Transport pathways of P from soil to water – partitioning and dominance of different flow paths

Christian Stamm
Eawag, 8600 Dübendorf, Switzerland

10 September, 2013

Contents

1. Relationships between P sorption and flow paths

2. Process chains in the landscape

3. Flow paths and ecological endpoints

4. Conclusions

Starting point

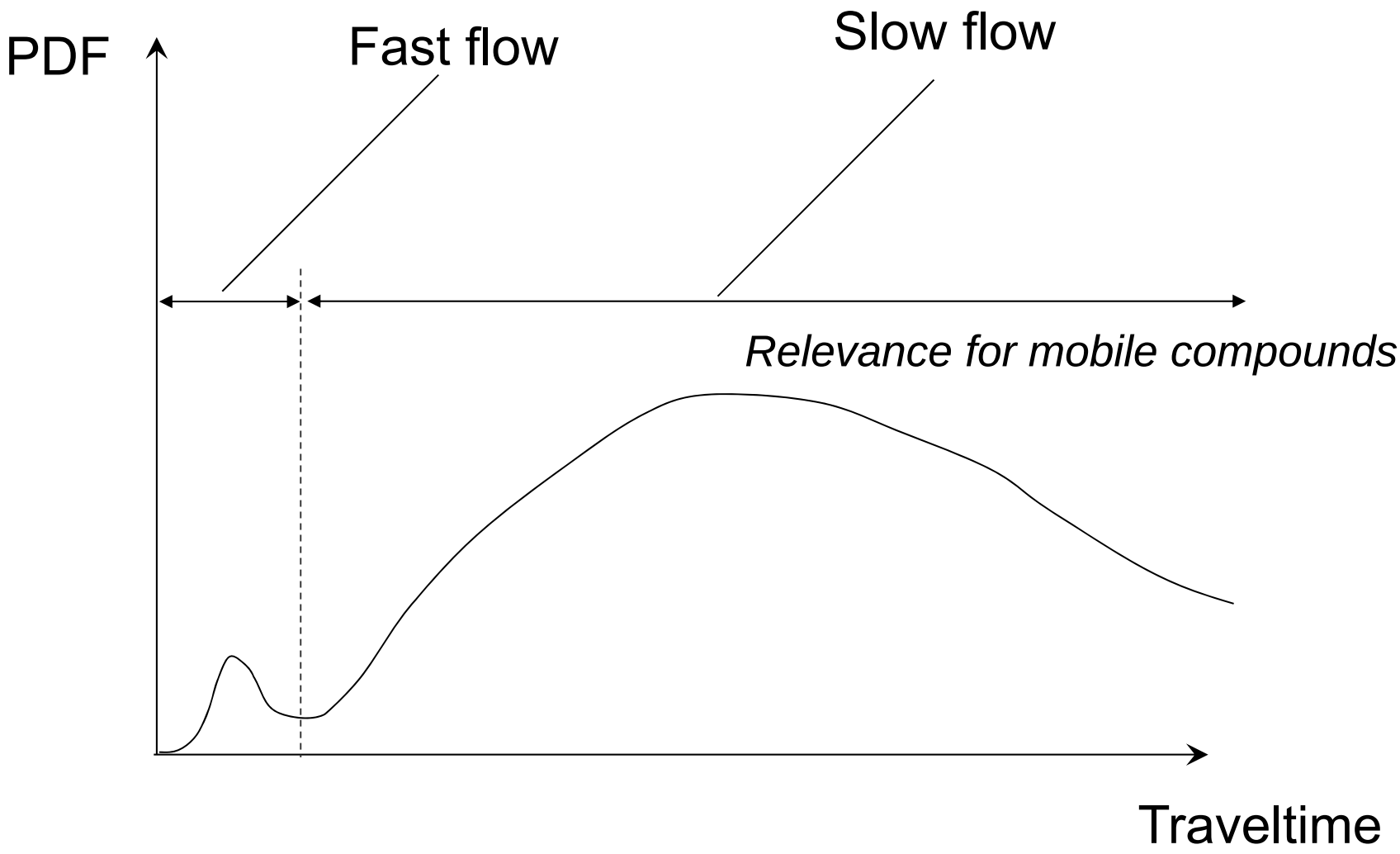
Water is the transport medium

→ large numbers of possible flow paths
→ which flow paths carry how much P of which form?

→ where does P enter the system (in which form)?

→ what's the fate of P along the flow trajectories?

How does P move from soils to water bodies?



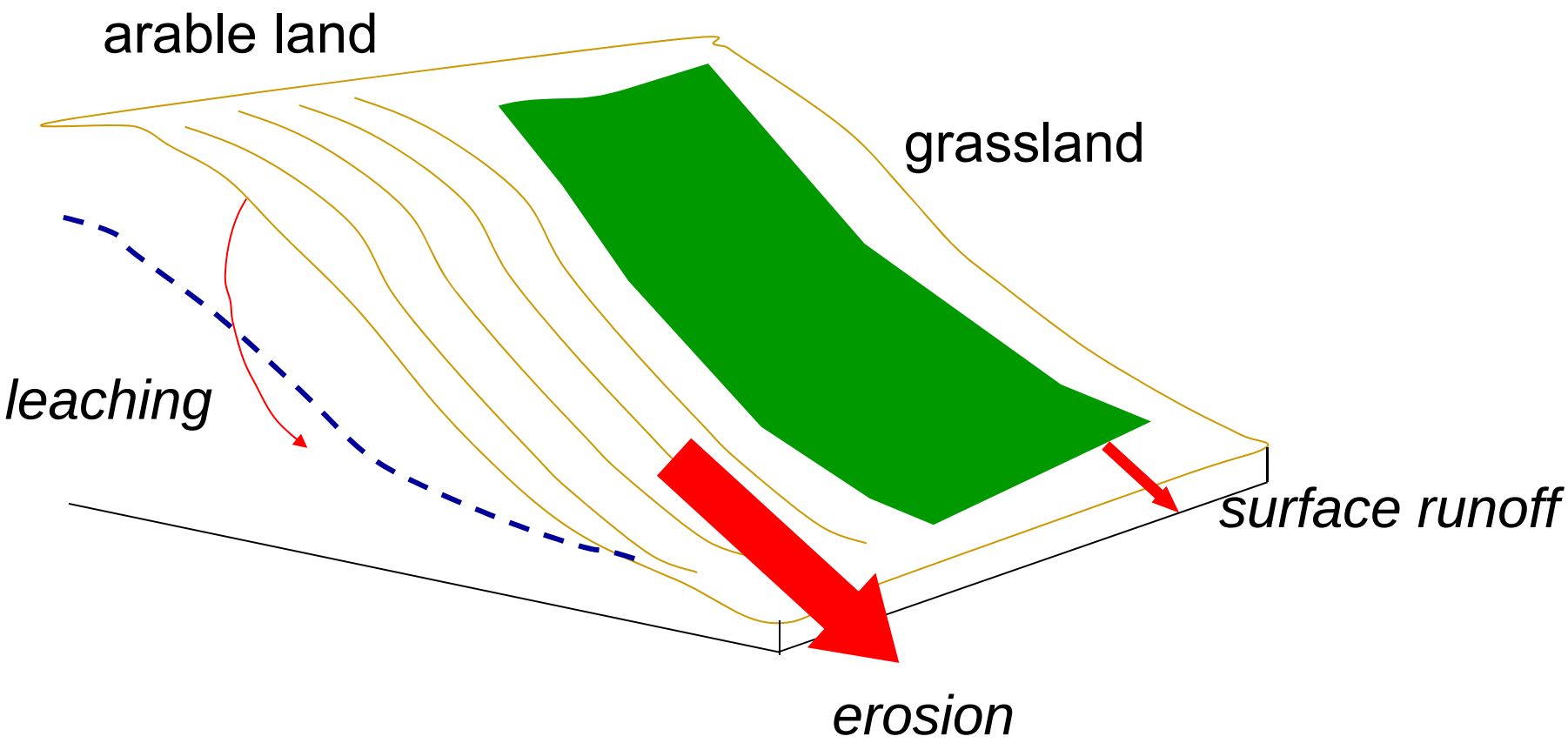
Starting point: traditional textbook knowledge

P sorbes strongly to most soils

→ low P concentrations in soil solution

→ Leaching not relevant for P losses
→ Subsurface drains not relevant for P losses
→ P mainly transported in particle-bound form (erosion)

Starting point: traditional textbook knowledge



Modification: exceeding sorption capacities

Classical assumptions hold only under certain conditions:

- Equilibrium in low to moderate P-input systems

But:

- Insufficient contact between P source and sorbing soil material (Example 1)

