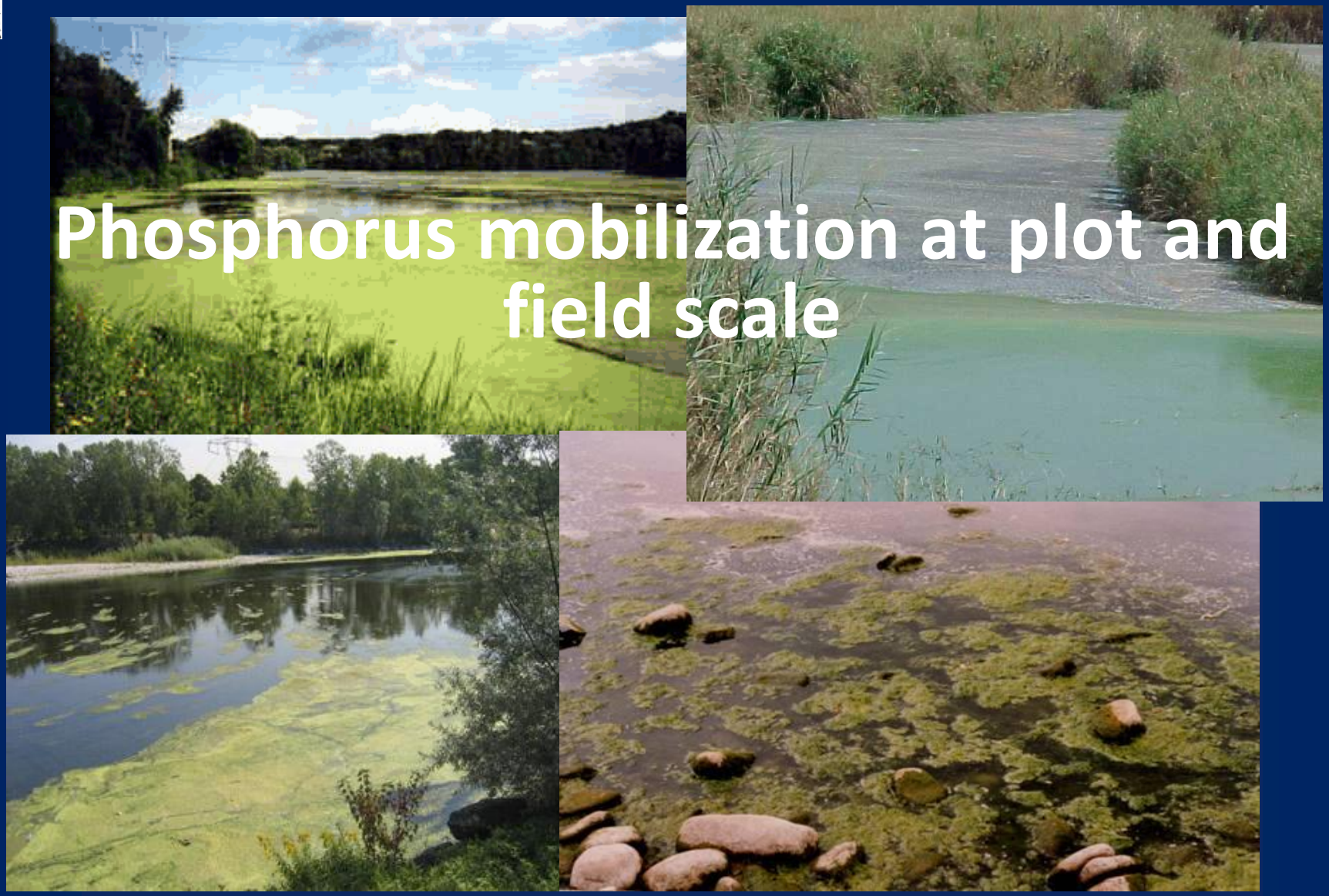
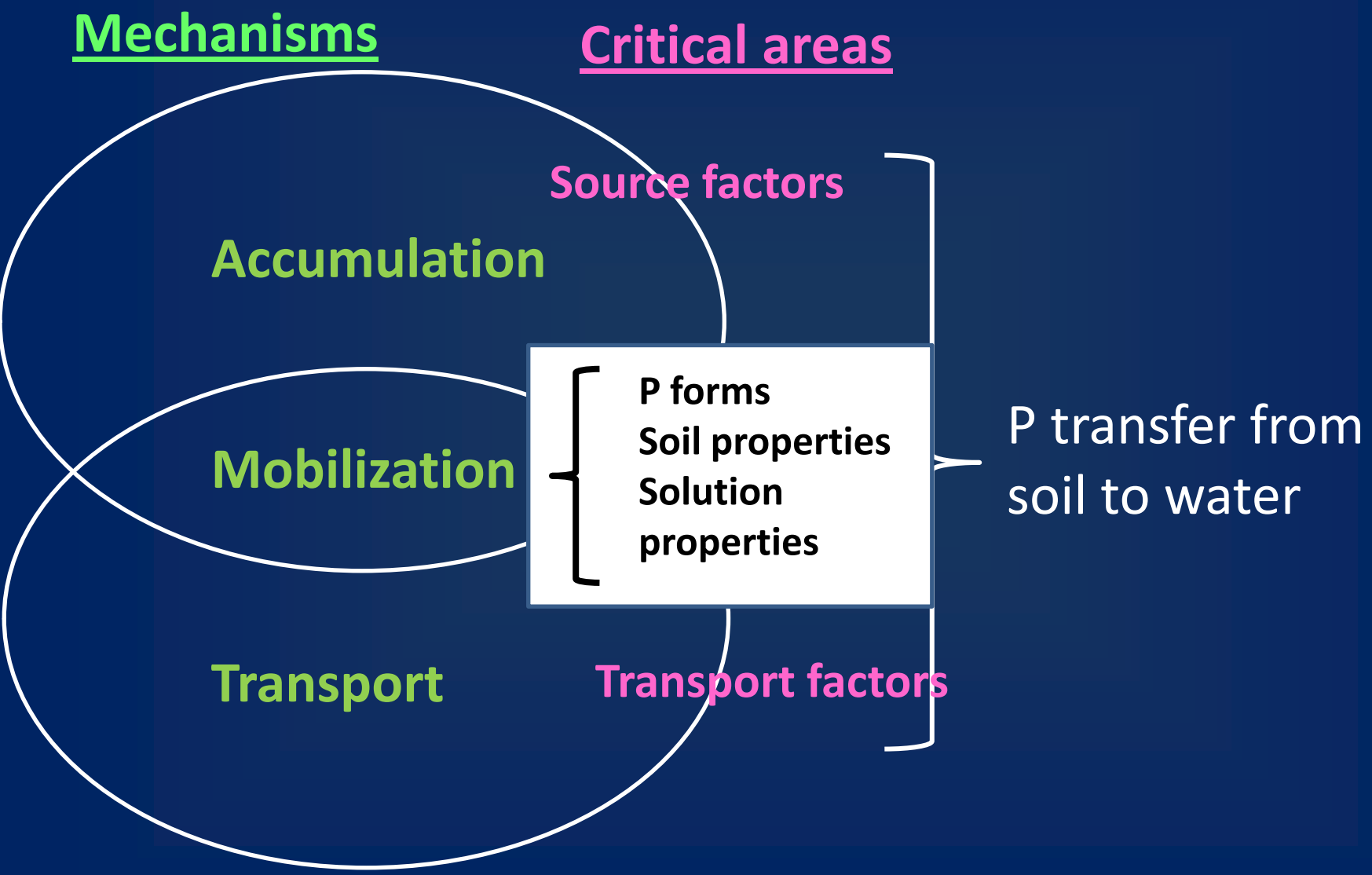
Phosphorus mobilization at plot and field scale



Elisabetta Barberis

Di.VA.PRA – University of Torino - Italy

Mobilization is the initiation of P movement:

