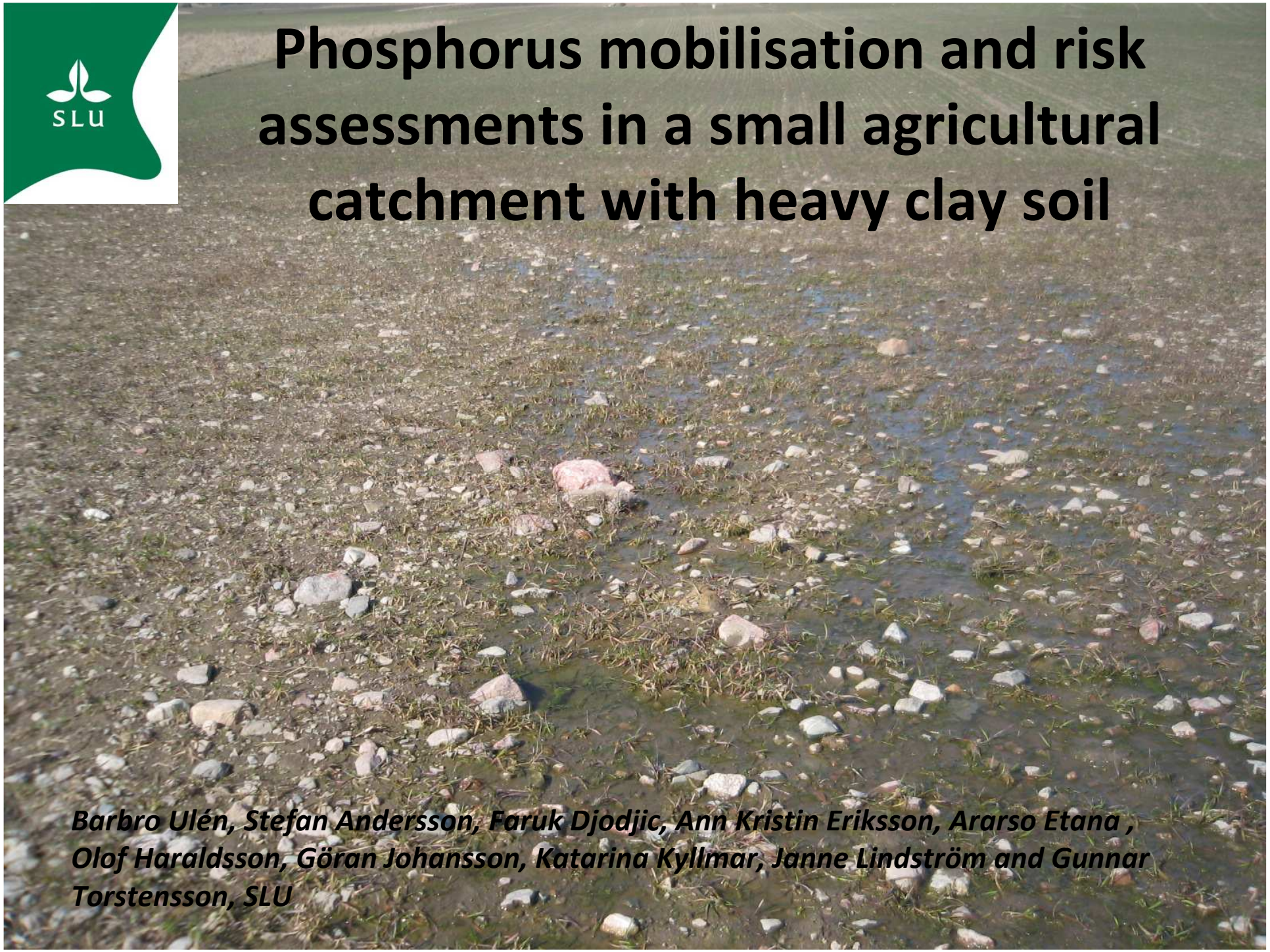
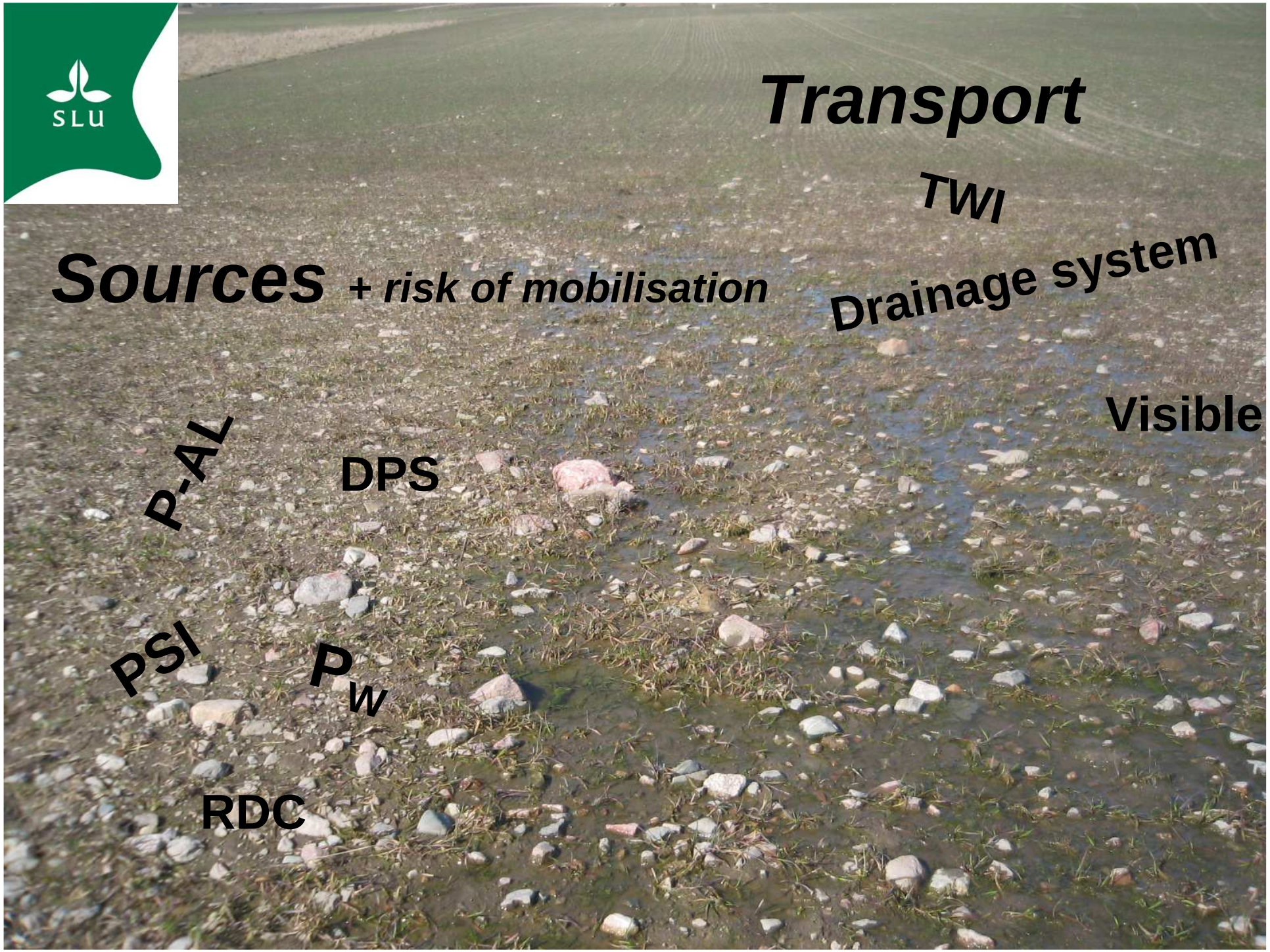
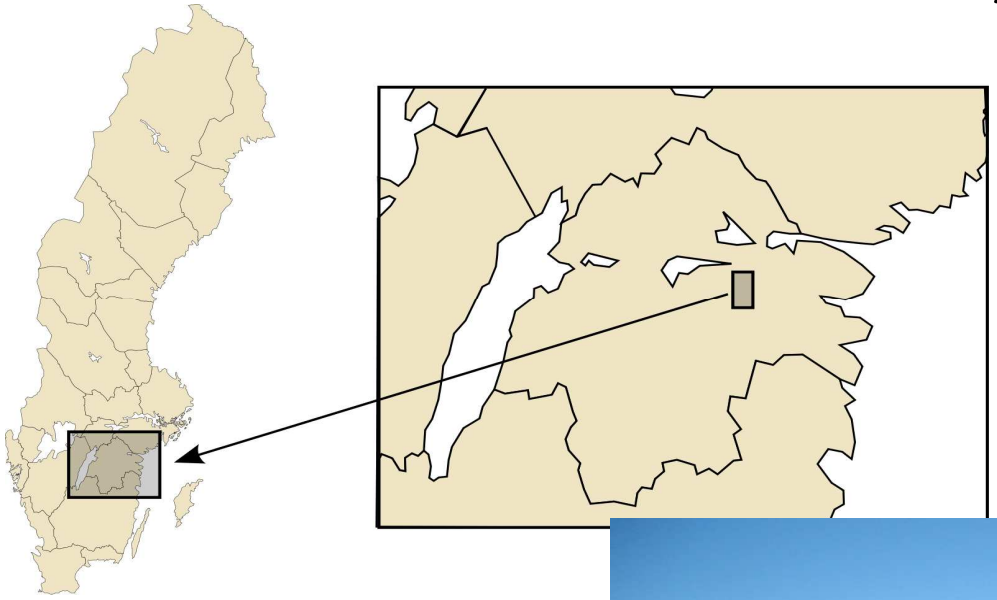
Phosphorus mobilisation and risk assessments in a small agricultural catchment with heavy clay soil