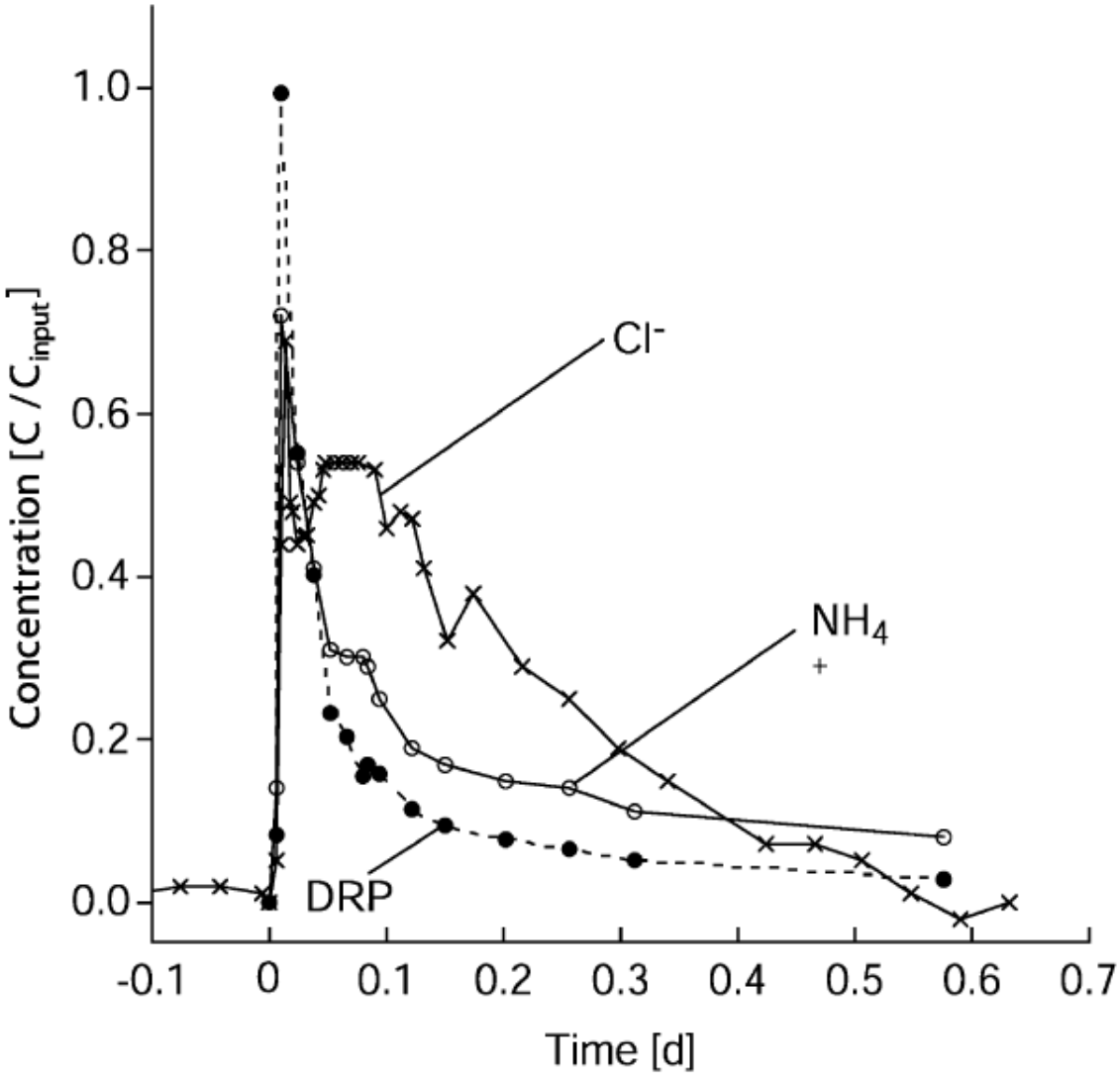
- Many agricultural soils receive(d) P in excess
→ exceedance of soption capacities (e.g. topsoils; Example 2)

- Low-sorption soils, mobile P fractions (e.g., organic soils, acidic sandy soils; Example 3)

Example 1: Incidental P losses

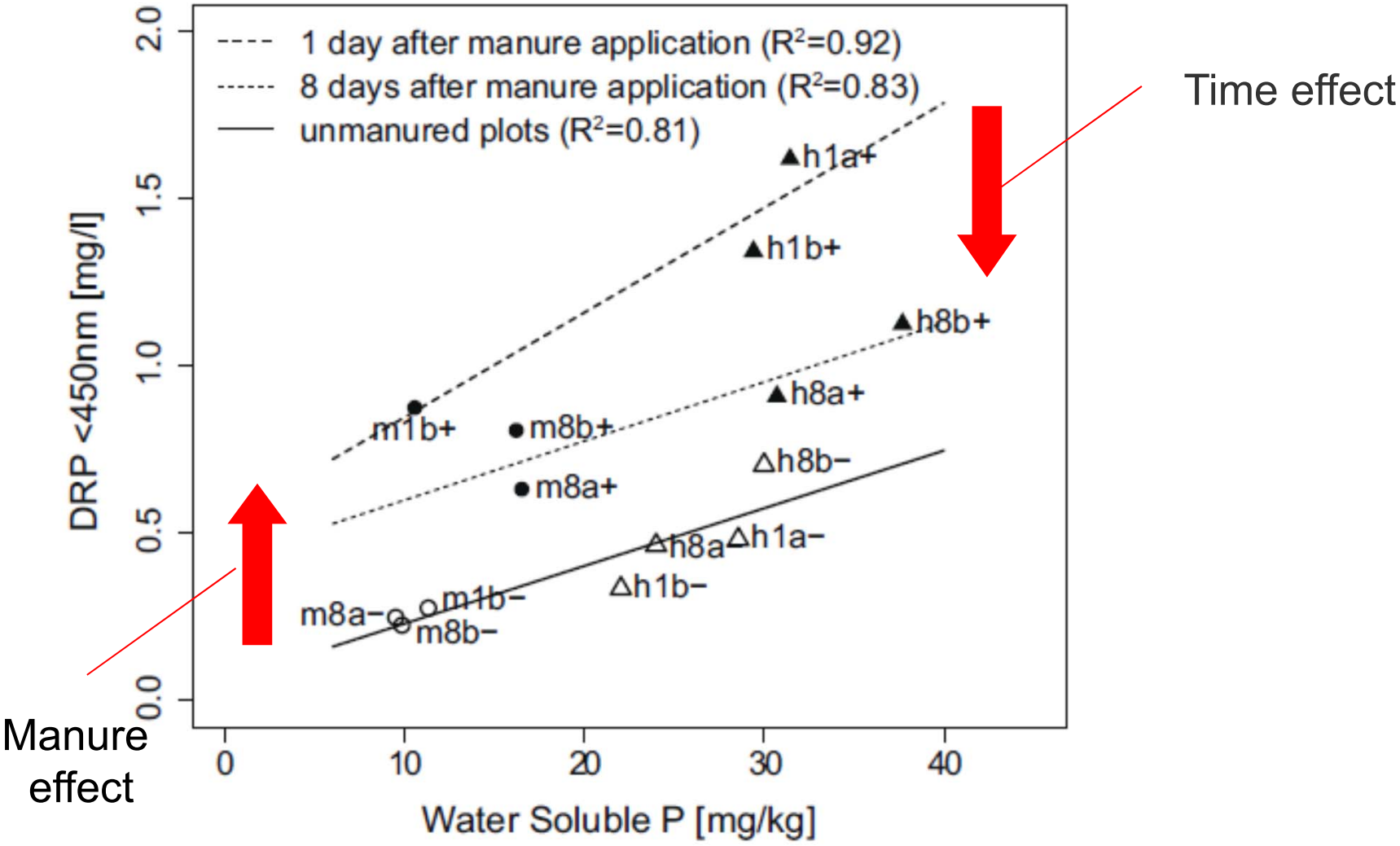
picture: Eawag

Limited soil contact: incidental P losses



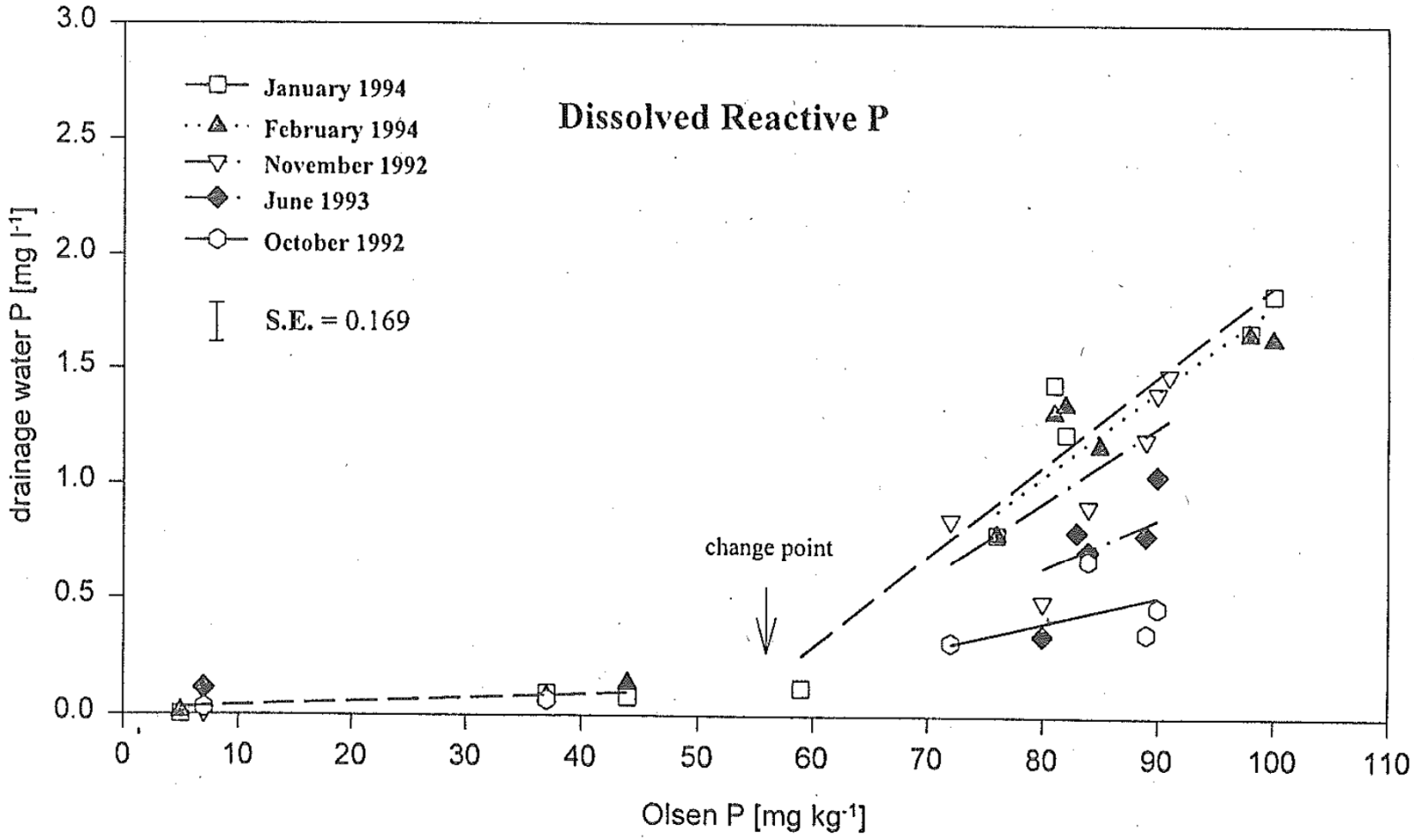
Stamm et al. (2002)