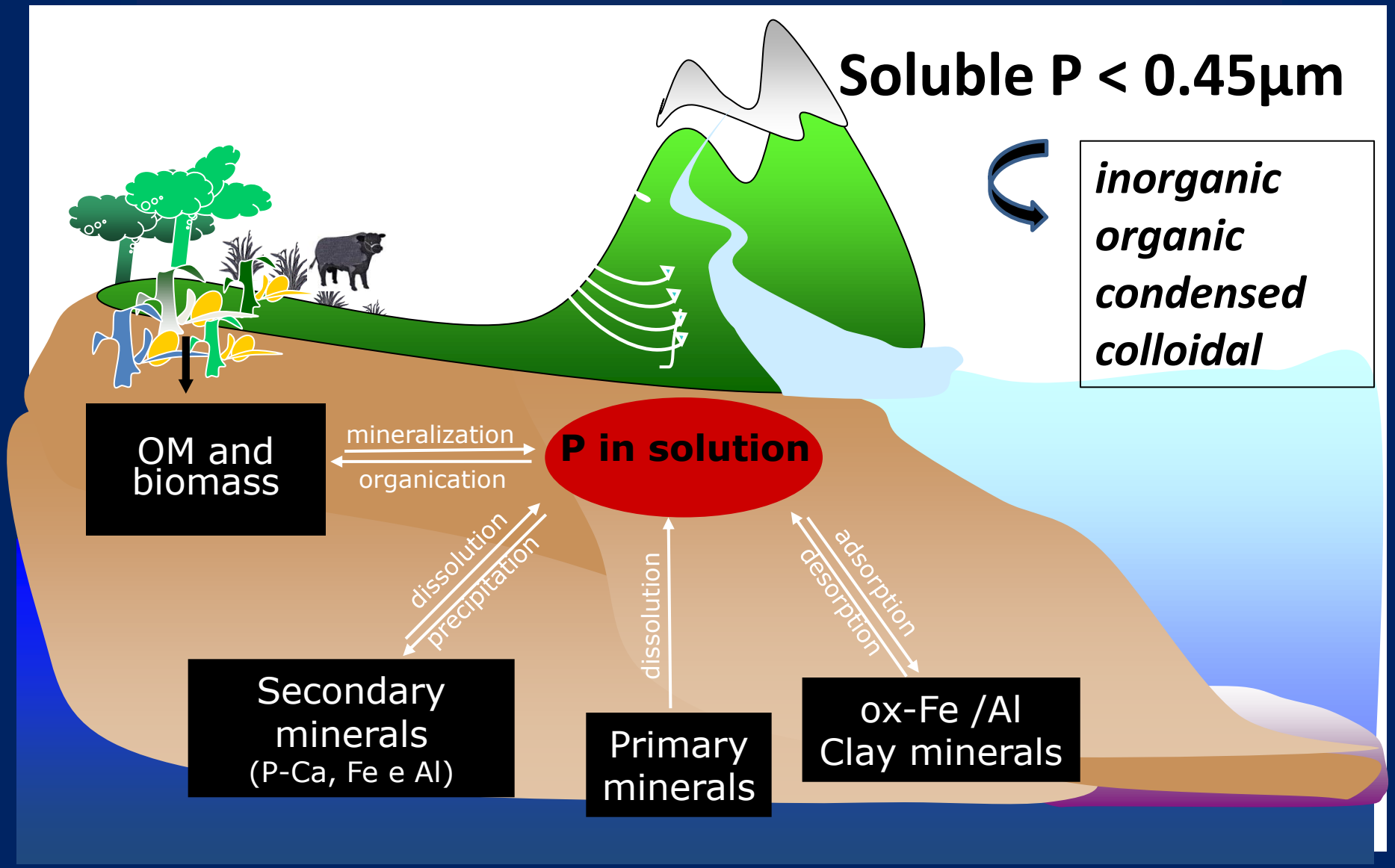


Processes for mobilization

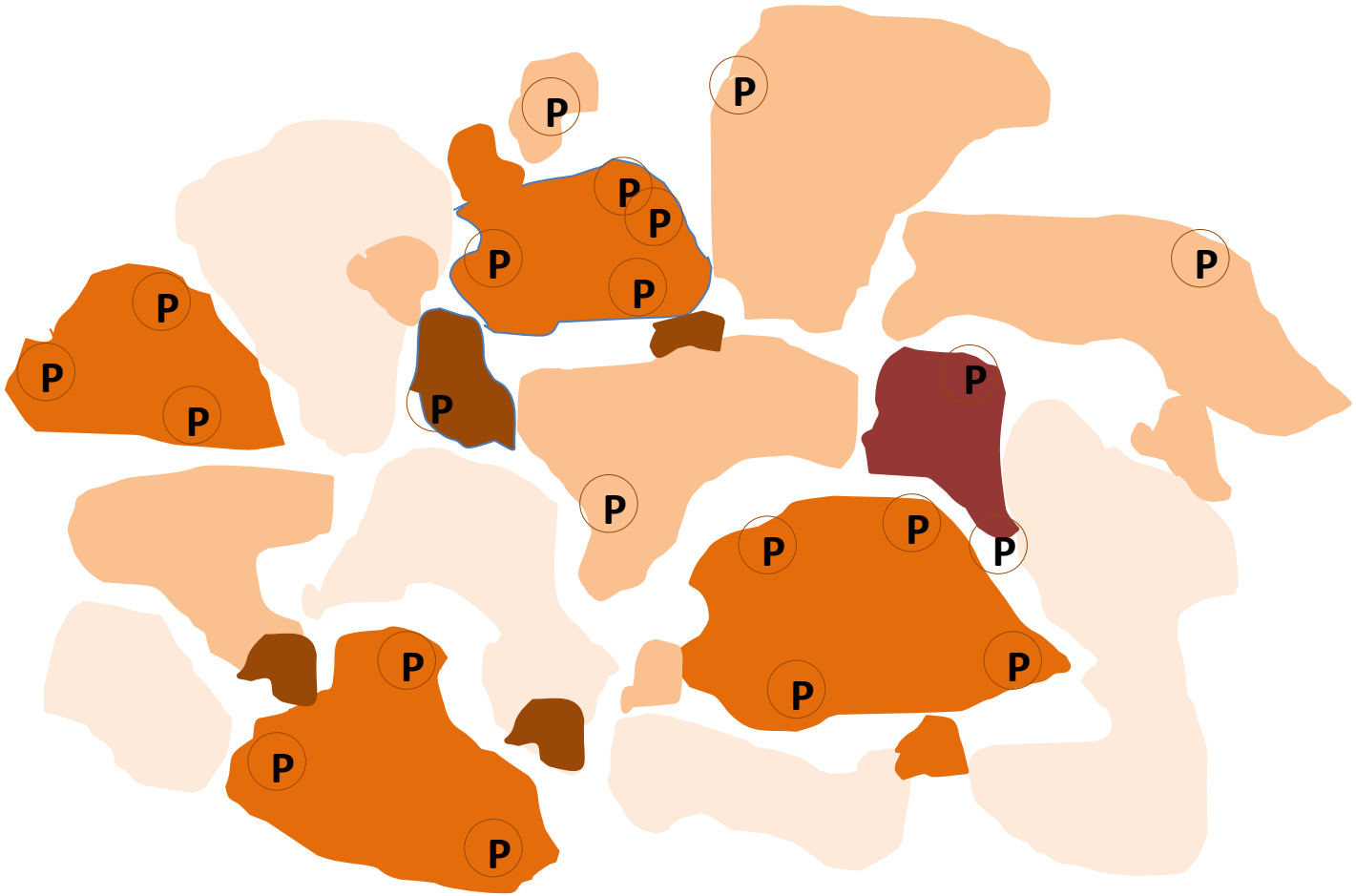
Solubilization

Detachment

Solubilization → Transfer of P from a solid phase to a water phase



Detachment ⟶ Particulate P >0.45µm

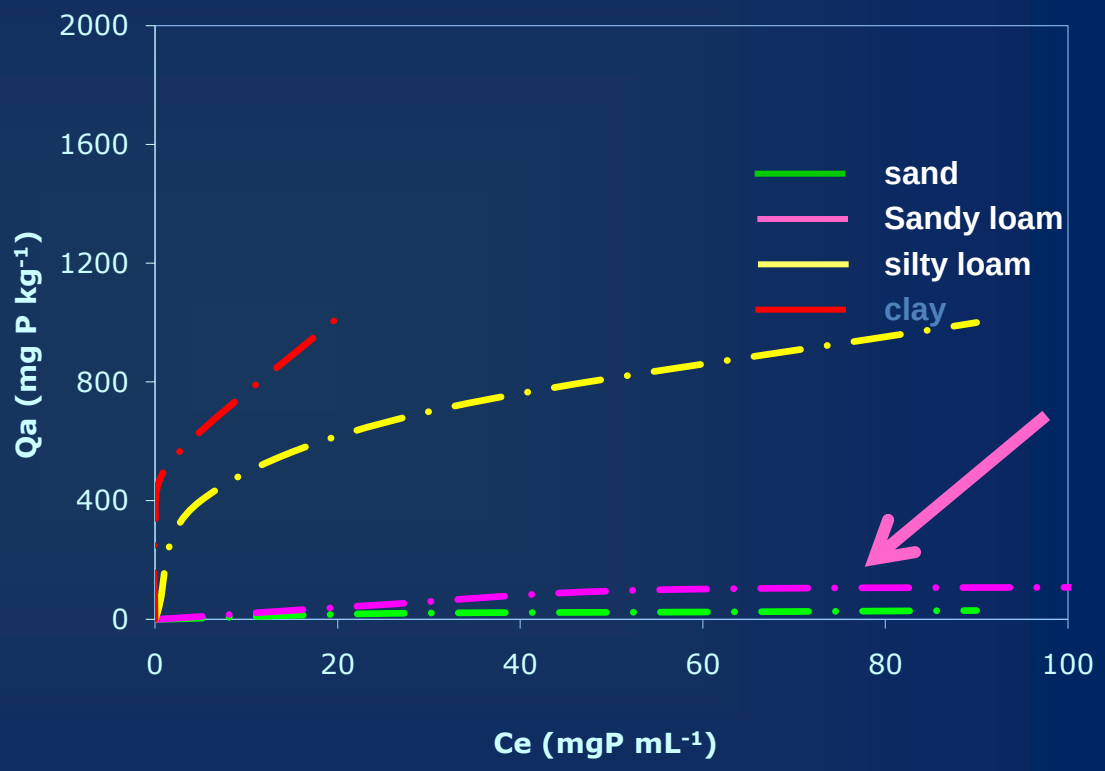


Sorption-Desorption

Soil with low P sorption capacity

Soil properties

1. **Texture: sandy**
2. **Low specific surface area**
3. **Poor in P sorbing constituents**



Leaching through sandy soils towards the ground water accounted for about 85-90% of the P losses from the agricultural land. (Breeuwsma and Silva; 1992)

