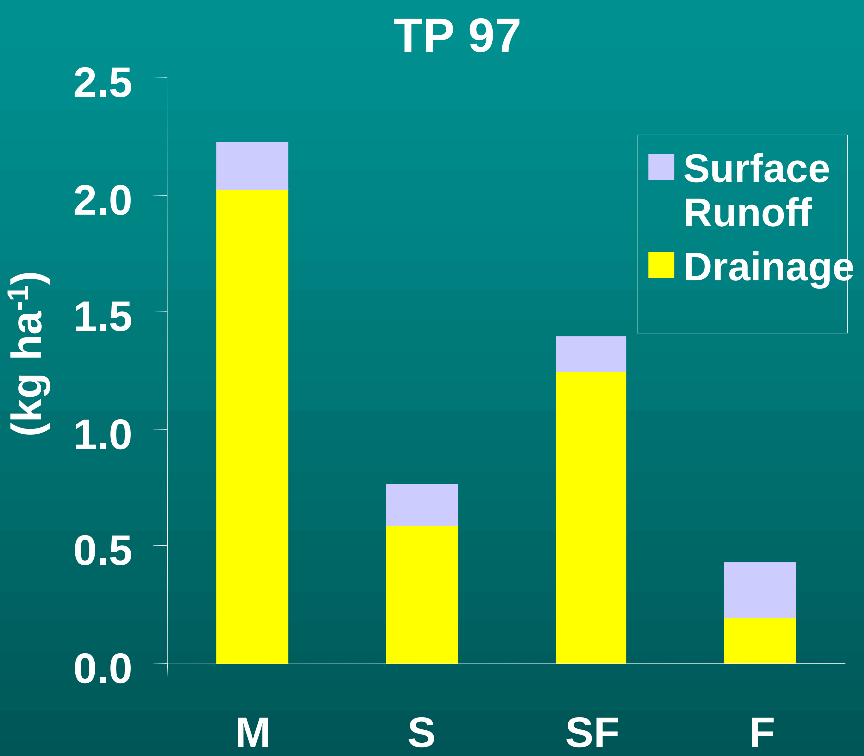


Value of the P saturation index as calculated by the ratio of Mehlich 3 extractable P to the Mehlich-3 extractable Al from the 0-5 and 5-20 cm layer of a Coaticook silt loam as affected by nutrient source and timing of manure application (Simard et al. 2000).