Time-effects on manure P availability



Hahn et al. (2012)

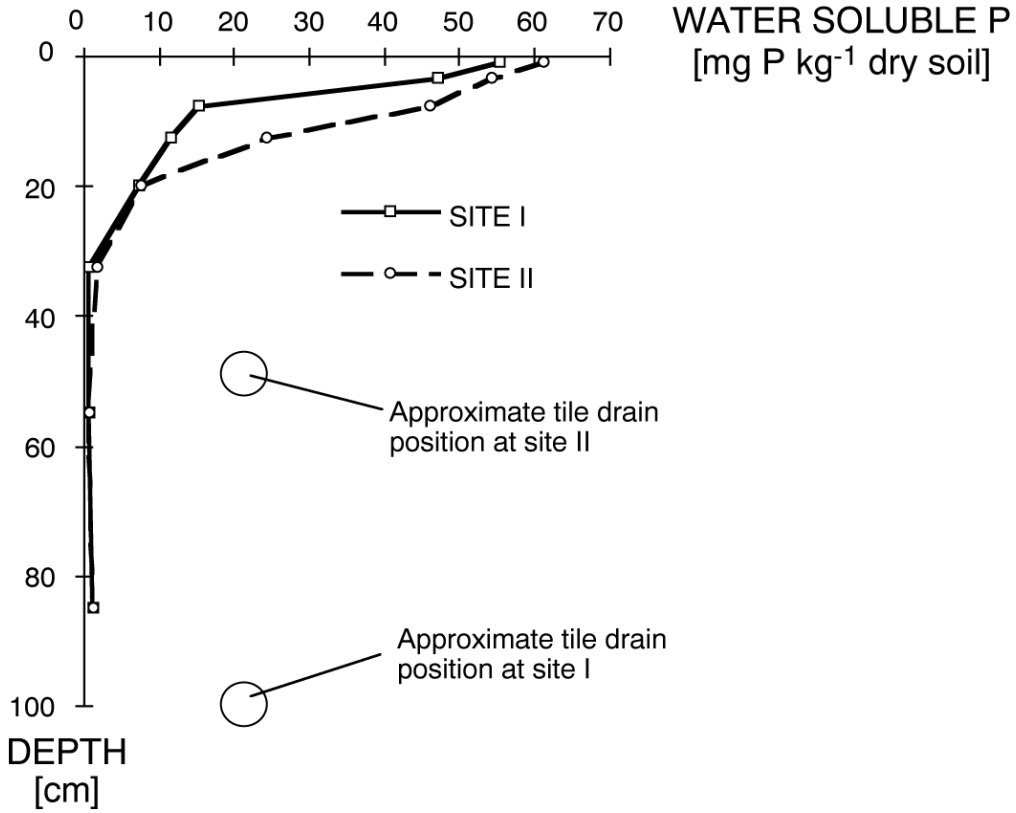
Example 2: P transport to tile drains



Hechrath et al. 1995

Interplay soil chemistry – soil physics

Soil chemistry:
exceedance of P sorption capacity



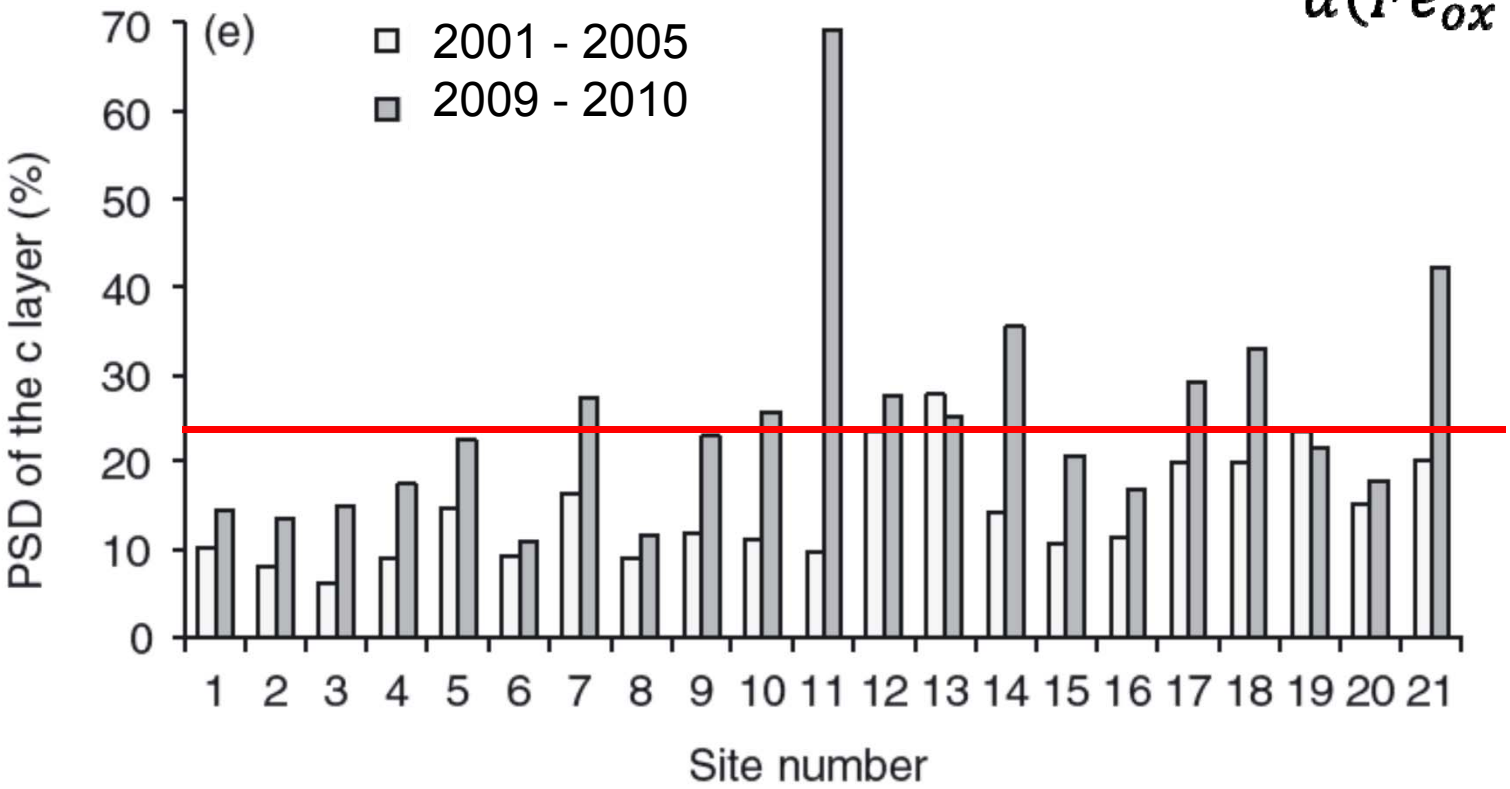
Soil physics:
preferential flow

Stamm et al., 1998

Example 3: Weakly sorbing soils

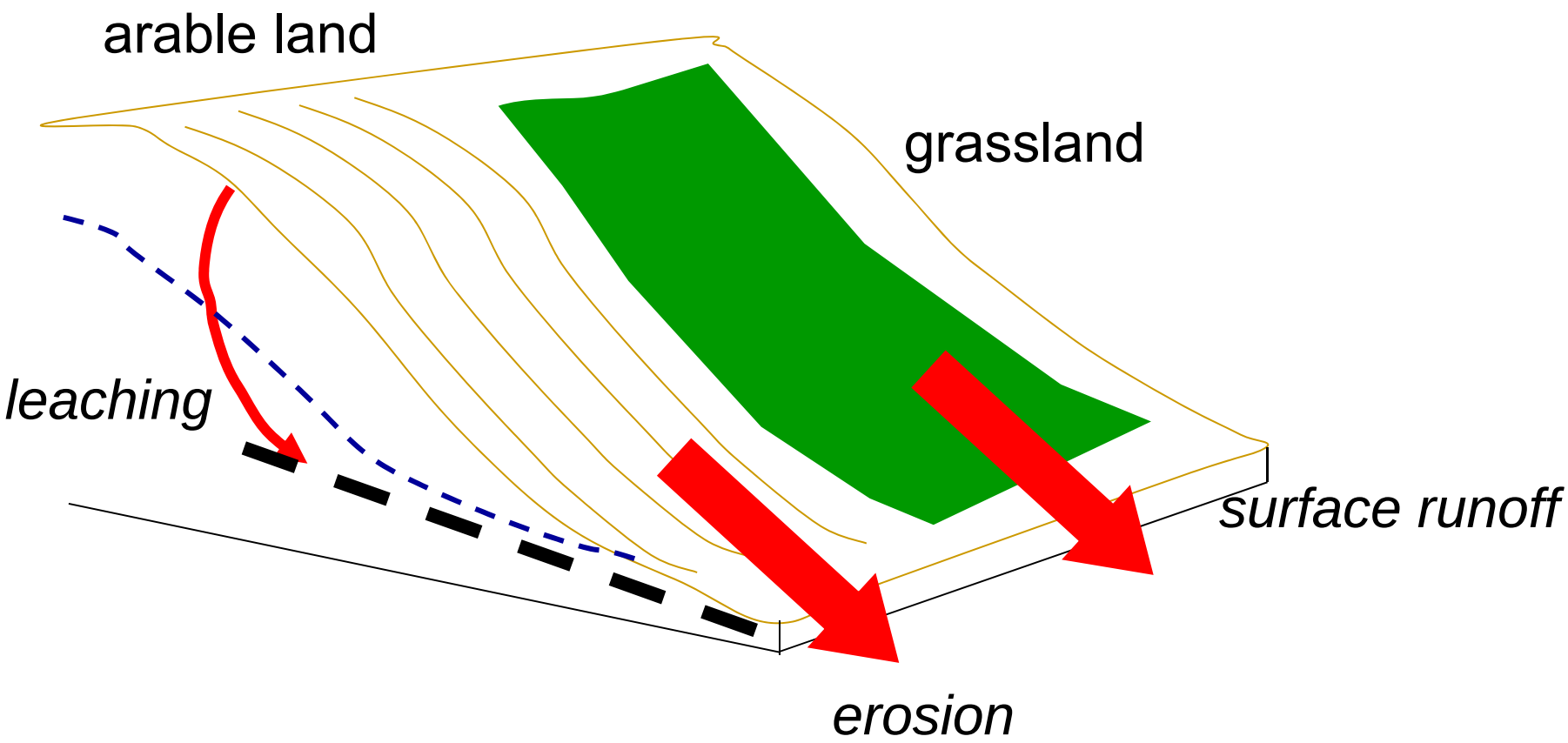
- weakly sorbing soils (acid sandy soils, organic soils)