Sorption-Desorption

Soil with high P sorption capacity

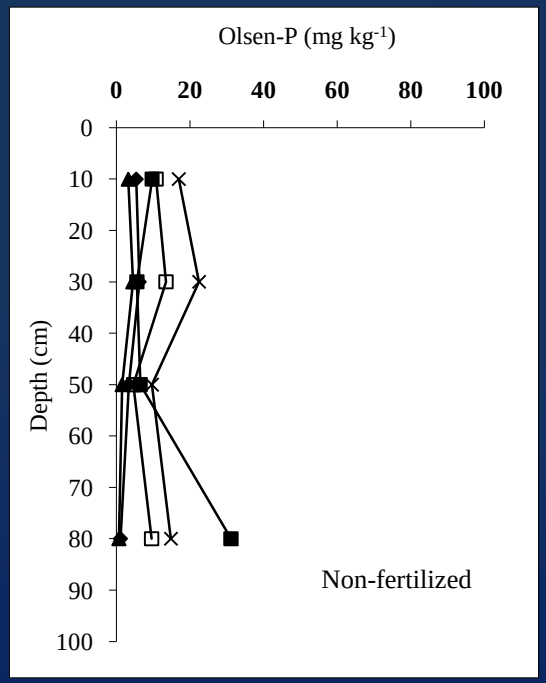
Soil properties

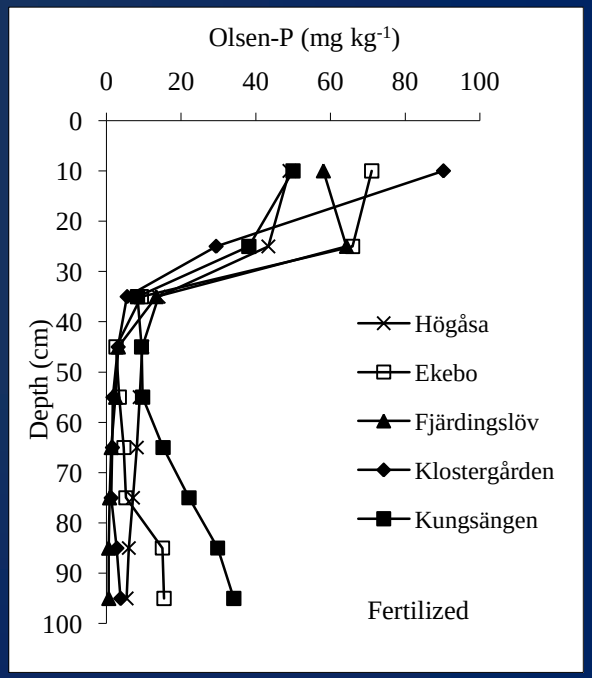
1. **Texture: clay**
2. **High specific surface area**
3. **Rich in P sorbing constituents**

1. ***in the humid temperate regions:*** ***poorly crystalline Fe and Al oxides and organic complexes (van der Zee et al., 1990)***
2. ***in the Mediterranean region:*** ***crystalline Fe oxides, carbonates and clay minerals (Peña & Torrent, 1990)***

In agricultural soils P tends to accumulate in the topsoil

P level	P addition
A	0
B	Replacement of P (R)
C	(R) + 15 kg P ha^{-1} y^{-1}
D	(R) + 30 kg P ha^{-1} y^{-1}





Borling K., Barberis E., Otabbong E. 2004. Nutrient Cycling in Agroecosystems.

Prediction of soil P susceptible to transfer to water in soluble forms.

Approaches

- Use of soil test P (STP)
- Evaluation of P sorption properties of soils
- Quantification of P in the soil solution

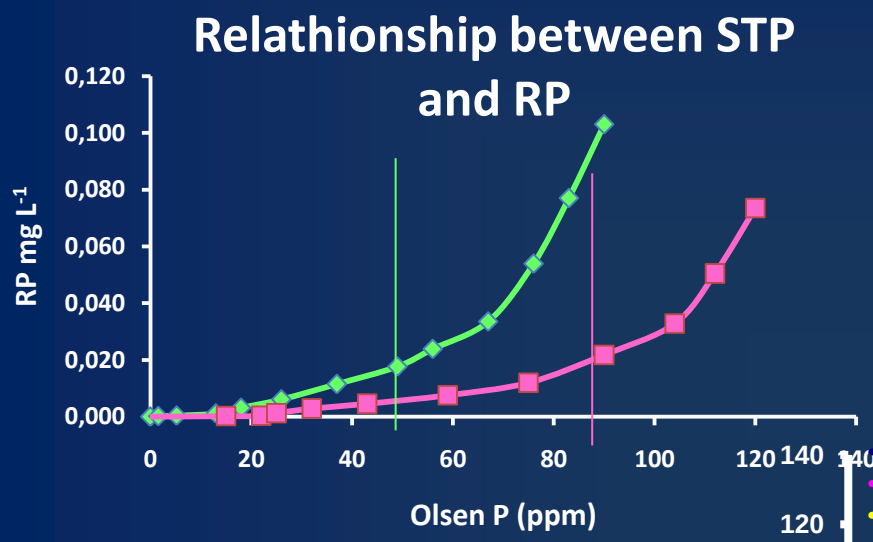
Experimental methodologies

Tested measuring P concentration and/or P forms in leachate

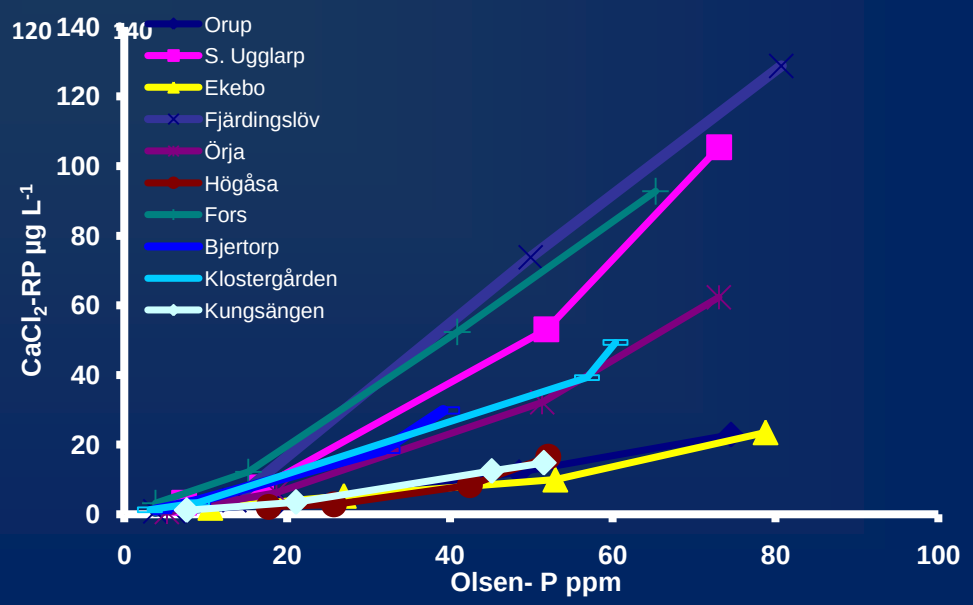
1. **Intact soil cores**
2. **Homogenized soil columns**
3. **Lysimiter**
4. **Porous cup**
5. **Drainage water**
6. **Surface runoff**

1. Solubilization: use of STP

The amount of P released from soil solid phases to solution is dependent on soil P status



Heckrath et al. 1995
McDowell and Condron, 1999
Hesketh and Brookes, 2000
……..



Borling, Otabbong, Barberis. 2004,.

2. Solubilization: evaluation of PSC

The amount of P released from soil solid phases to solution is dependent on the degree of P sorption saturation (DPSS)

$$\text{DPSS (\%)} = \frac{\text{sorbed P}}{\text{P Sorption Capacity (PSC)}} \times 100$$

$$\text{DPSS (\%)} = \frac{P_{ox}}{\alpha\,(Fe_{ox}+Al_{ox})} \times 100$$

van der Zee *et al*. (1987)

2. Solubilization: evaluation of PSC

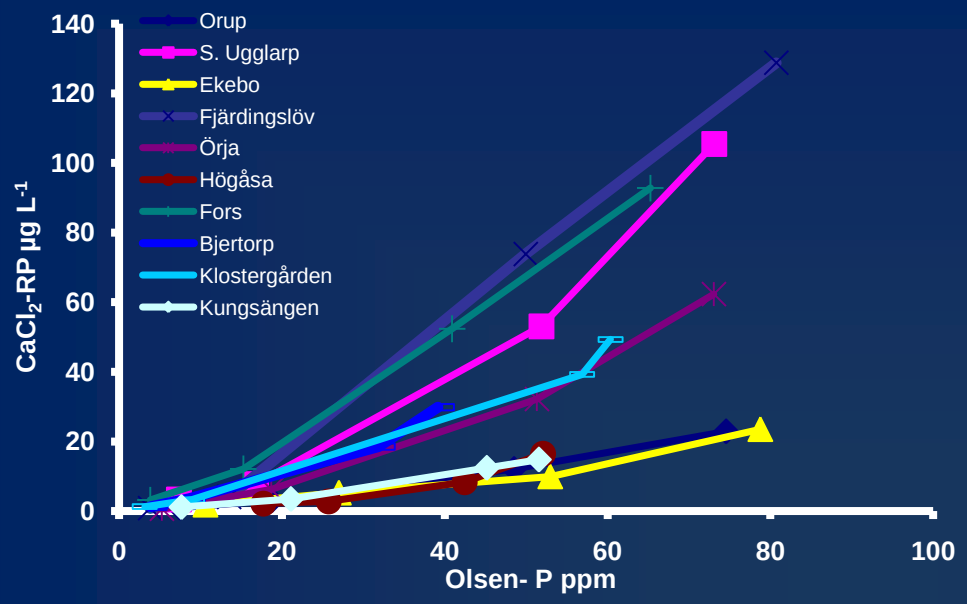
The amount of P released from soil solid phases to solution is dependent on the degree of P sorption saturation