Barbro Ulén, Stefan Andersson, Faruk Djodjic, Ann Kristin Eriksson, Ararso Etana , Olof Haraldsson, Göran Johansson, Katarina Kyllmar, Janne Lindström and Gunnar Torstensson, SLU


Transport
TWI
Drainage system
Sources + risk of mobilisation
Visible
P-AL
DPS
PSI
P_W
RDC

Catchment E23 with heavy clay soil



Mineral P fertilisation close to zero

Mean soil P balance close to zero

Tile drainage system
on average since 1937


Culvert opening


Wooden structures to
prevent stream bank erosion

Transport

Ditches and drainage systems need improvements

Concentrations in the stream

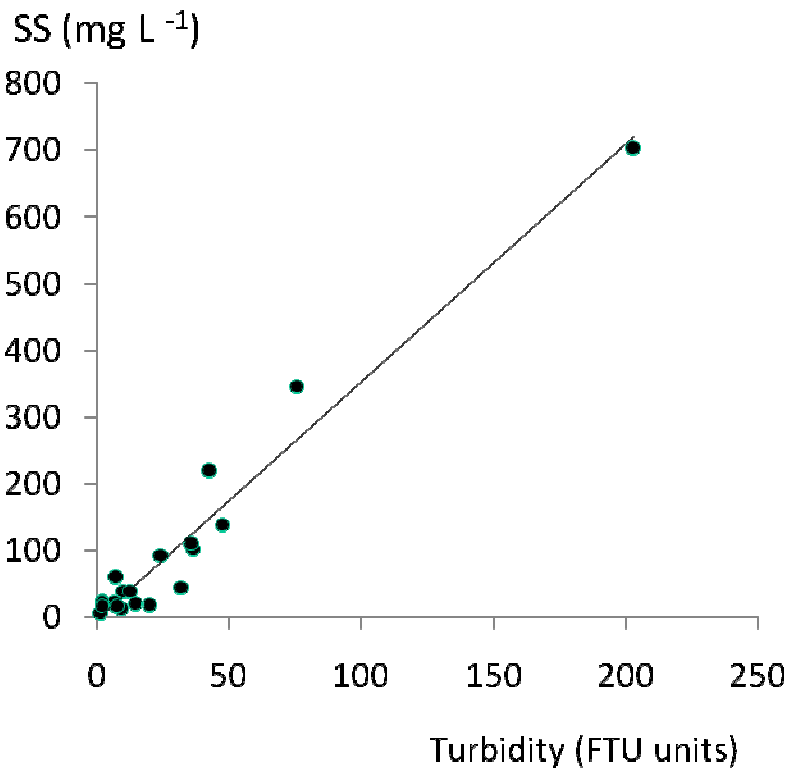
On-line measurement of turbidity and NO_3N

Flow-proportional water sampling at the endpoint

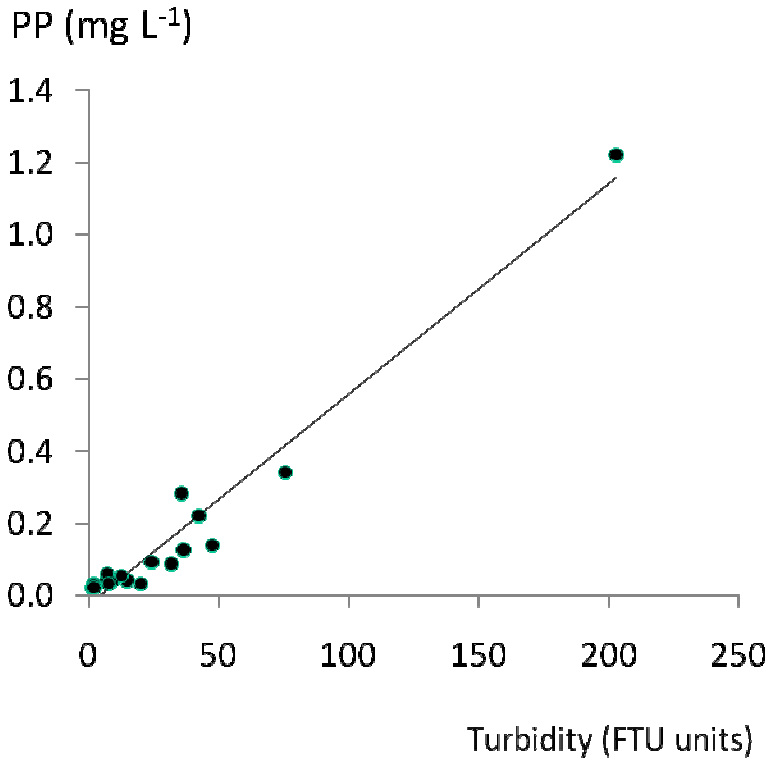
Manual synoptic water sampling of the entire catchment