$$PSD = \frac{P_{ox}}{\alpha(Fe_{ox} + Al_{ox})}$$



De Bolle et al., 2013

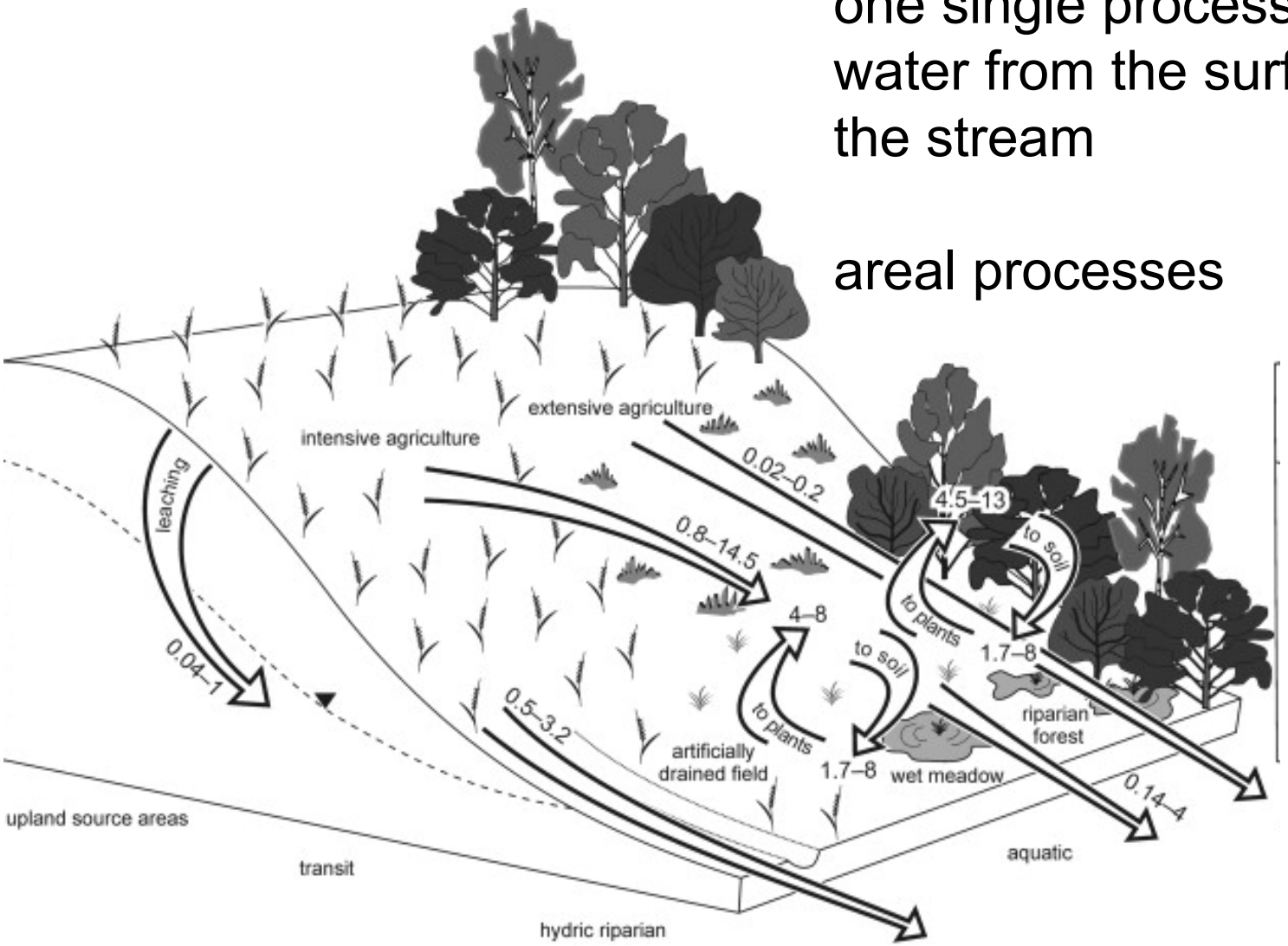
Modified conceptual picture



Textbook knowledge: Flow paths

one single process transfers water from the surface to the stream

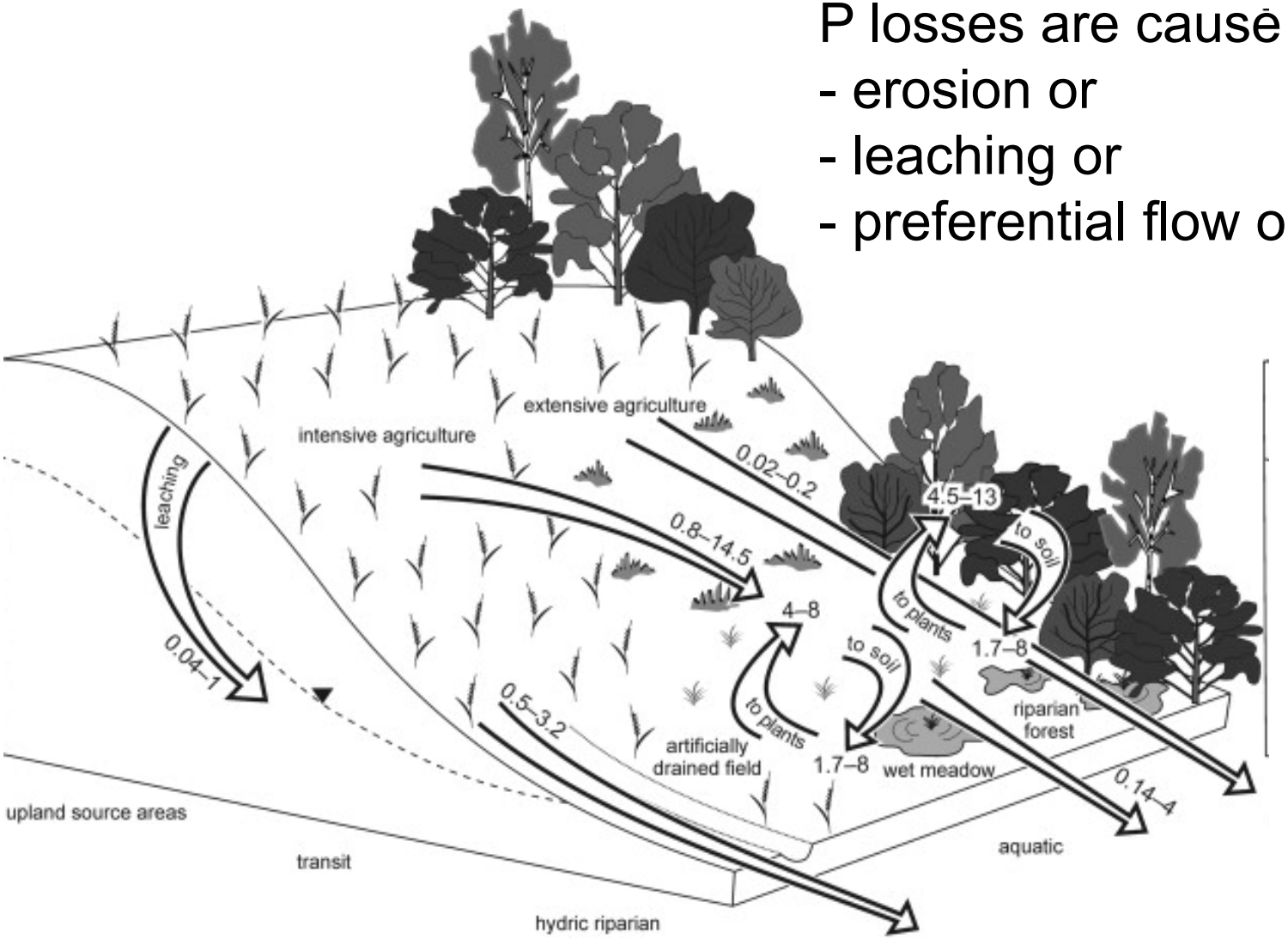
areal processes



Pärn et al., 2012

Textbook knowledge: Flow paths

P losses are causė by either
- erosion or
- leaching or
- preferential flow or ....