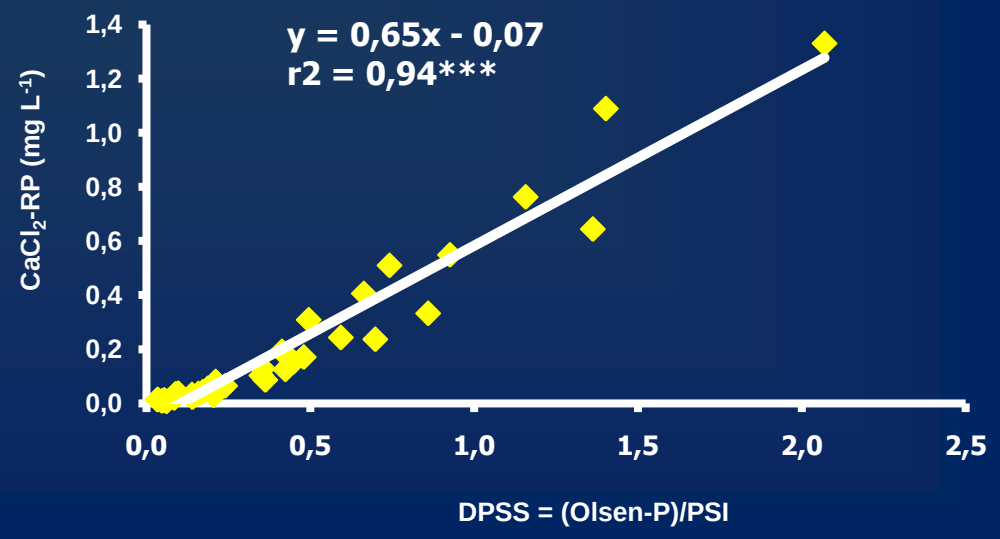
$$\text{DPSS (\%)} = \frac{\text{sorbed P}}{\text{PSC}} \times 100$$

Psorbed
- STP
- IEP
- Resin or strip

PSC
- X_{max}
- PSI
- Pedotransfer

2. Solubilization: evaluation of PSC





Extraction of soils at different solution:soil ratio

1:1

10000:1

Simulate leaching conditions

1.2:1 *versus* RP in leachates
Chapman et al., 1997

Simulate runoff or interactions between soil and rain

100:1 *versus* RP in runoff
Yli-Halla et al. 1995

Water
$CaCl_2$ 0,002- 0,01 M

Detachment

Detachment of soil particles and colloids with attached P is mainly due to forces exerted by moving water and repulsive forces between colloidal particles.

Particulate P >0.45µm

$$P_{loss} = \frac{\text{Mass of P}}{\text{Mass of erodible soil}} \times \frac{\text{Mass of erodible soil}}{\text{Volume}}$$

P concentration of soil particles

the loss of soil

Detachment

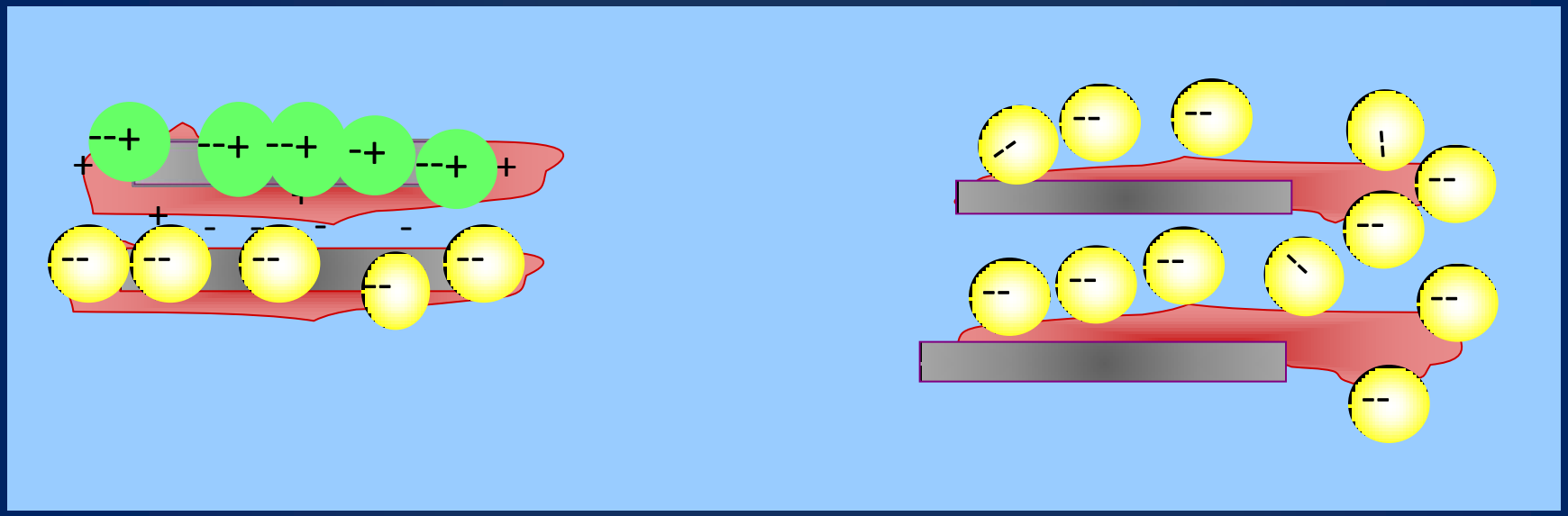
Physical factors:

- rain splash energy
- slaking forces
- shear forces of overland flow

Chemical factors

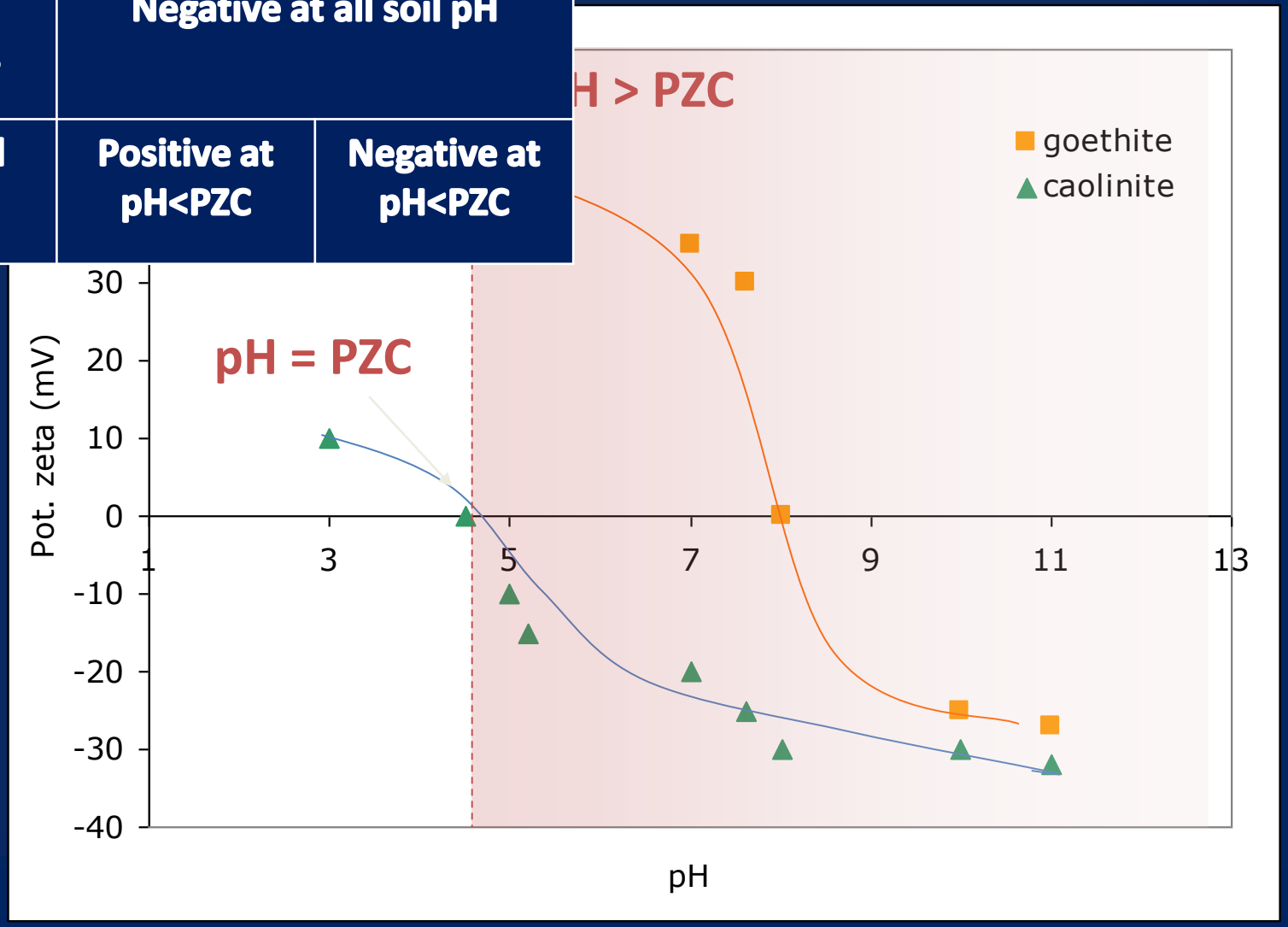
- properties of dispersible particles
- properties of soil solution