Concentrations in the stream

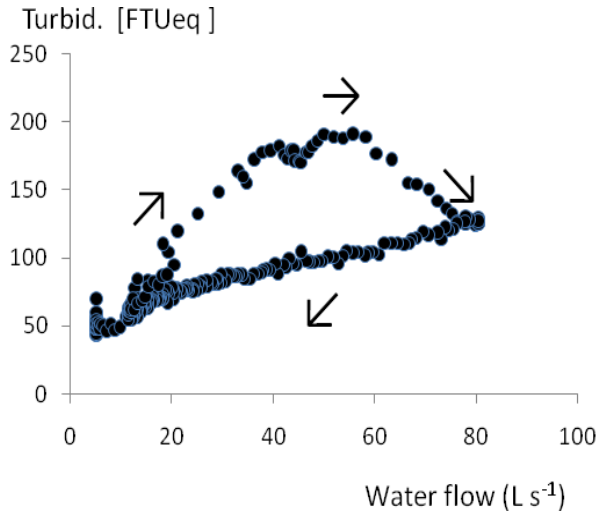
Turbidity - suspended solids (SS)

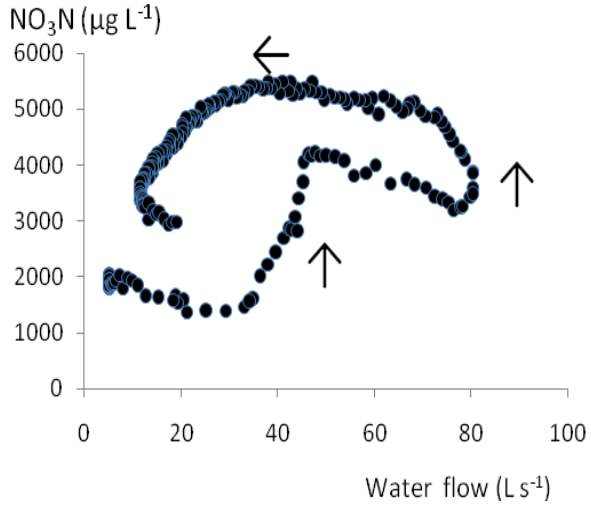


Turbidity - particulate-bound phosphorus (PP)



Concentrations in the stream - related to flow (hysteresis curve) in a flow event