Pärn et al., 2012

Reality: Process chains

Examples:

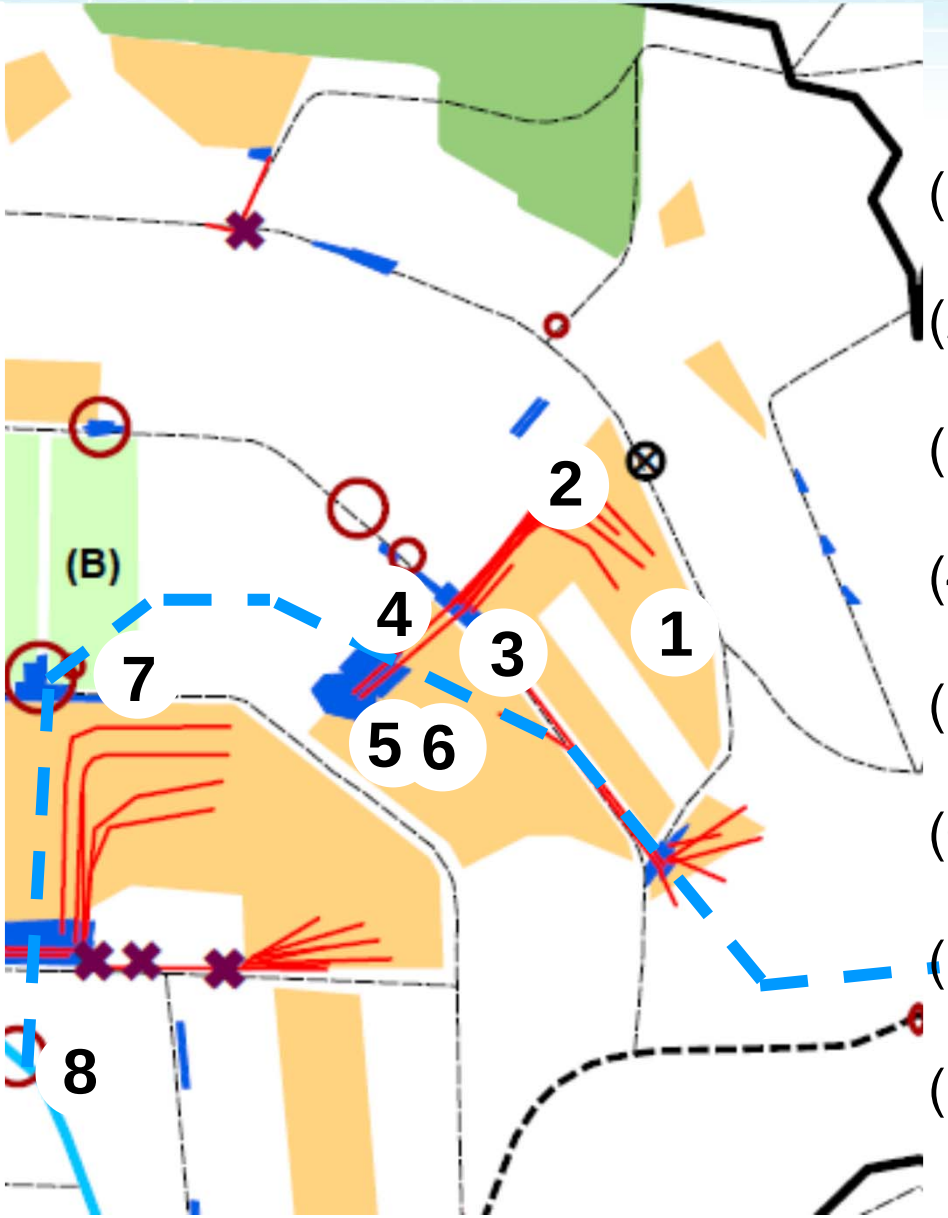
run-on → erosion;