Dispersion/flocculation behavior of colloids depends on their charge



Detachment

	Particles Charge	
Organic matter	Negative at all soil pH	
Clay minerals	Negative at all soil pH	
Fe and Al oxides	Positive at pH<PZC	Negative at pH<PZC

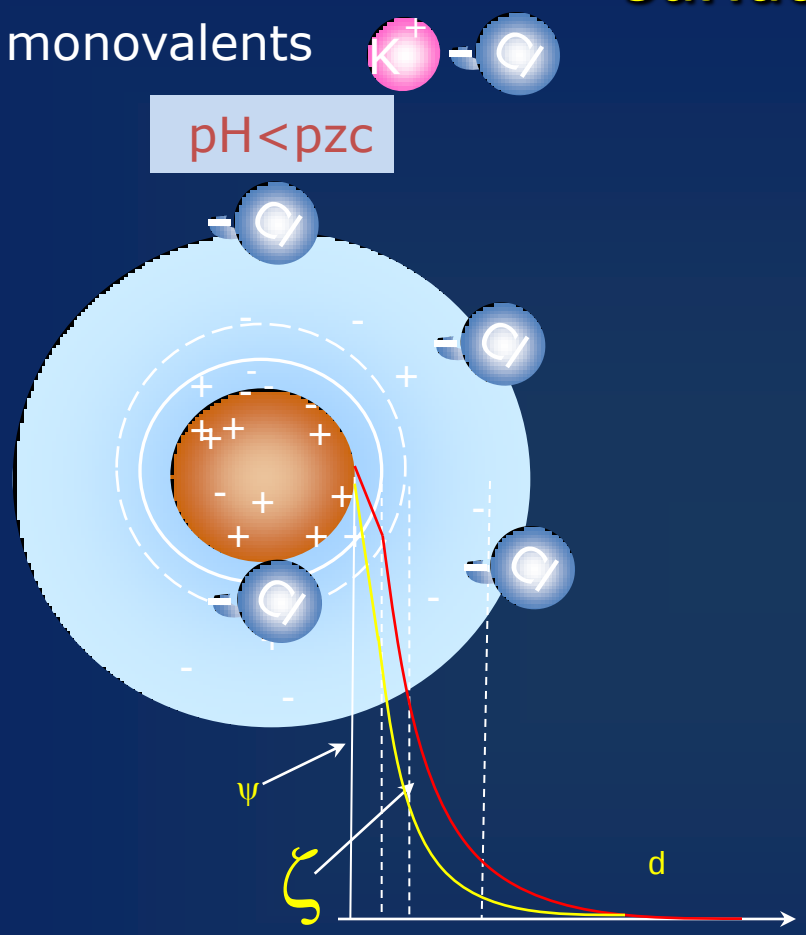


Surface charge

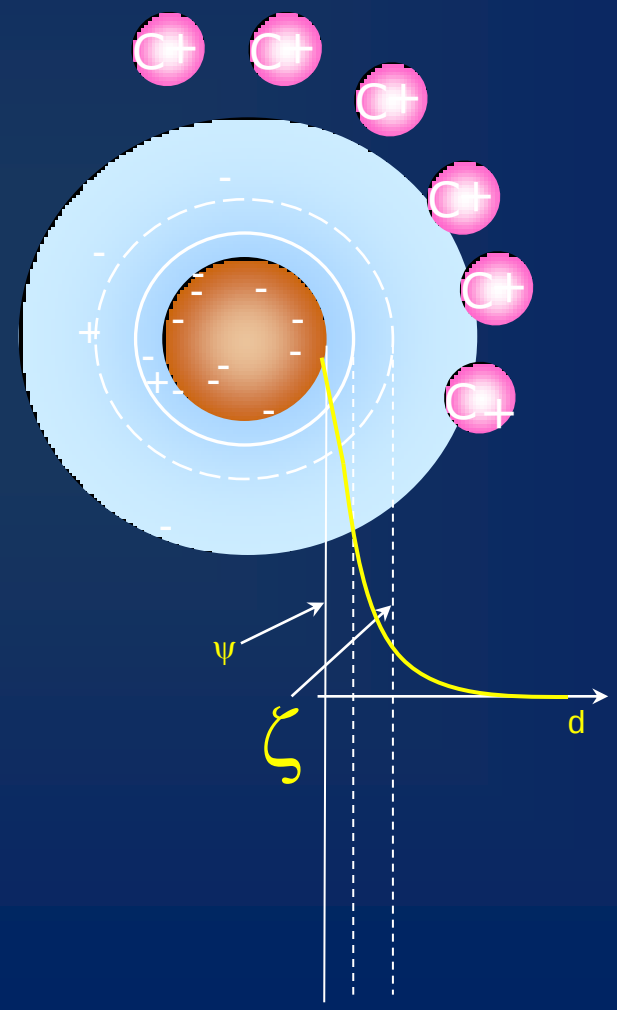
- pH
- Ionic strenght
- Ionic composition