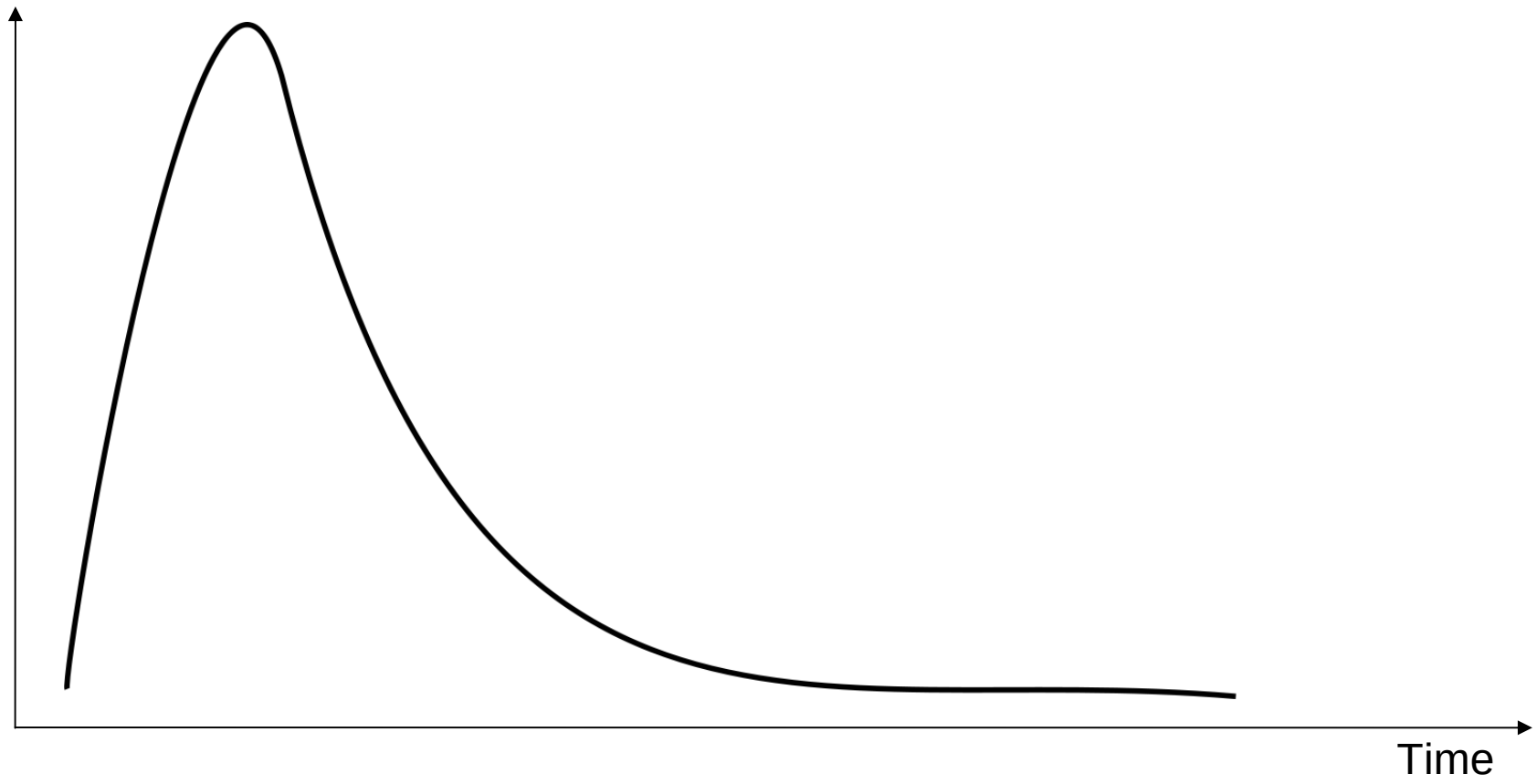




Concentrations in the stream

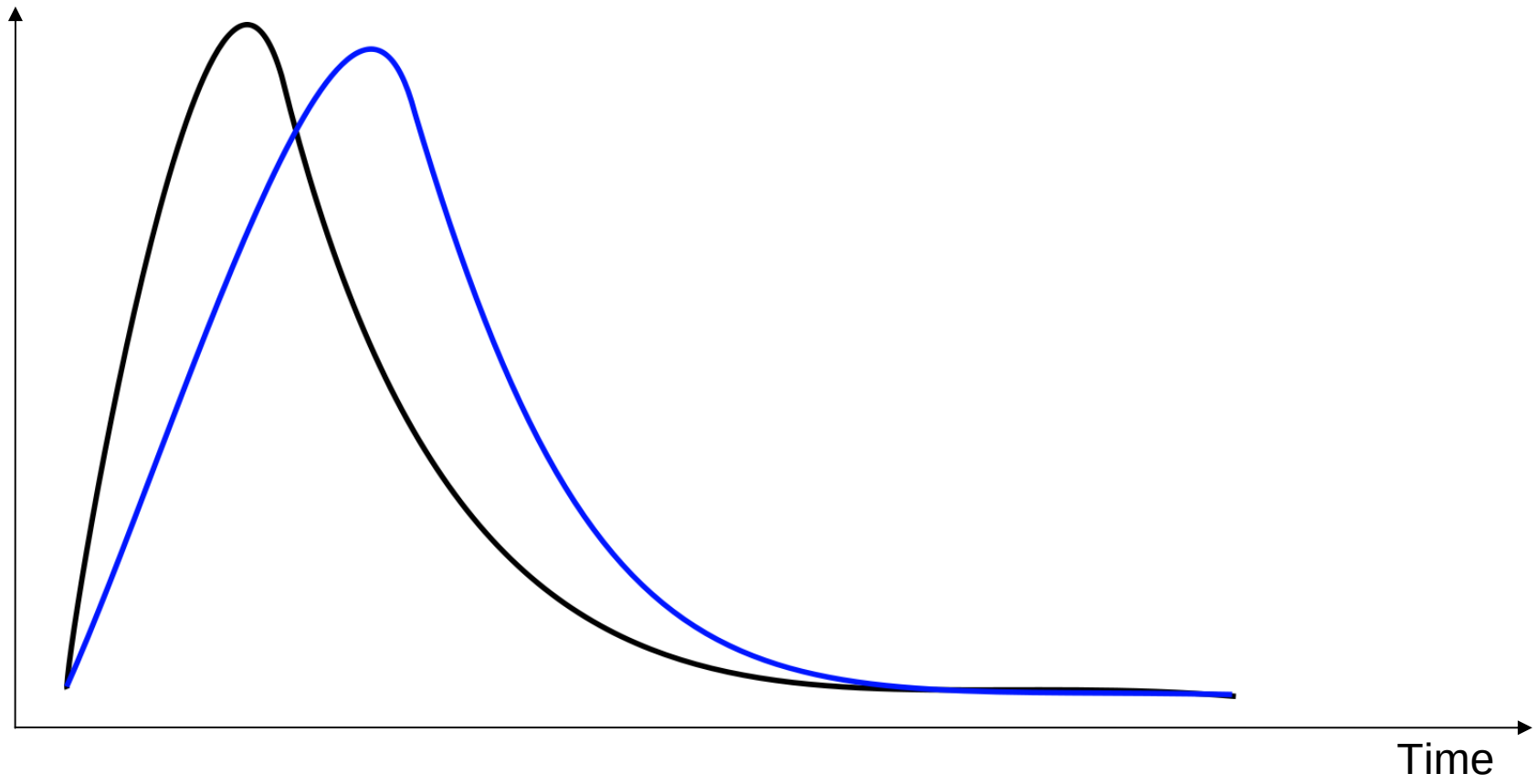
Particle peak arrives earlier than nitrate peak in stream water

- First particles (and particulate bound P)