runoff → macropore flow → subsurface drainage

TP retention → release of DRP in buffer zones

Surface runoff → ponding → re-infiltration

Process chains



(1) Sheet erosion

(2) Rill erosion

(3) Ponding on field road

(4) Run-on onto lower field

(5) Ponding in internal depression

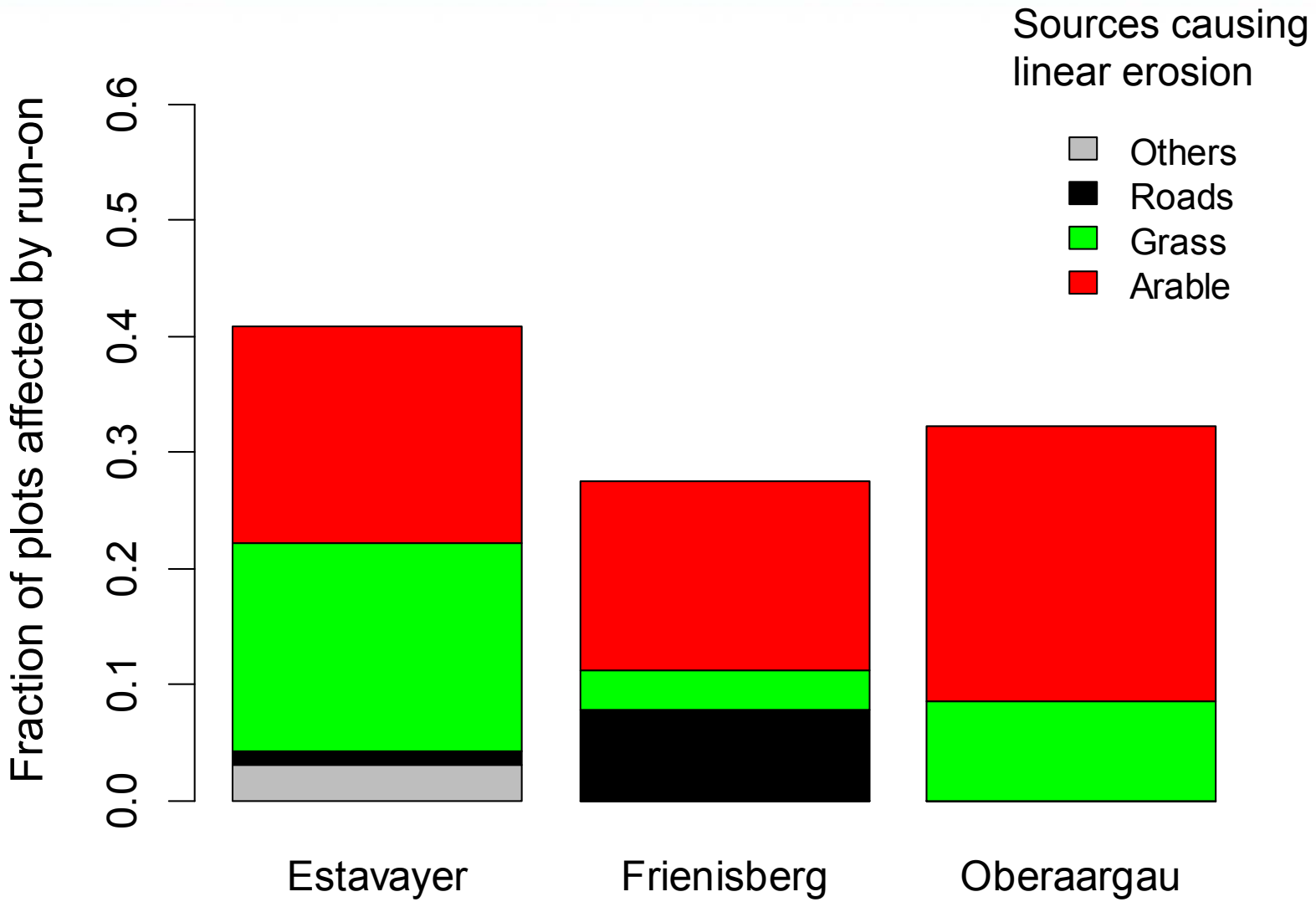
(6) Macropore flow

(7) Subsurface drains

(8) Entry into stream

Doppler et al., 2012

Run-on effects



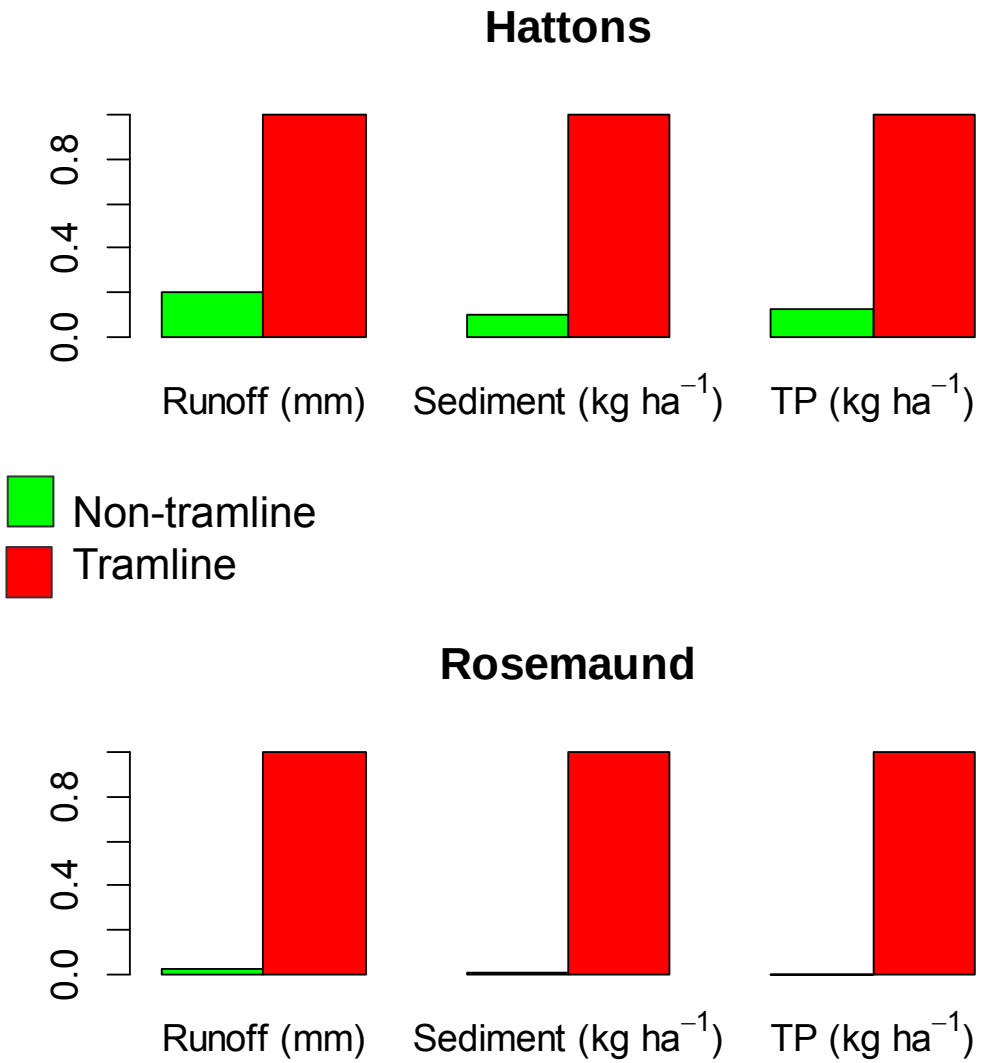
data: Ledermann et al., 2011

Role of small-scale structures

Frey *et al*., 2009; picture: C. Leu (Eawag)

Micro-structures: Tramlines

Picture: C. Leu



Silgram *et al*., 2010

Limitations: ecological endpoints

Target: Decreasing P in standing waters (lakes, estuaries, etc.)

C_{effect} ~ P-load

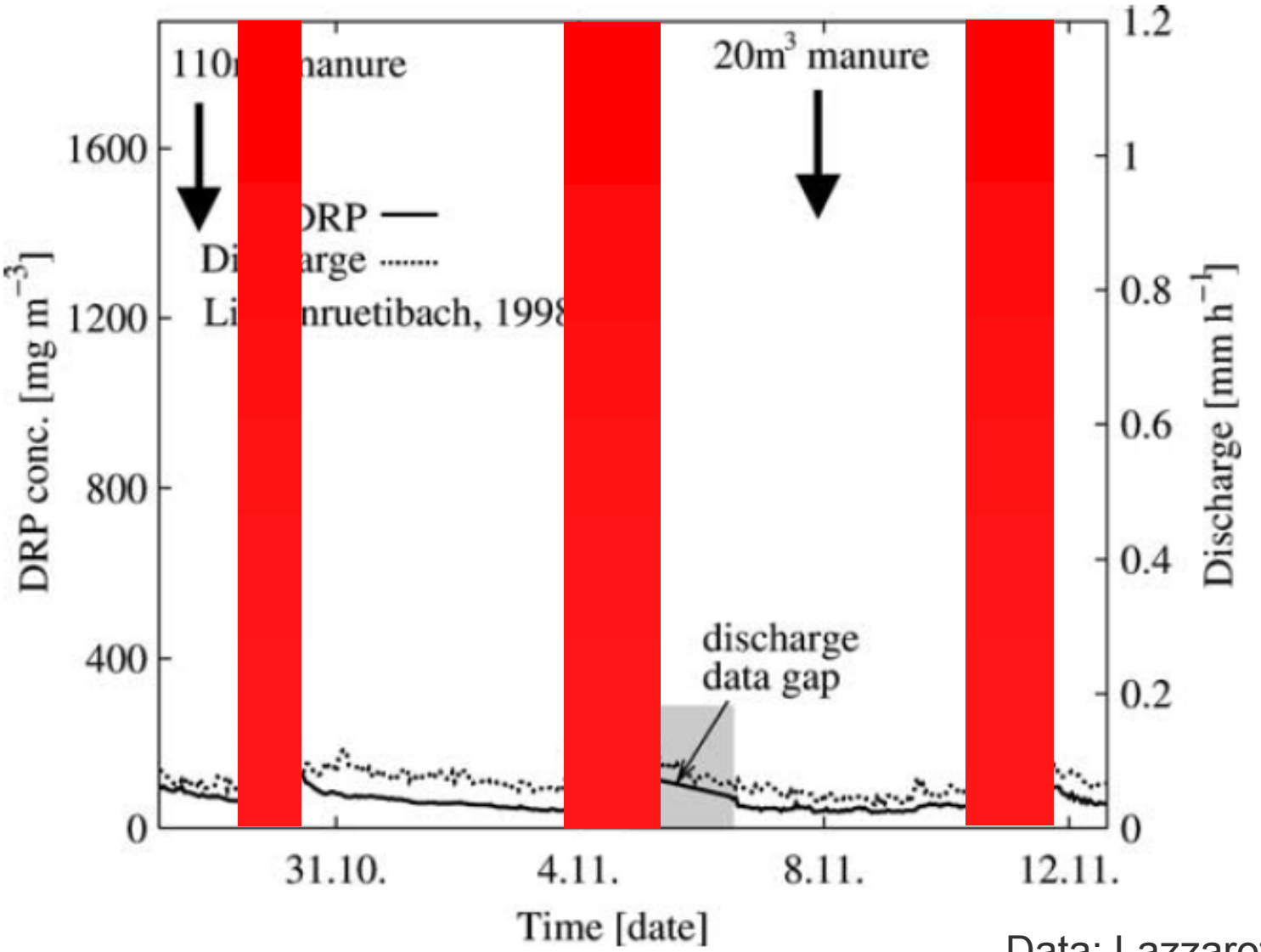
↓

Controlled by discharge peaks

↓

Controlled by fast flow processes

Critical periods



Data: Lazzarotto et al. (2005)

CSA and ecological endpoints

Target: Decreasing P in flowing waters (streams)