- monovalents

pH<pzc

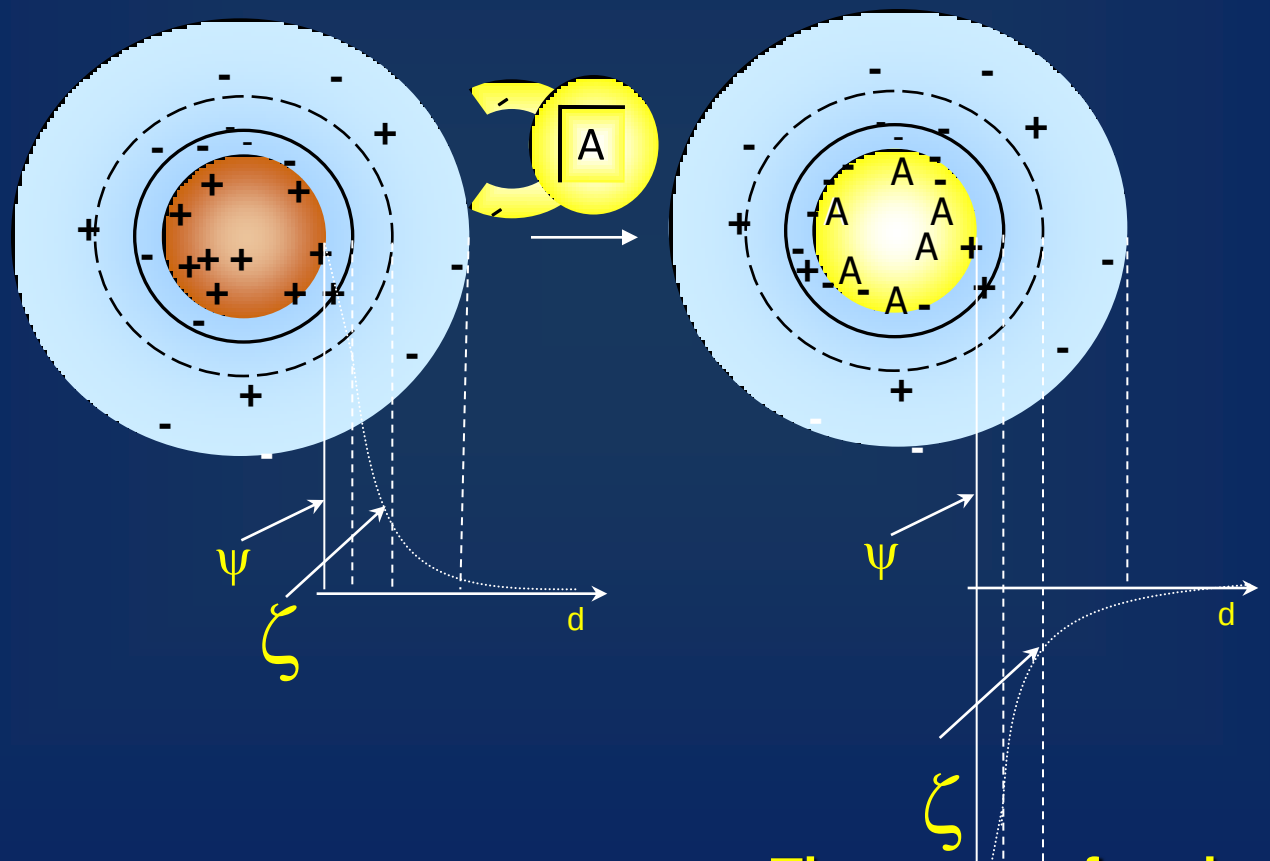


- polivalent



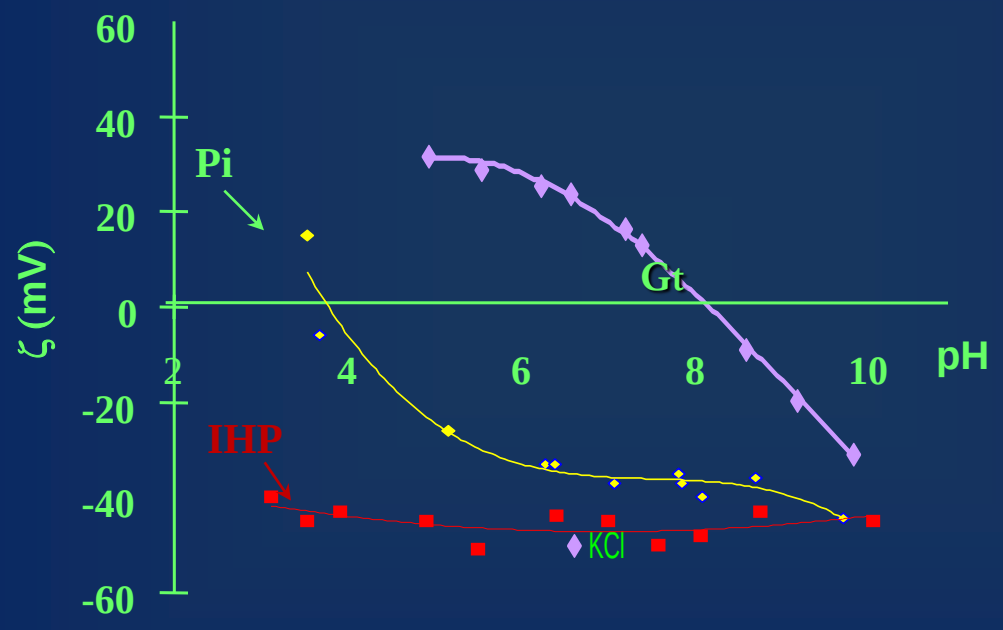
↑ Ionic strenght ↓ dispersion

Effects of anions adsorption on surface properties

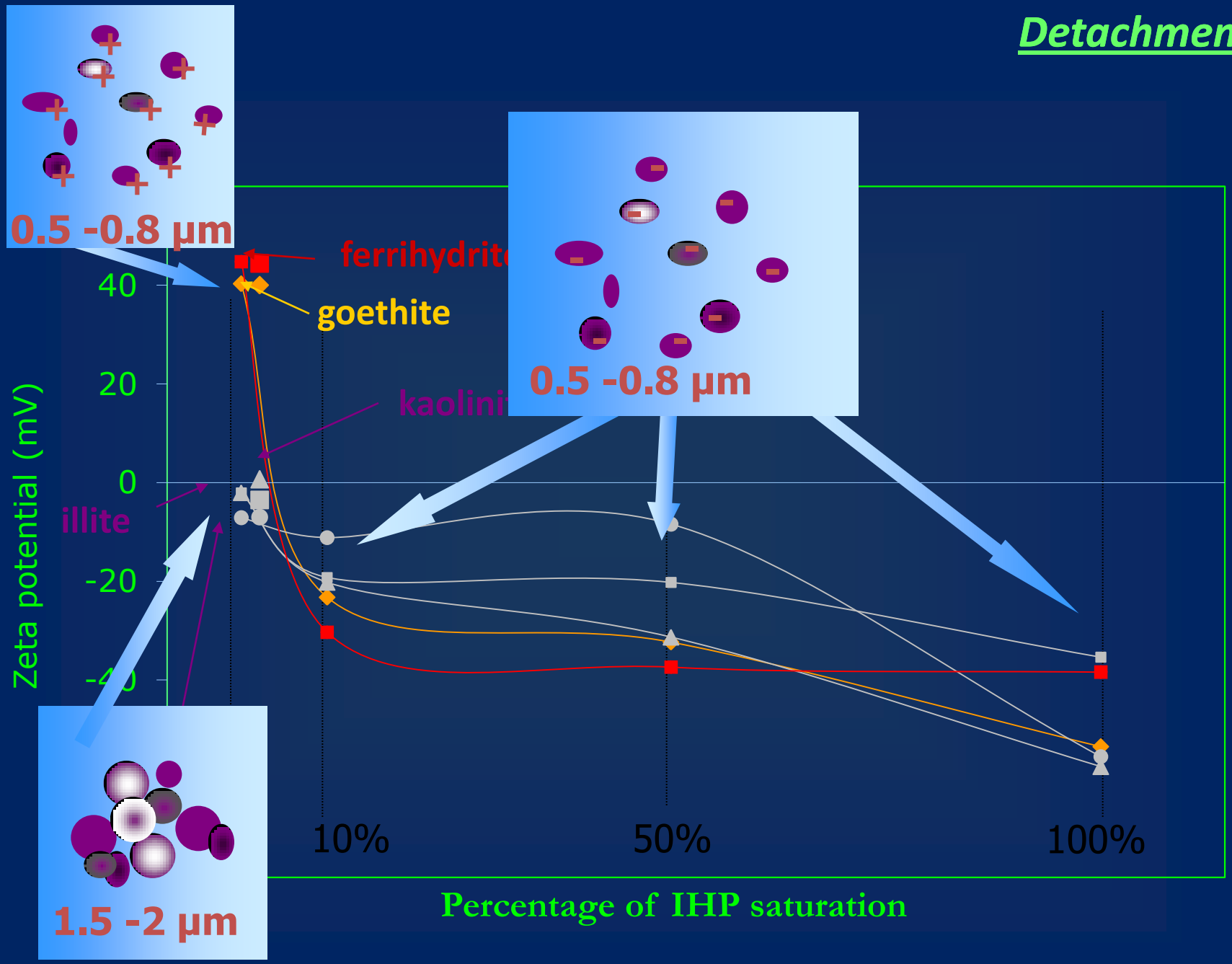


The new surface is more negative

Sorption of Pi and IHP on goethite
Effect on Zeta Potential (ζ)

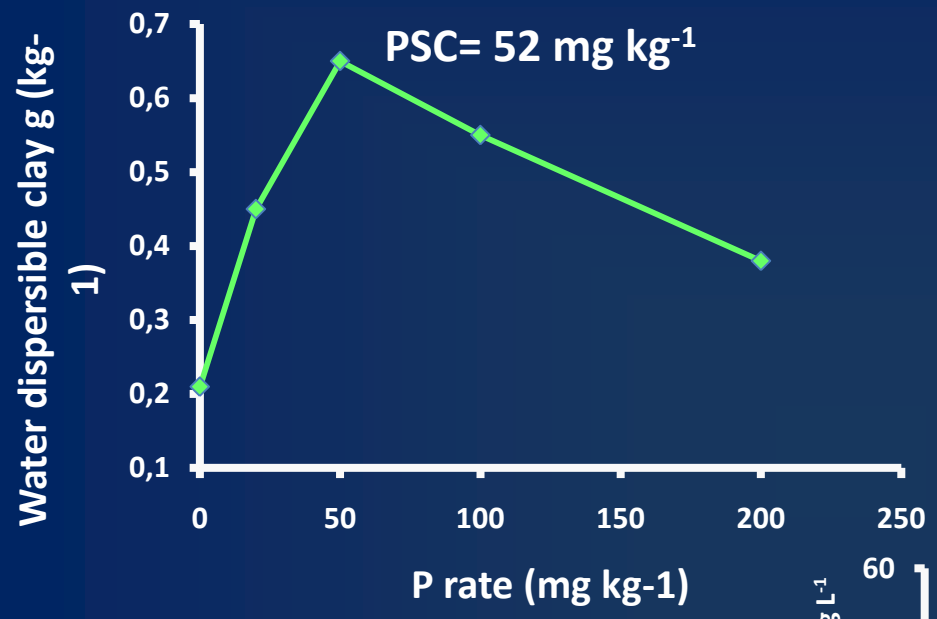


Detachment

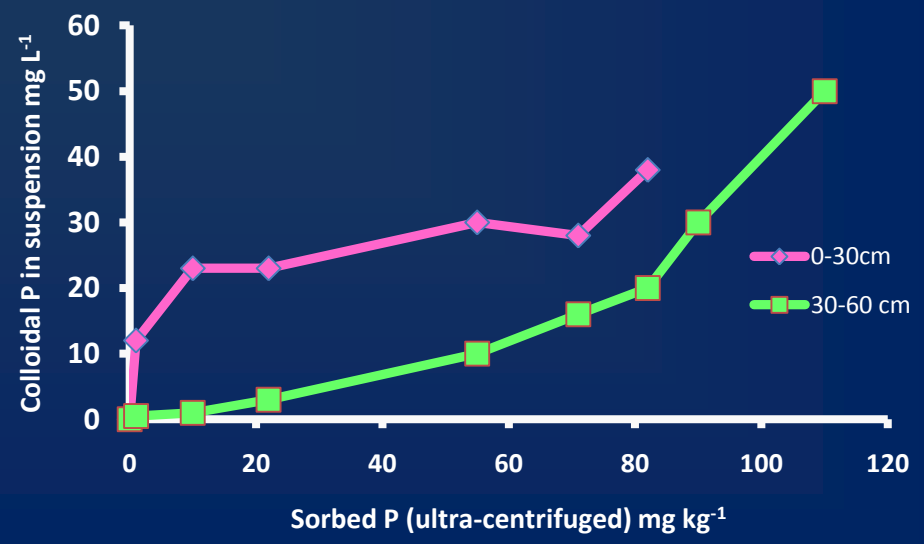


Celi and Barberis 2005

Effects of P application rate on water dispersible clay



Adapted from Zhang , He, Calvert, Stoffella, 2003. Soil Sci.