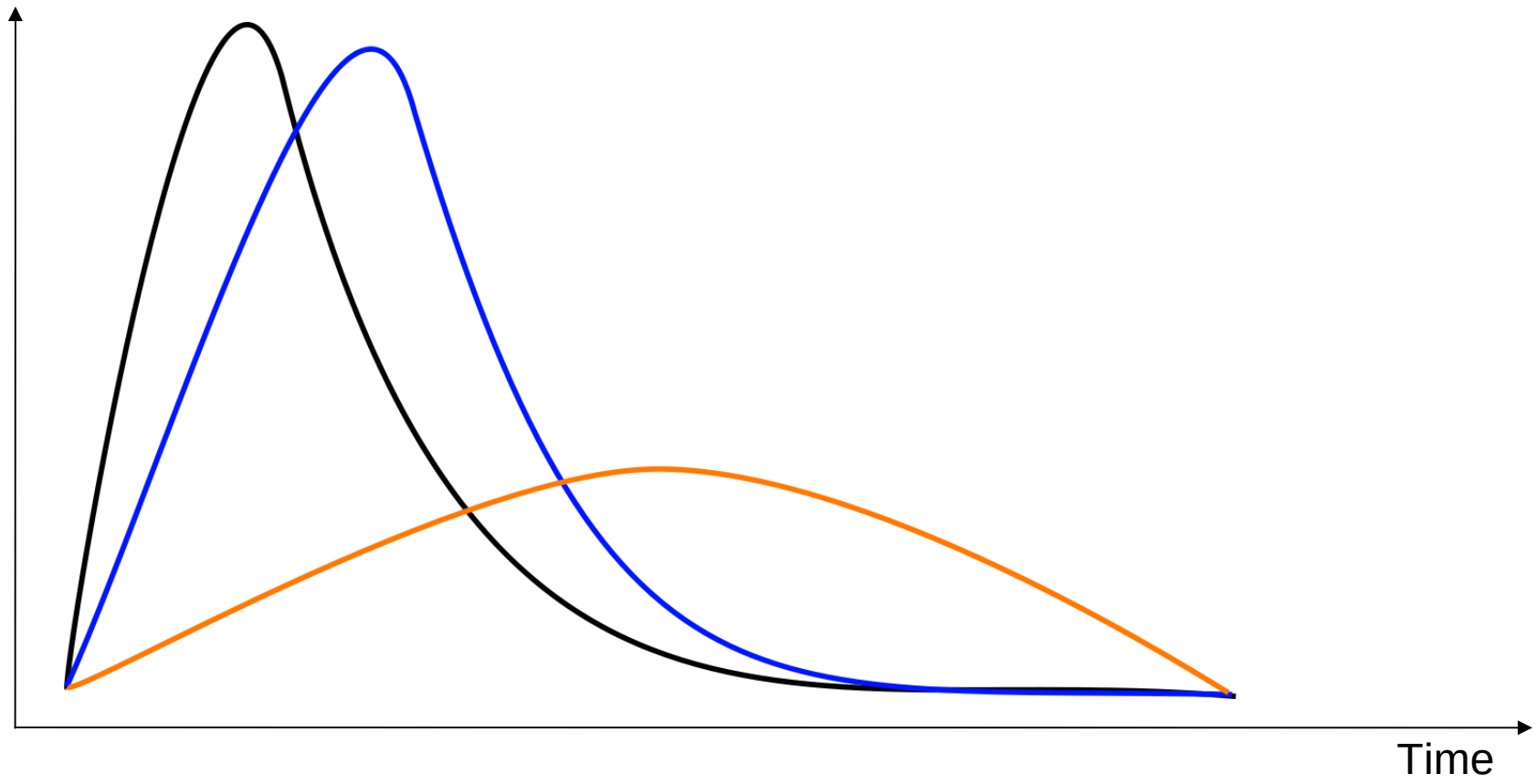
Concentrations in the stream

- First particles
- Then peak water flow



Concentrations in stream

- First particles
- Then peak water flow
- After 4-8 hours the nitrate peak



Concentrations in the stream

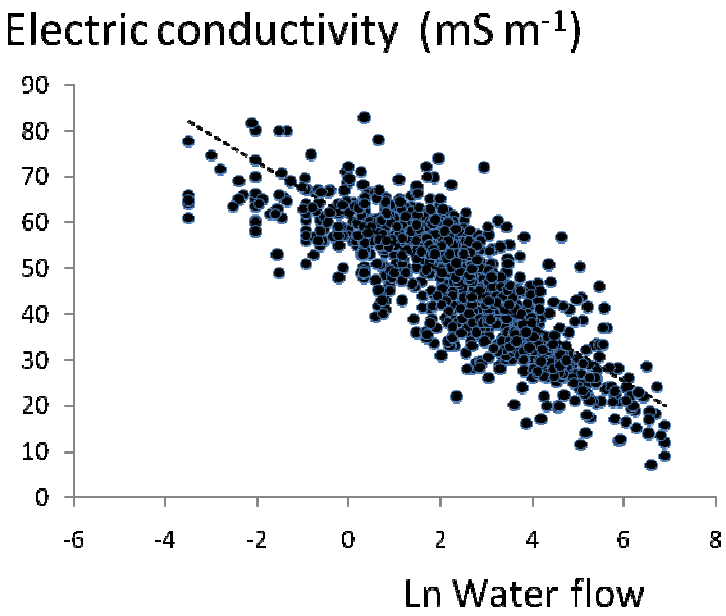
	SS (mg/l)	PP (mg/l)	DRP (mg/l)
High flow pulses autumn			
End of culvert	**280**	**0.13**	**0.07**
End of catchment	**450**	**0.76**	**0.09**

Concentrations of PP and SS increase in high flow pulses in the open stream especially in autumn
Concentrations of dissolved reactive phosphorus (DRP) increase to a lesser extent

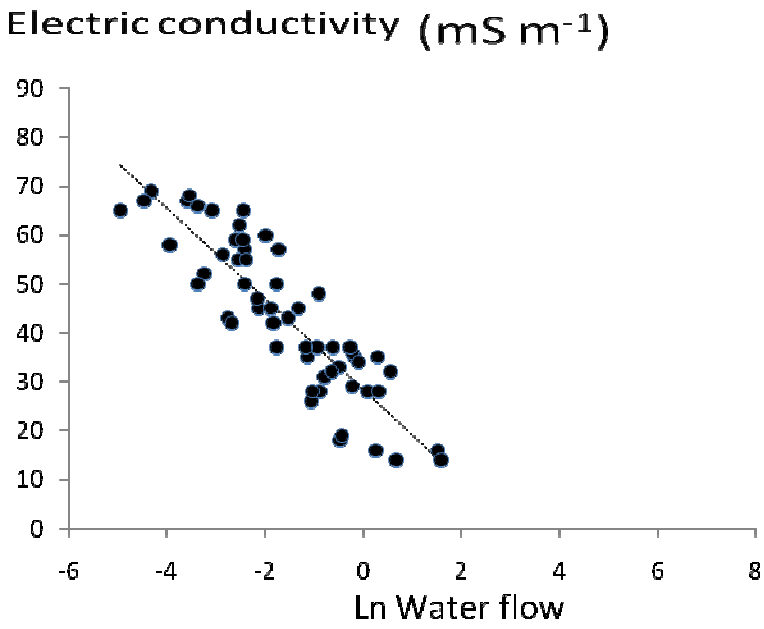
Agreement with flow-proportional sampling