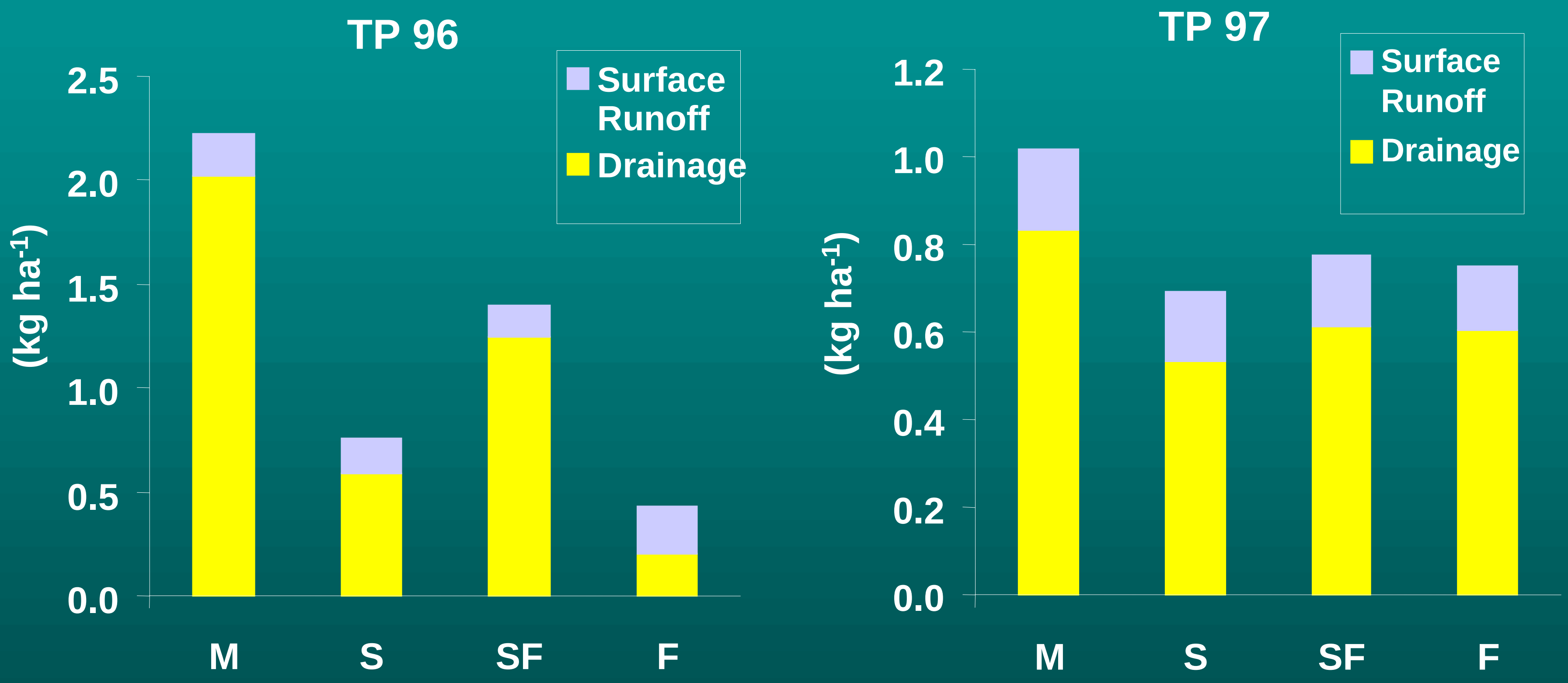
Values of the P index as influenced by crop type and nutrient management (Simard et al. 1999).

	Corn	Forages
Mineral fertilizers	126	113
HLM 100 % spring	341	295
HLM 50-50	355	275
HLM 100 % fall	355	330





TP loads in surface runoff and drainage water under corn in 1996 and 1997 (Simard et al. 2001)



TP loads in surface runoff and drainage water under forages in 1996 and 1997 (Simard et al. 2001)