Adapted from Siemens, Ilg, Lang, Kaupenjohann, 2004. Eur. J. Soil Sci.

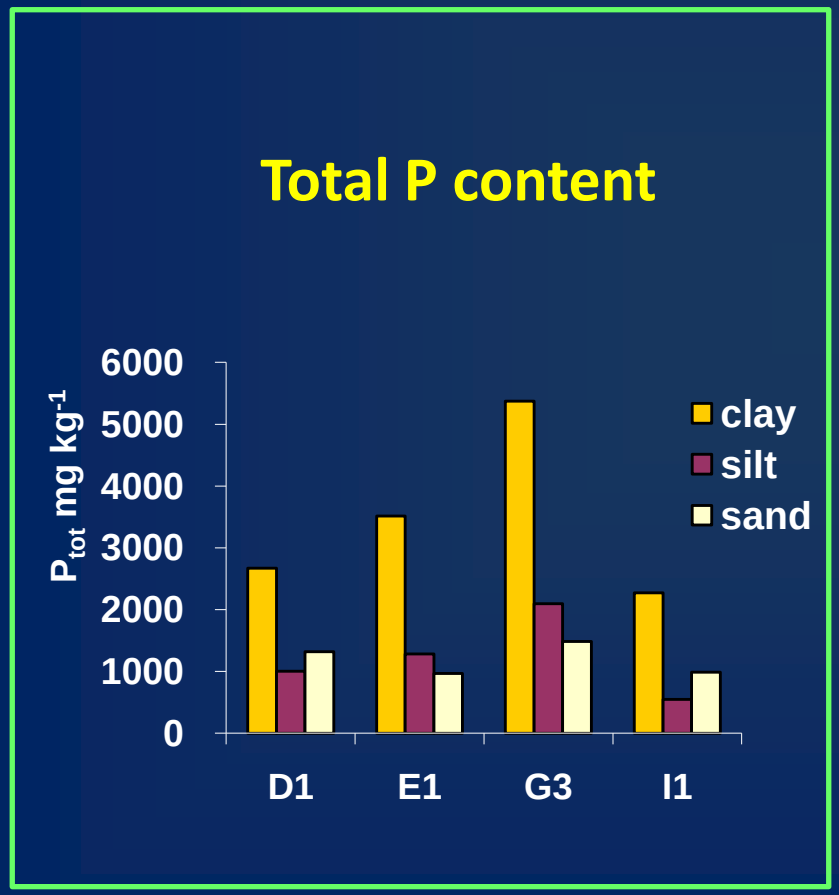
Prediction of soil P susceptible to transfer to water in particulate forms.

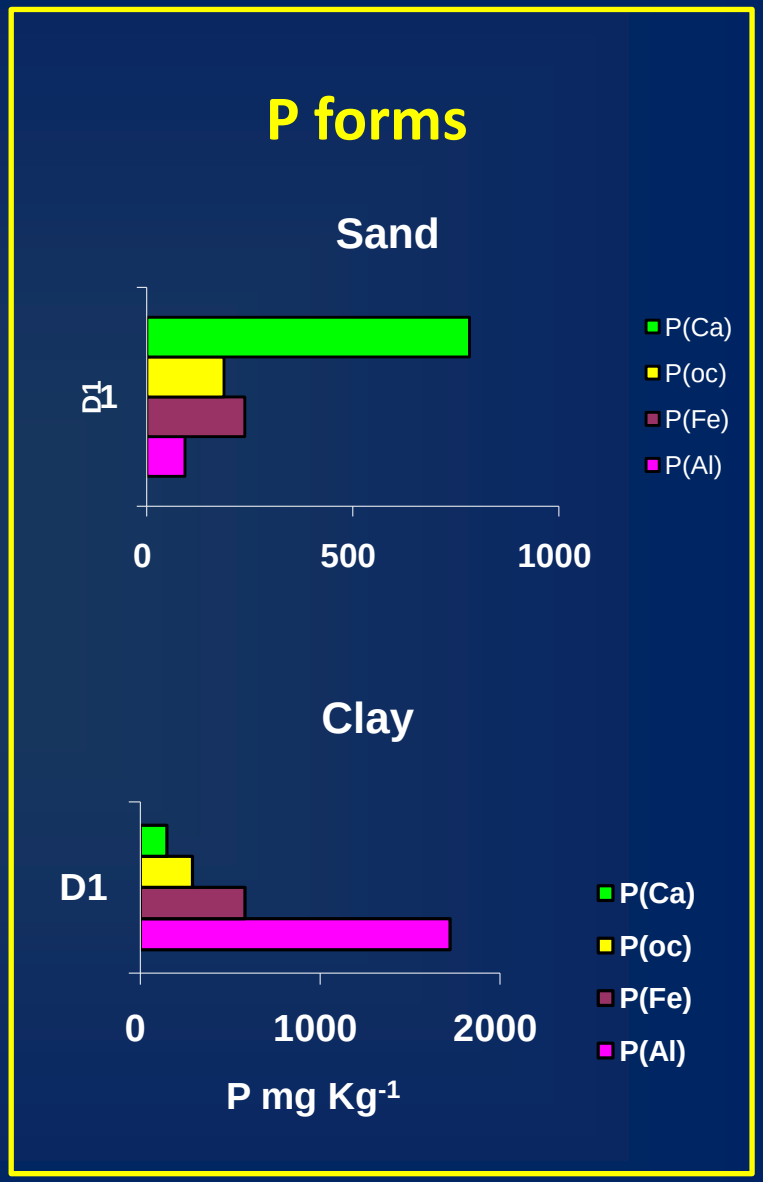
Approaches

Physically based

- *Wet sieving*
- *Dispersibility of a single aggregate*
- *Percolation stability test*
- *Erodibility tests*
- *Soil dispersibility tests*