Transport in stream/soil

Stream-end of catchment

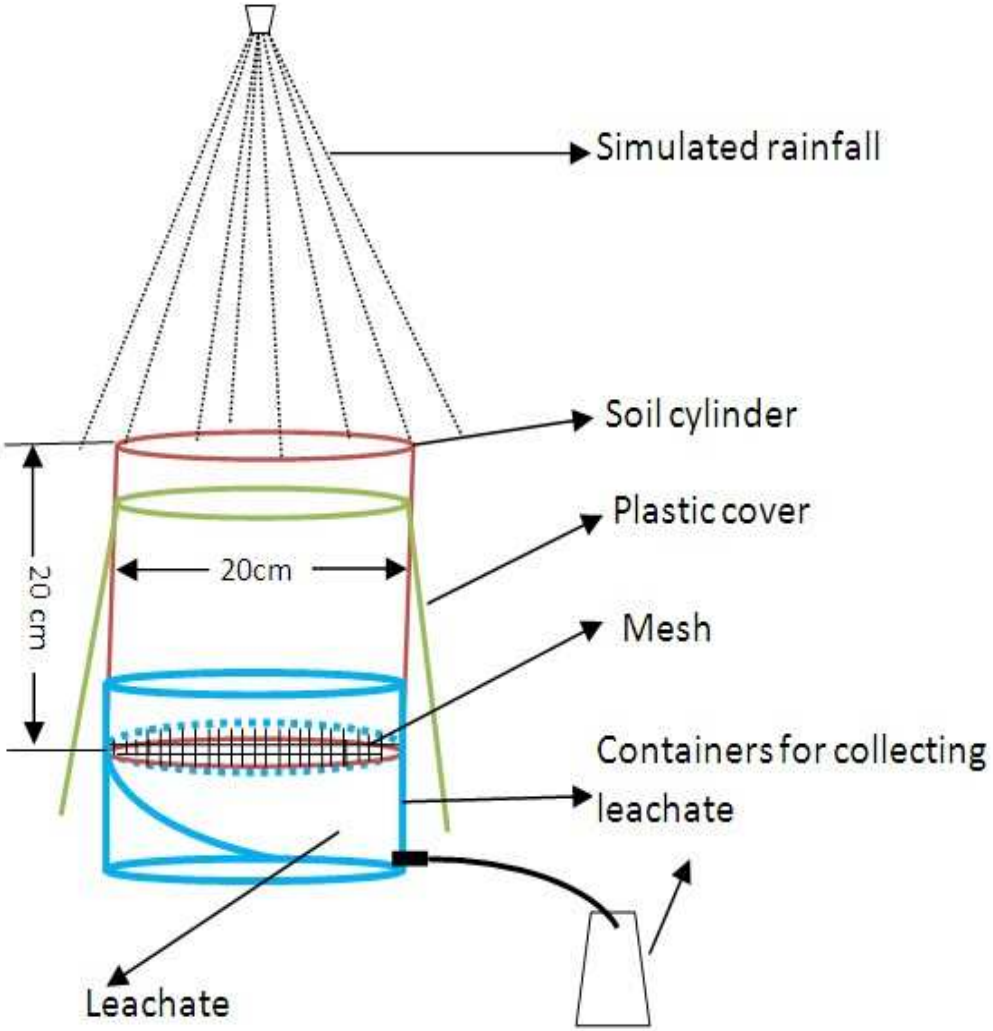


Stream - culvert opening

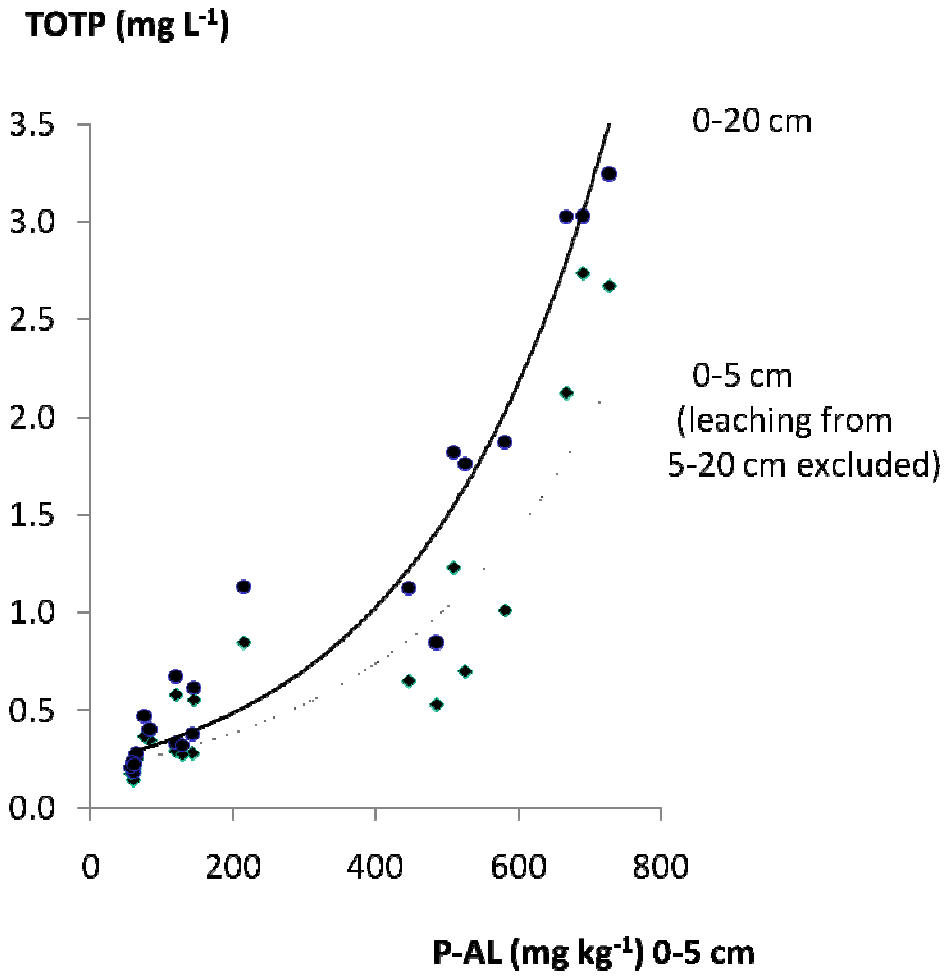


Water rich in salts slowly passing through the soil
Water poor in salts – channelized flows in the soil

Sources
+ risk of mobilisation



Sources + risk of mobilisation

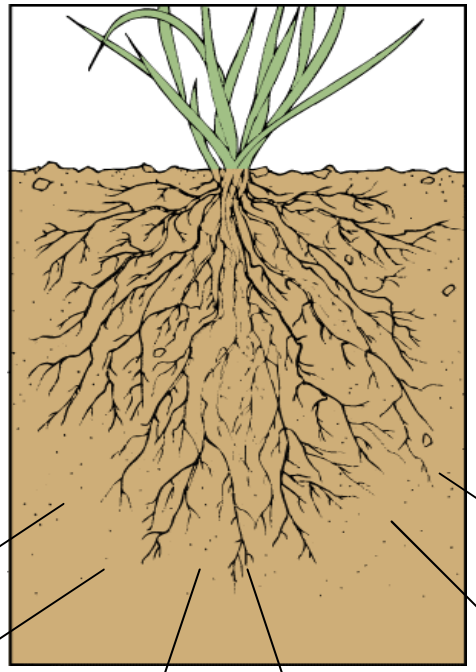


Higher risk for P leaching with higher P-AL topsoil content

Not-inversed topsoil – most of the P from 0-5 cm

Sources

P-AL measured in an extract with ammonium lactate (weak organic acid)



Root exudates with organic acids – the crop can take P bound to iron (Fe) - and aluminium (Al) in the soil