$C_{effect} \sim C_{mean}$

↓

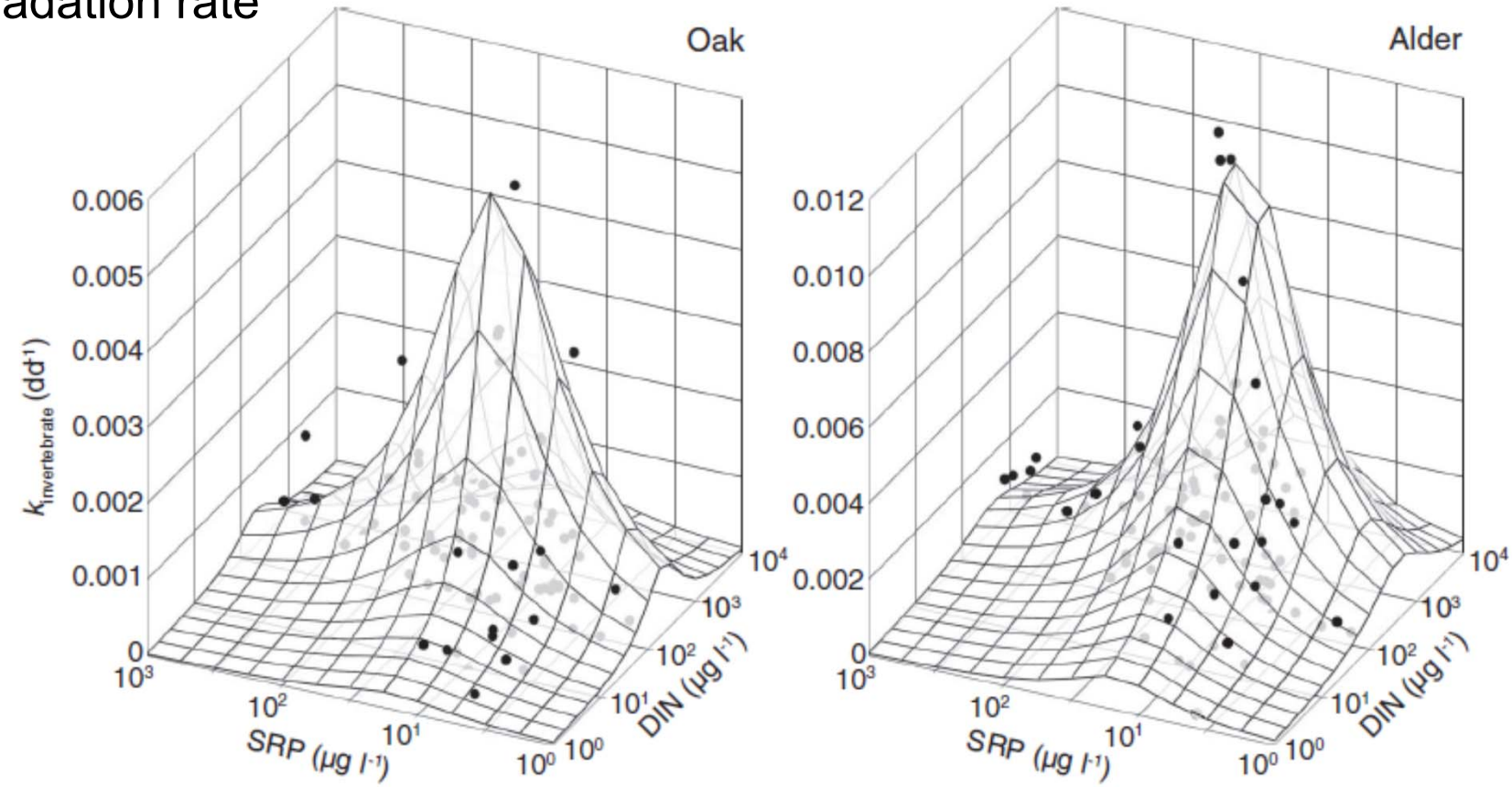
Controlled by baseflow

↓

Controlled by base flow processes

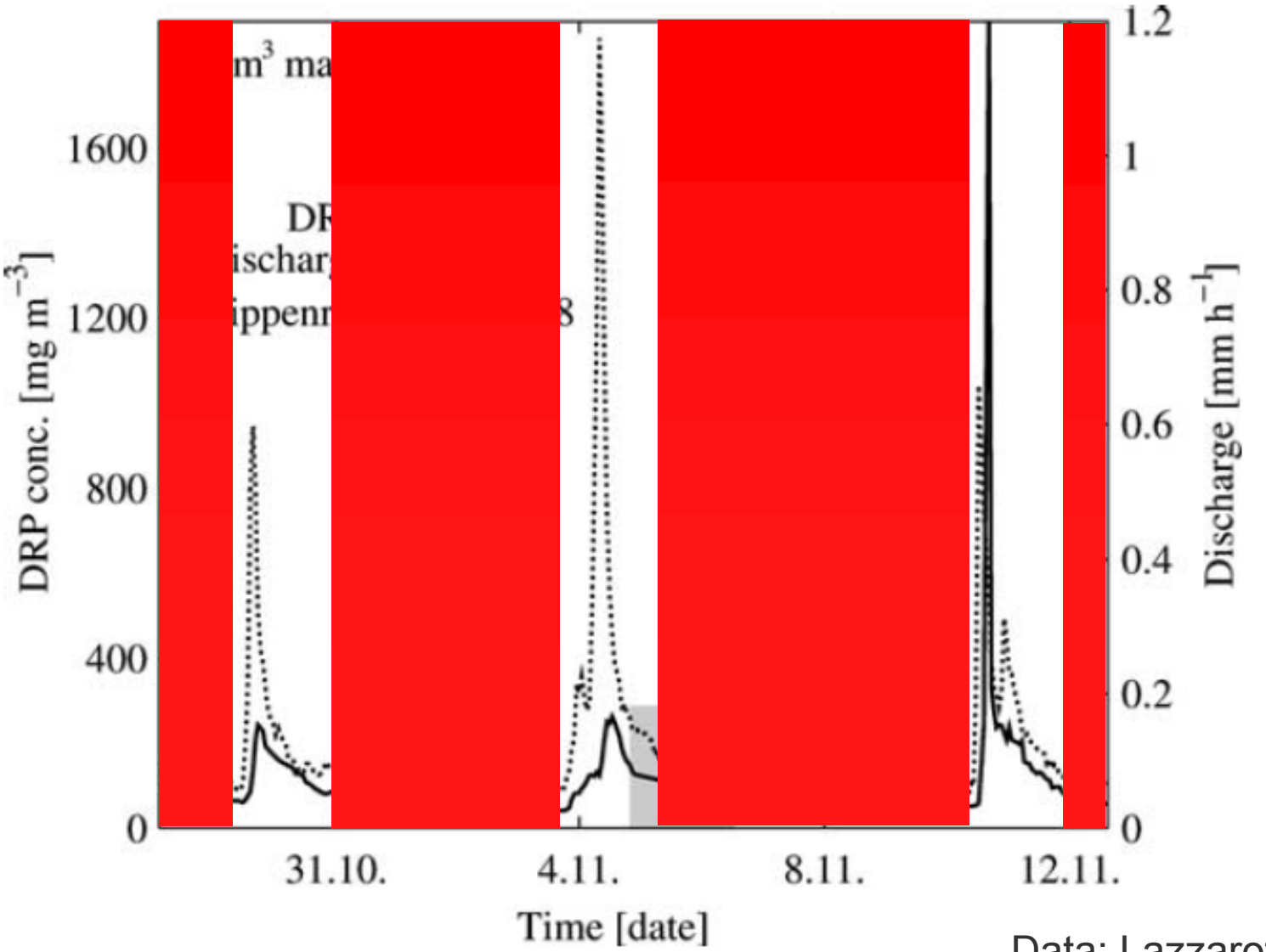
Ecological endpoint: streams

Leaf litter
degradation rate



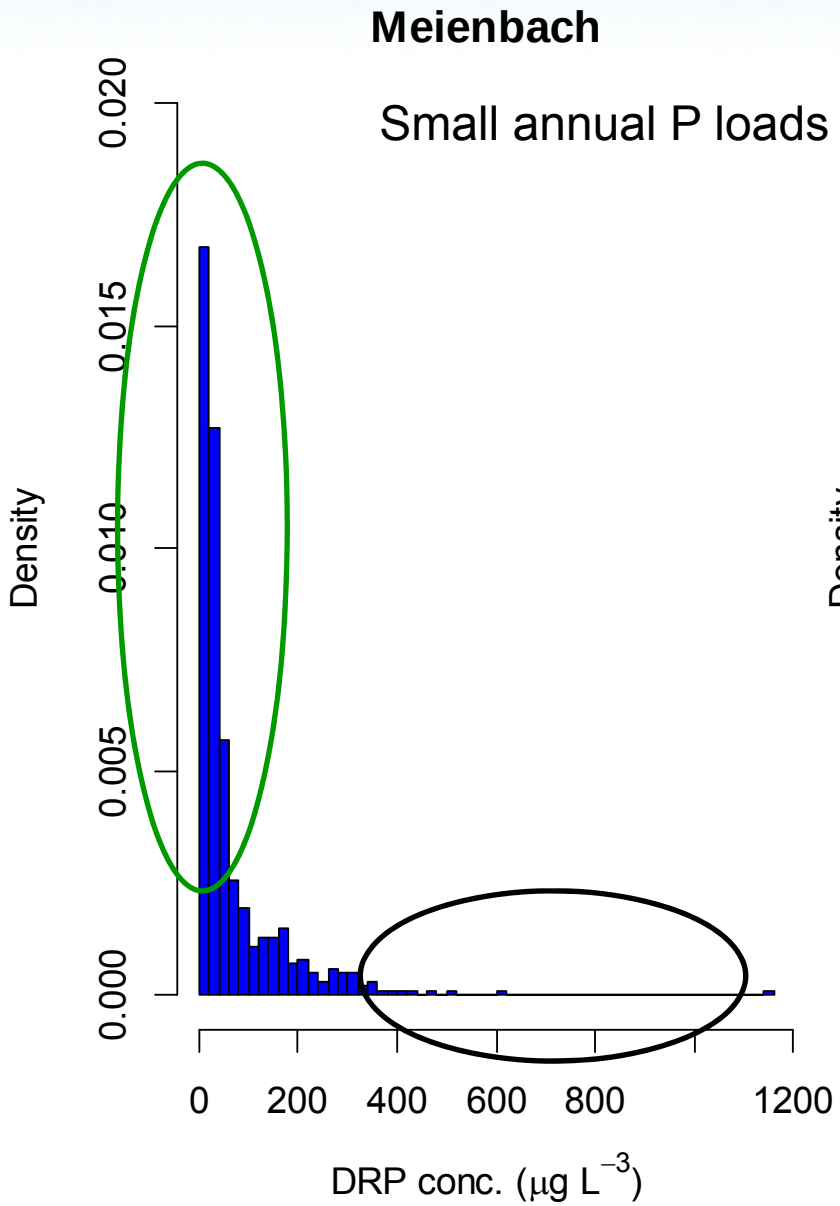
Woodward et al., 2012

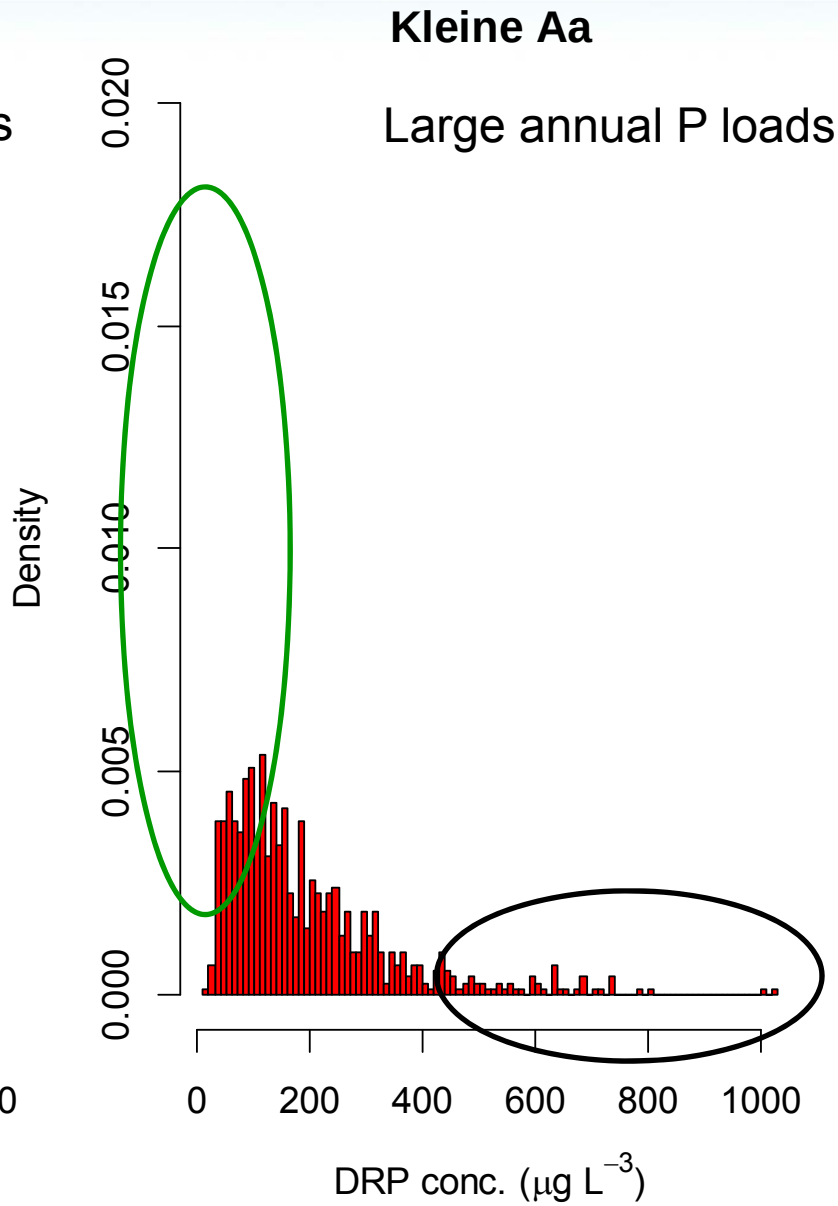
Critical periods



Data: Lazzarotto et al. (2005)

Baseflow concentrations





Data provided by the cantonal authorities of Lucerne

CSA and ecological endpoints

Target: Decreasing P in standing waters (lakes, estuaries, etc.)

$C_{effect} \sim C_{mean}$