Total soil P content is not a good index of particulate P

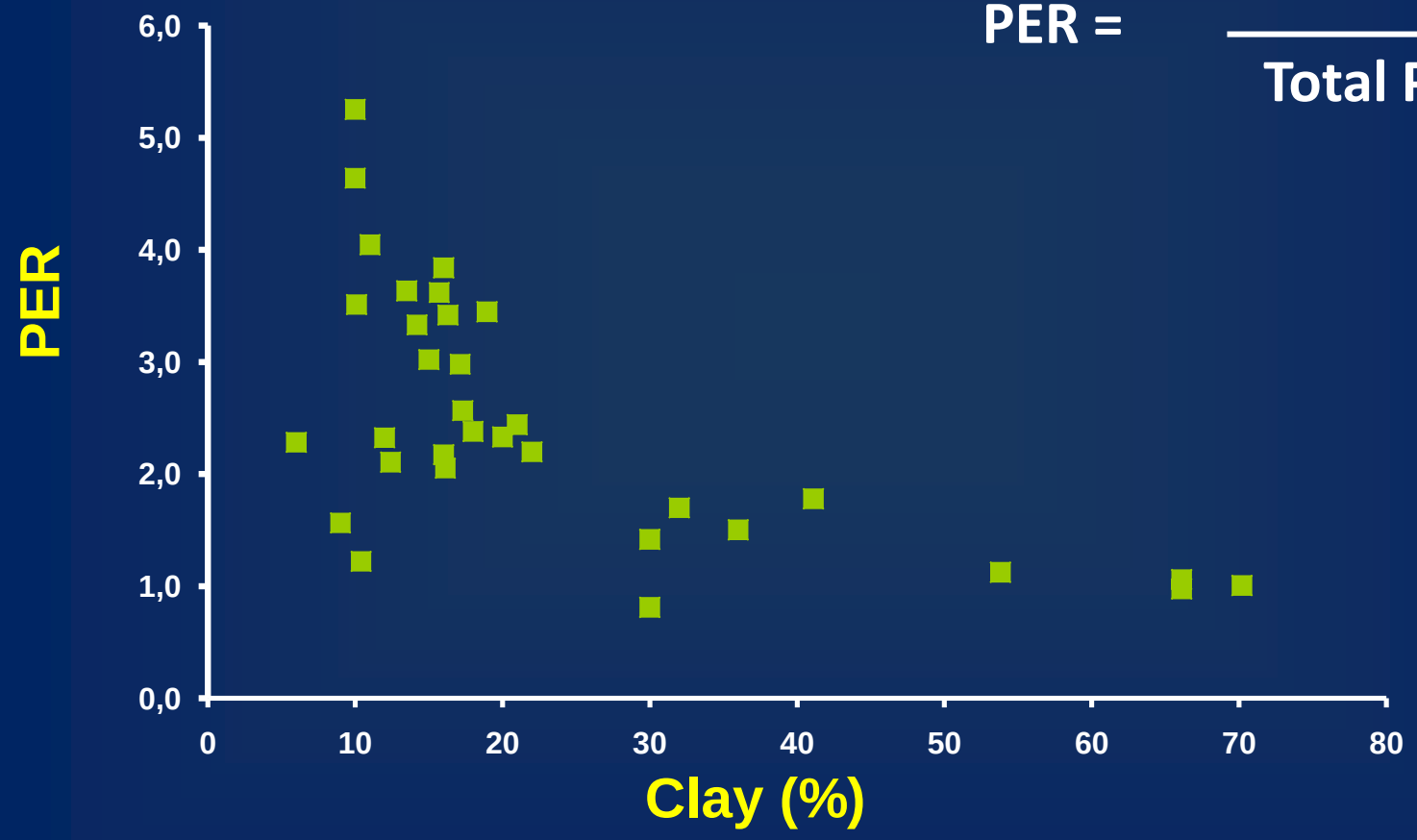




Modified from: Scalenghe, Edwards, Barberis Europ. J. Agr. 2007

Detachment

$$PER = \frac{\text{Total P in clay}}{\text{Total P in soil}}$$



Barberis and Withers 2002

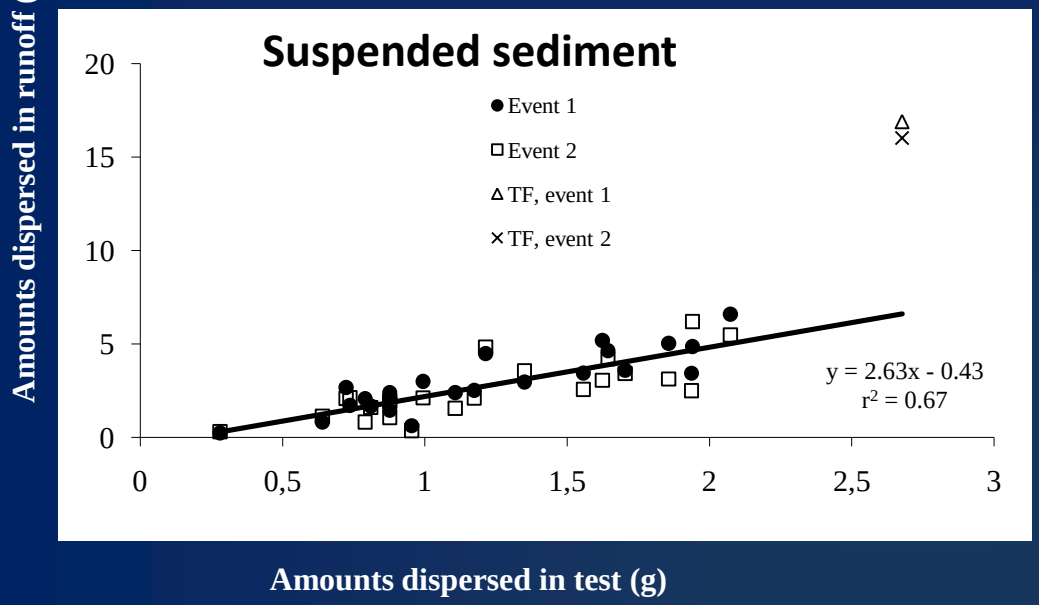
Prediction of soil P susceptible to transfer to water in particulate forms.

- *Soil dispersibility tests*
  - Measure of suspended solids and P
  - Calibration with indoor/outdoor simulation

- Withers, Hodgkinson, Barberis, Presta, Hartikainen, Quinton, Miller, Sisak, Strauss, Mentler. 2007. Soil Use and Manag.

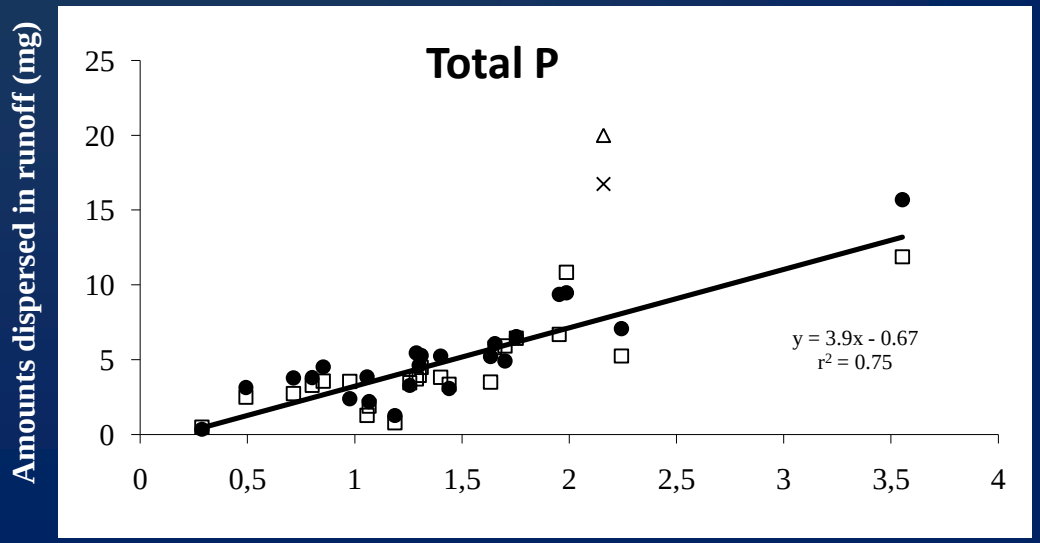
- Udeigwe, Wang, Zhang. 2007. J. Env. Qual.

Detachment



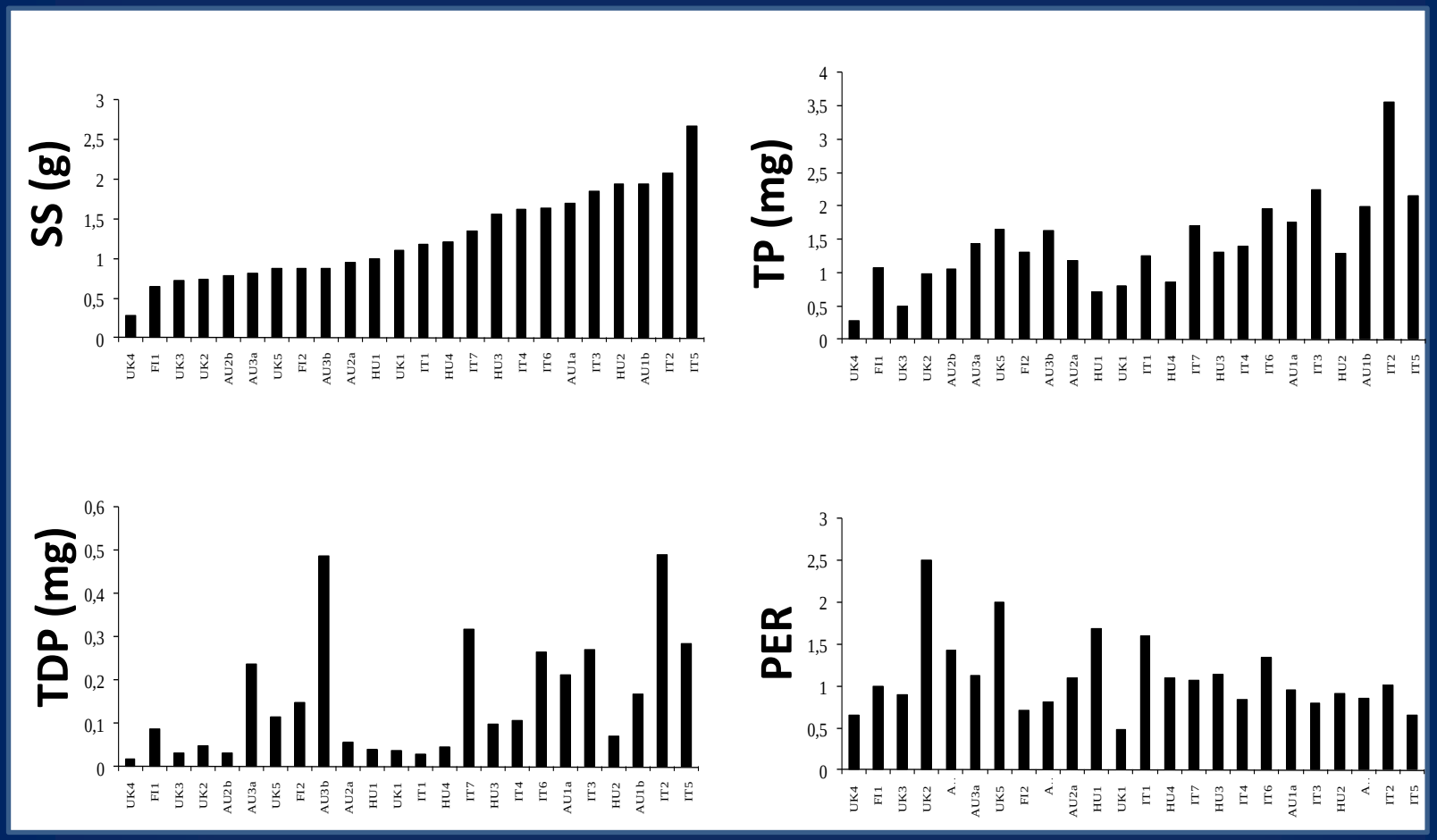
DESPRAL test

Gentle water dispersion test at solution to soil ratio 20:1



Withers, Hodgkinson, Barberis, Presta, Hartikainen, Quinton, Miller, Sisak, Strauss, Mentler. 2007. Soil Use and Manag.

Det achment



Withers, Hodgkinson, Barberis, Presta, Hartikainen, Quinton, Miller, Sisak, Strauss, Mentler. 2007. Soil Use and Manag.

Correlations between Total suspended sediment (TSS) and detached P and soil properties

TSS

Correlated with

- Clay
- pH
- Organic matter

$$\ln TSS = -1.319 + 0.378*(\ln clay) + 0.017 * (silt) -0.151*(\ln Olsen P)$$

TP detached

NOT or poorly Correlated with

- Total soil
- Olsen P

Udeigwe et al. 2007; Withers et al. 2007; Borda et al. 2010


Thank you