Organic acid

Organic acid

Organic acid

Sources + risk of mobilisation

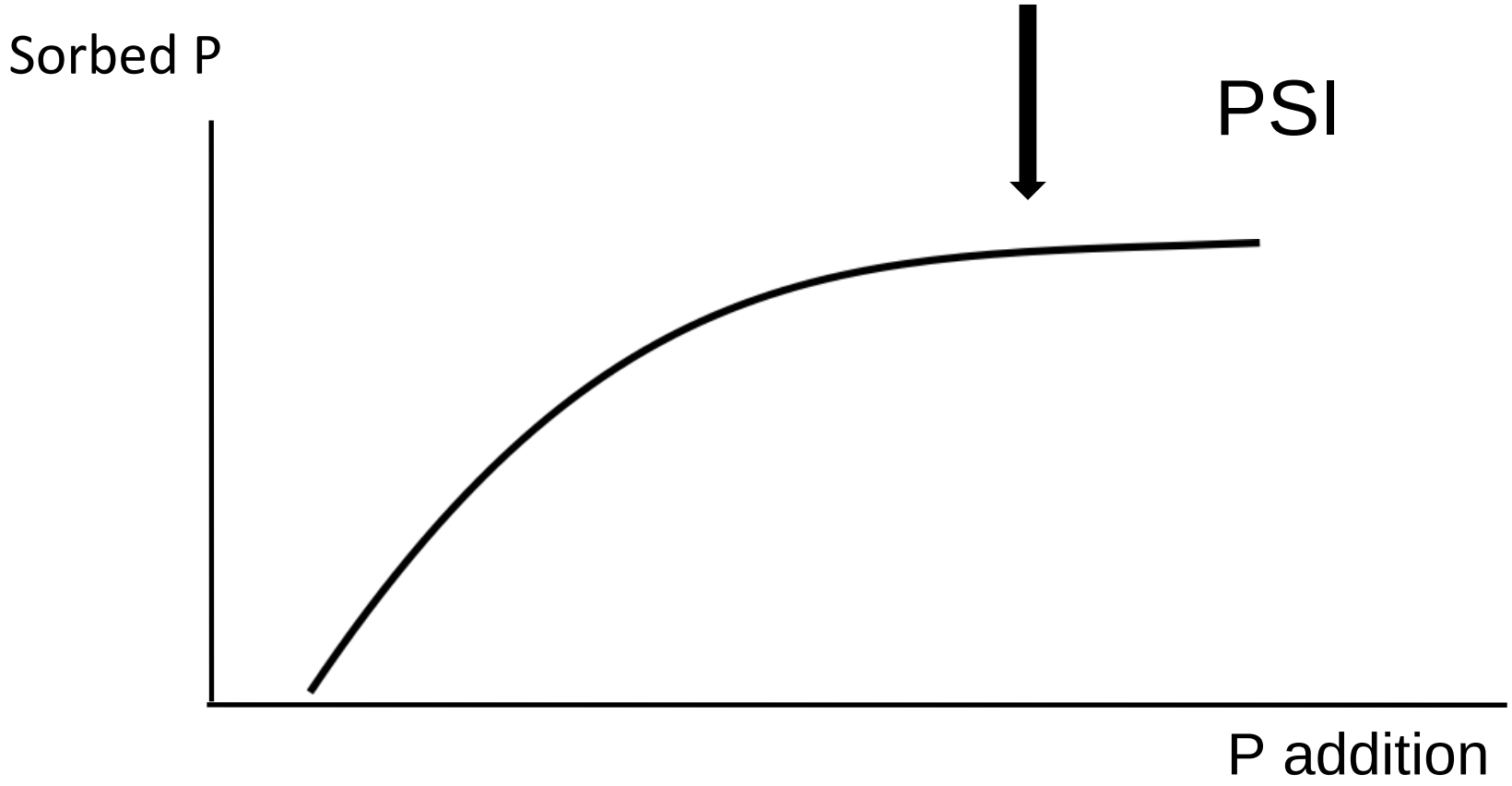
”degree of phosphorus saturation ”(DPS) in **the lactate extract** (mole basis)

$$DPS = \frac{P\text{-}AL}{Fe\text{-}AL + Al\text{-}AL} \times 100$$

Numbers higher than 25 also in the subsoil means enhanced risk for high P leaching

Sources + risk of mobilisation

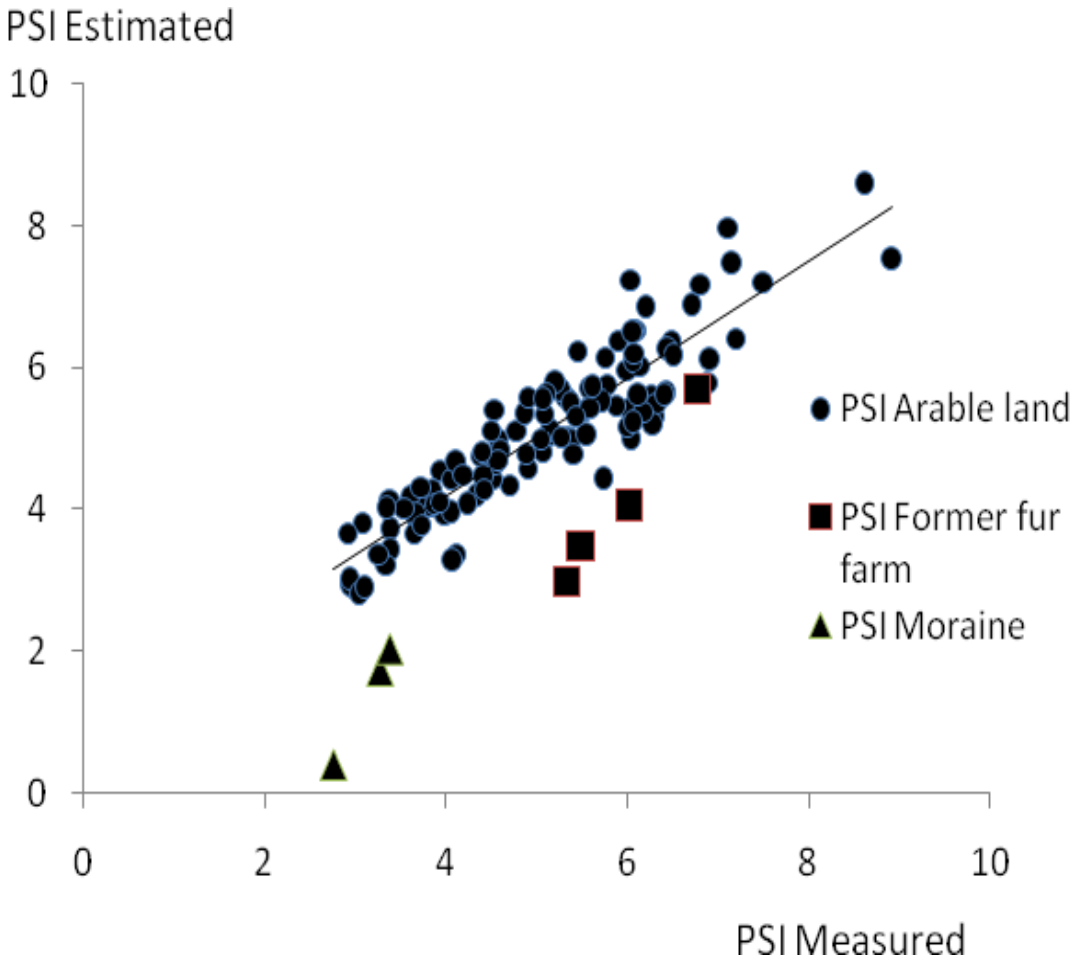
How much P can the very soil material sorb or release?