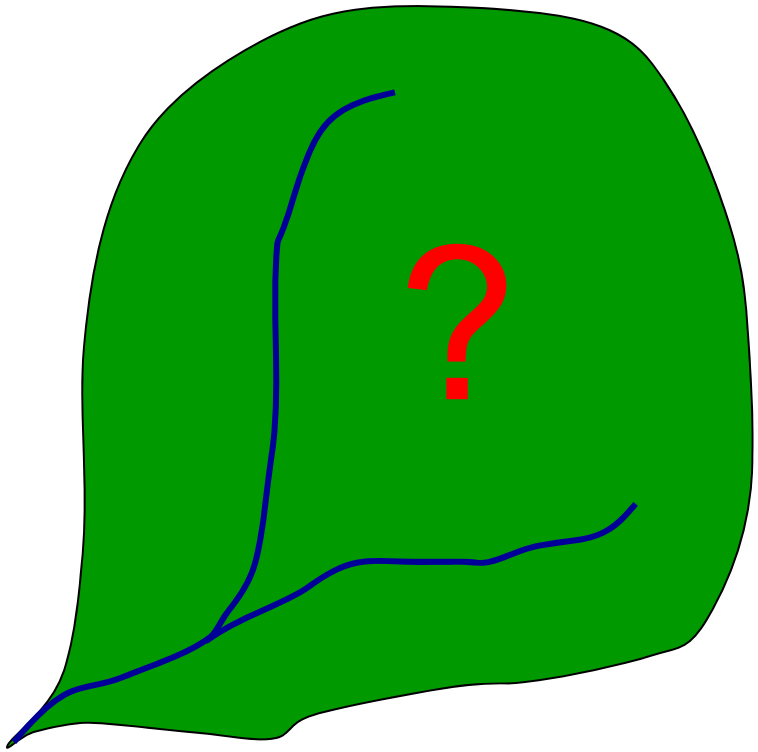
↓

Controlled by baseflow

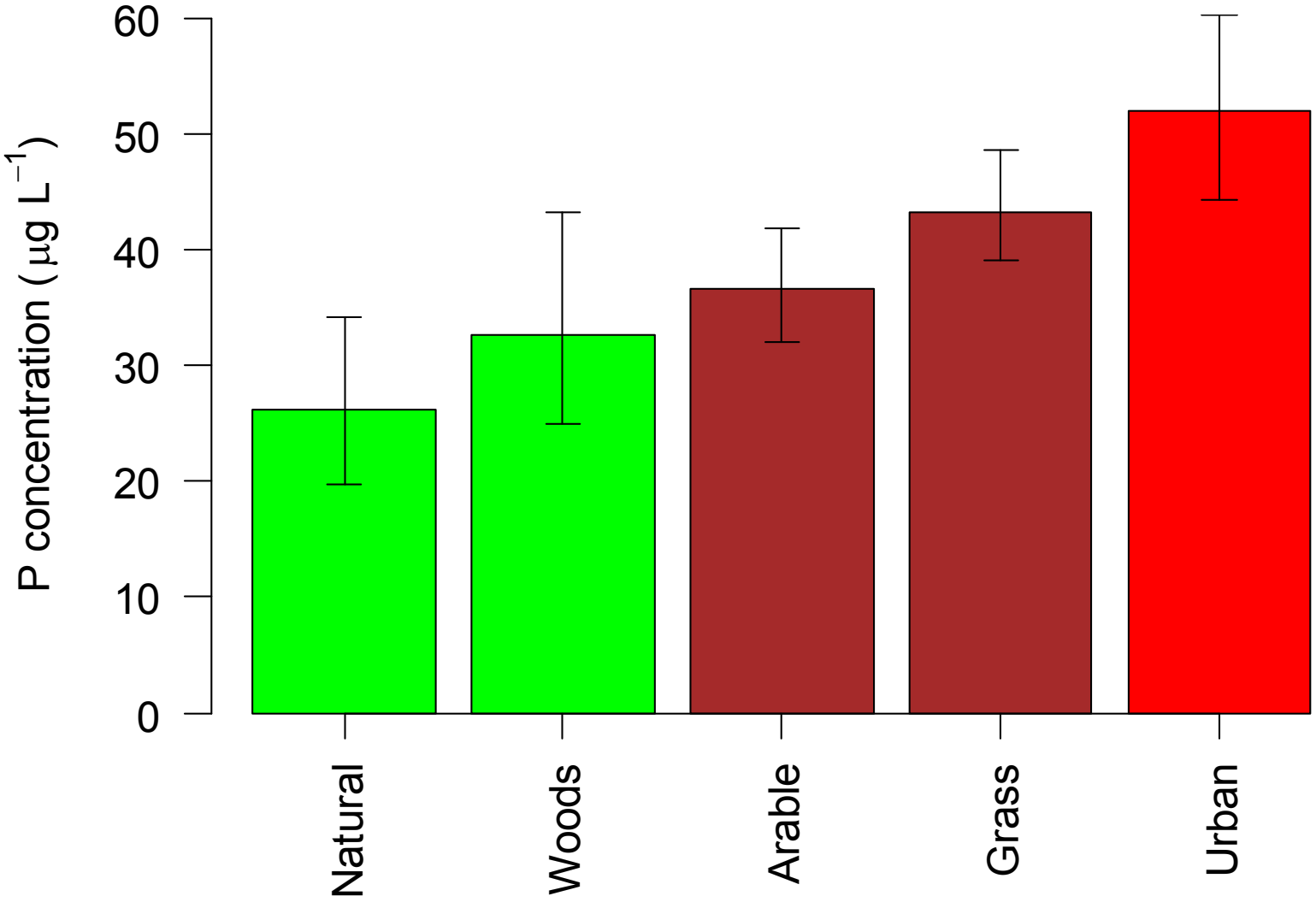
↓

Controlled by:

- *groundwater processes?*
- *hyporheic processes?*
- *bank storage?*



P concentrations in groundwater



Holman et al., 2008

Conclusions

1. Relevance of transport processes depend on ecological endpoint

2. Process-chains at the landscape scale
   Relevance of small-scale structures at the catchment scale

→ Challenges for measurement, modelling and management!

3. Interactions stream-riparian areas for base flow conditions

Thank you for the attention!