Sharpley 1995

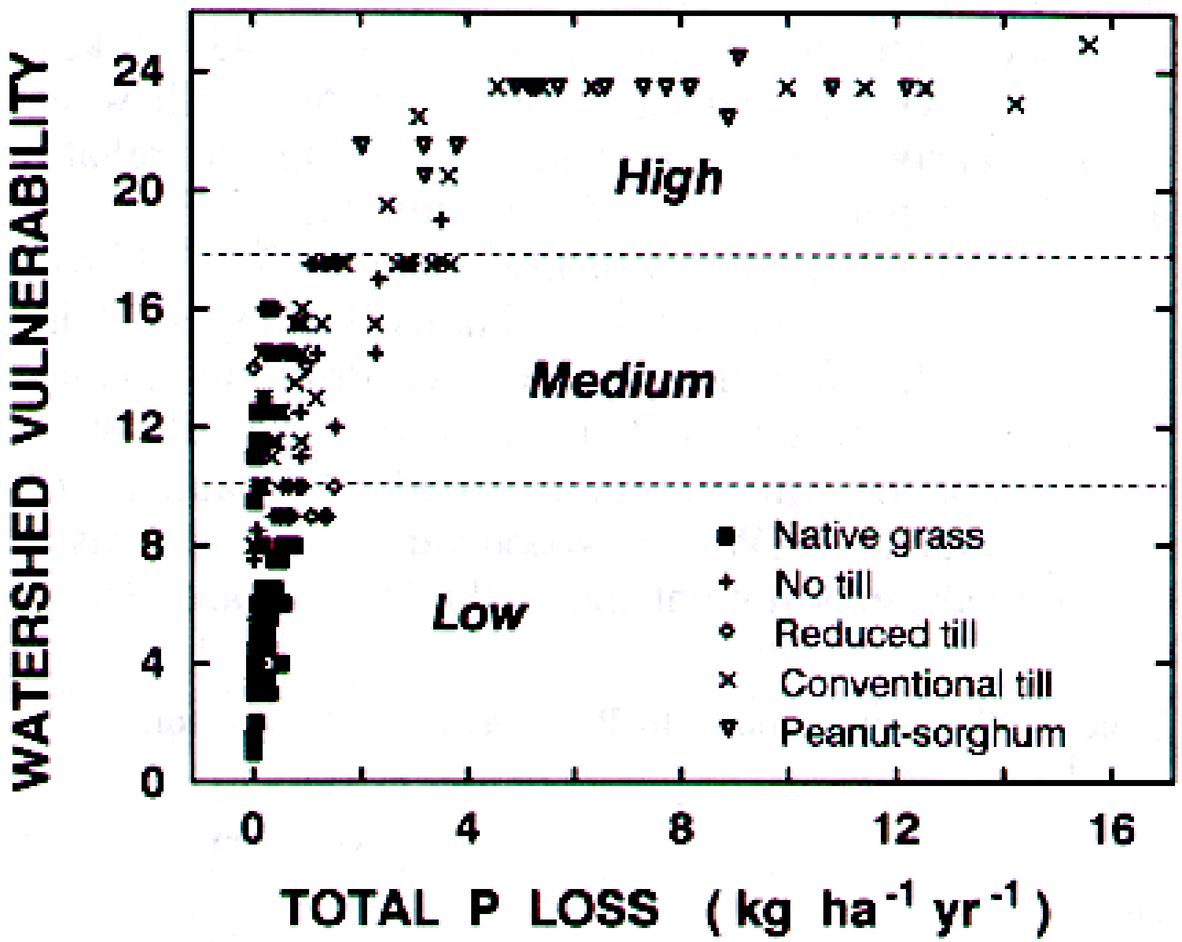


Fig. 1. Relationship between P index rating of watershed vulnerability to P loss in runoff and measured total P loss in runoff.

A modified P transfer index for the Prairies

- Adapted from current models
- separate components for mode of transport, charge and management
- risk of wind erosion adapted from Padbury and Stushnoff (2000)
- distance to waterbody should be included
- multiplicative index