Correlation between PSI and maximum amount of P that can be sorbed (Börling, et al., 2003)

Sources + risk of mobilisation

PSI and concentrations of Fe + AL and P in Al extract
-two fields exceptions -

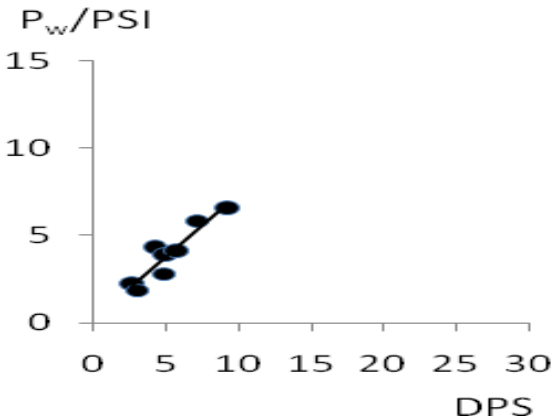


PSI and much manure??

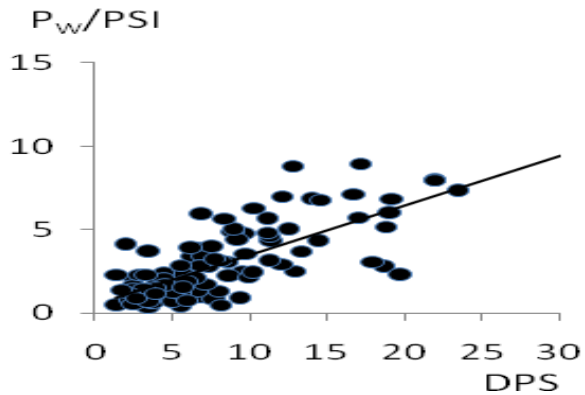
Sources + risk of mobilisation

Pw/PSI and DPS in AL-extract

Round-up treated broad bean



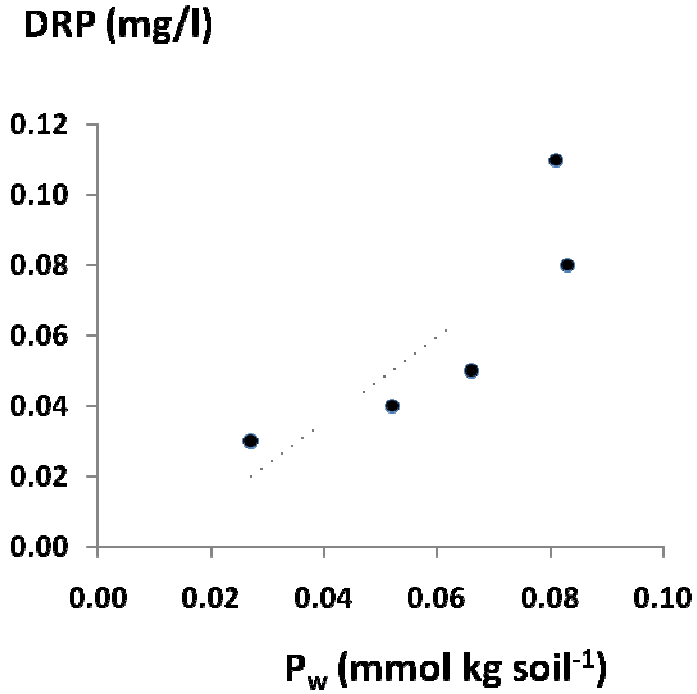
All other sites in the catchment



P_w - leaching from crop residues

Sources + risk of mobilisation

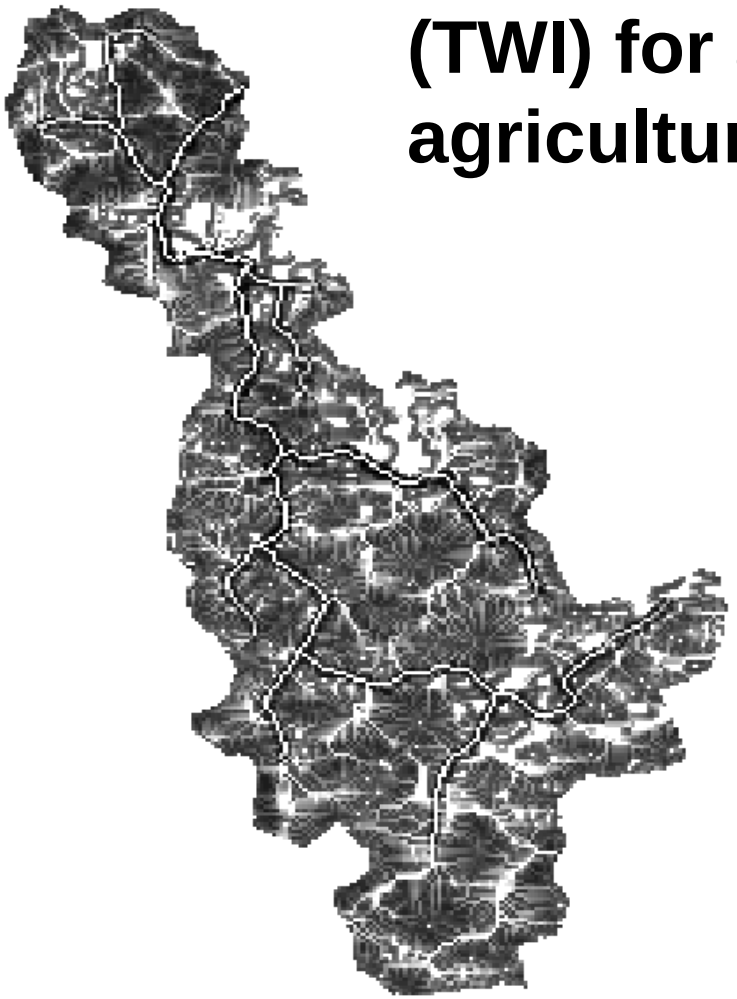
DRP in tile drains and water-soluble P (Pw) in soil



Water-soluble P (Pw) approx 2% of P-AL

Transport

Topographical wetness index (TWI) for a small drained agricultural catchment?



Significantly different TWI for 4 of the largest fields

Transport

	Physical properties		**Water retention**
Depth (cm)	Clay (%)	Porosity (vol %)	Sat. hydraulic conductivity (m day^{-1})
10-15	60	45	0.007
35-40	80	50	**0.003**
75-80	80	56	0.020

Transport

Saturated hydraulic conductivity :

0.007- 0.06 m day^{-1}

Theoretically, tile drain spacing should be reduced

11 m drain spacing between instead of current 14-16 m

Risk assessment

Areas in catchment E23

Sources	Transport (rills, ponded water)	Transport (re-drainage needed)	Source ***and*** transport
10 %	**3 %**	**12 %**	**7 %**

Conclusions

Important factors to be considered:

- Small P soil pools (P_w)
- Short- and long-term effects of manure addition (PSI)
- Open stream management and bank erosion
- Soil hydrology in drained agriculture landscape
- Efficiency of artificial drainage system

Measures will start – structure liming, open stream management, manure with better precision

Thanks to Formas – Swedish Research Council for Sustainable Development