And……

- Weight relating to each subcomponent would have to be adjusted regionally…

Components of a new indicator of risk of soil P contamination of surface waters

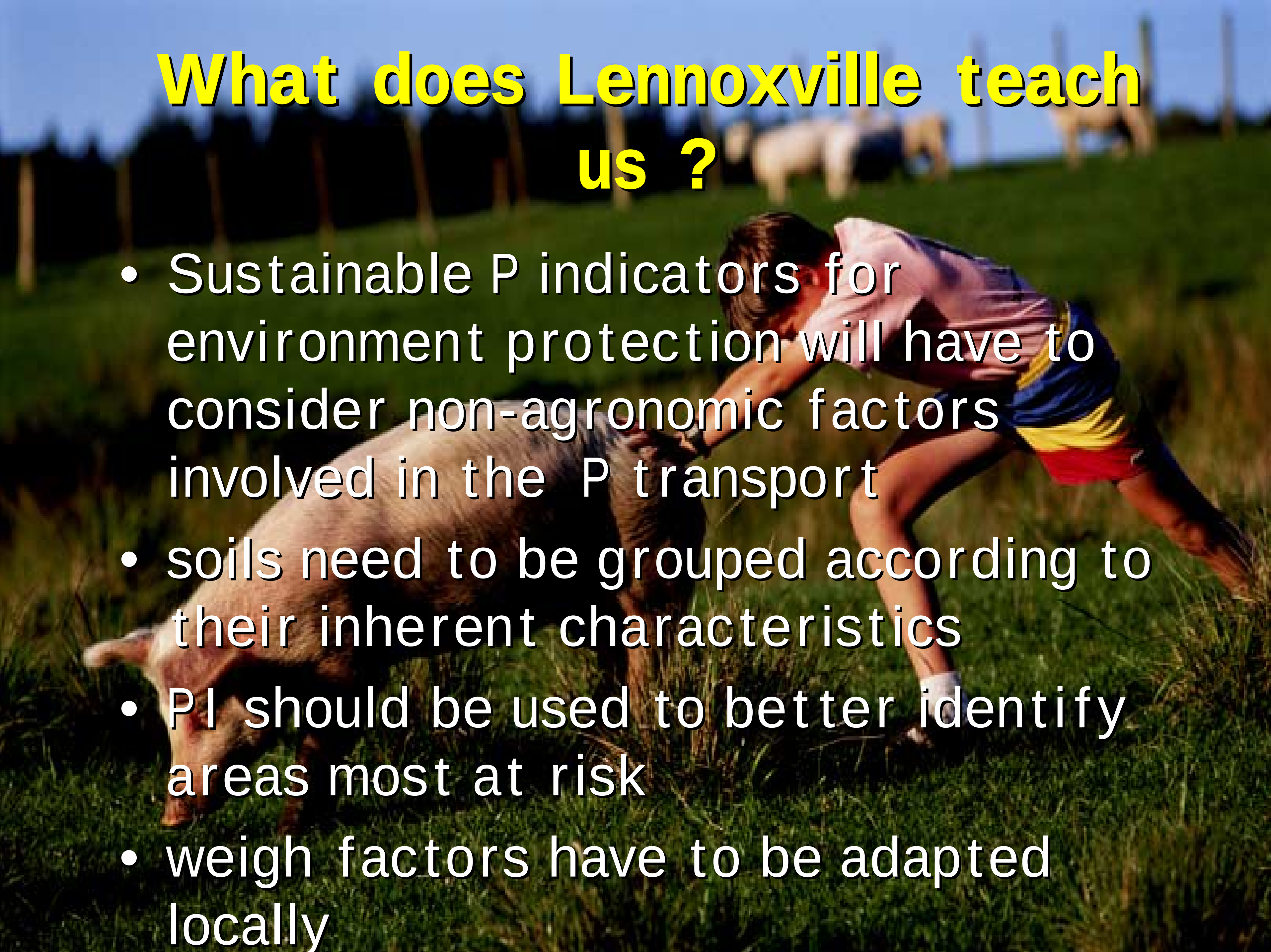
Modes of transport components :
Risk of water erosion
Risk of surface runoff
Risk of wind erosion
Risk of incidental transfer : Surface transfer of manure/fertilizer particles
Preferential flow
Distance to a waterbody
Charge components :
Soil-test P
Degree of soil P saturation
Management components :
Fertilizer Padded (kg/ha)
Manure P added (kg/ha)
Manure and Fertlizer application mode
Grazing intensity

Manure management based on N

- P accumulation and high DSPS
- increase in livestock production in the Prairie provinces will accentuate these effets.
- Surface transport is probably the main pathway in the Prairies
- does land that recieved manure frequently transfer less ?

Assumption and Predictions ?

- P does not move in calcareous soils ?
- Increase in soil P load may increase the risk of transfer by lateral flow or seepage
- flooding
- irrigated areas



What does Lennoxville teach us ?

- Sustainable P indicators for environment protection will have to consider non-agronomic factors involved in the P transport
- soils need to be grouped according to their inherent characteristics
- PI should be used to better identify areas most at risk
- weigh factors have to be adapted locally

Conclusion

- **Long term manure application has had a large impact on the quality of surface waters in Eastern Canada. The economic reality favours intensification of confinement livestock operations in the Prairies since less grain is transported to the eastern Canada markets. Sound manure management strategies will certainly be key factors for a sustainable agricultural industry.**

Acknowledgements

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