Hydrologic controls on the export dynamics of dissolved and particulate phosphorus in a headwater agricultural catchment

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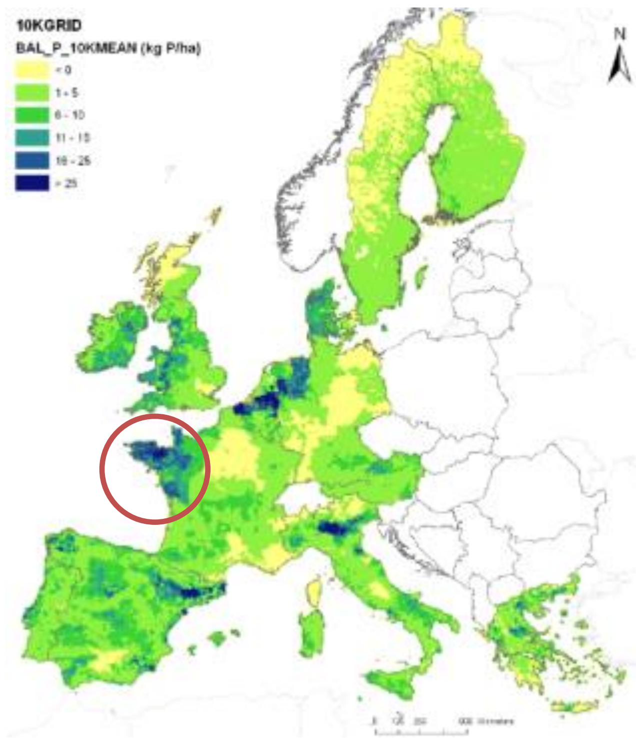
P pressure in regions with intensive livestock farming

Context - motivation

- Excess P in regions with intensive livestock farming leads to high P levels in soils

- P issue in French Brittany
  - **80% of drinking water** supply originates from surface waters: P limited ecosystems
  - Cyanobacteria in **recreational lakes**: 17/36 closed during summer 2011

- **High SRP/TP ratio in surface water** due to high P levels in soils & vegetated buffer strips trapping particulate P ***(Dorioz et al., AEE, 2006)***



(Grizzetti et al., 2007)

HS 2.3.6. Eutrophication risk: assessing the impact of agricultural N & P pressure at regional scales. Poster. Dupas et al.

Objectives

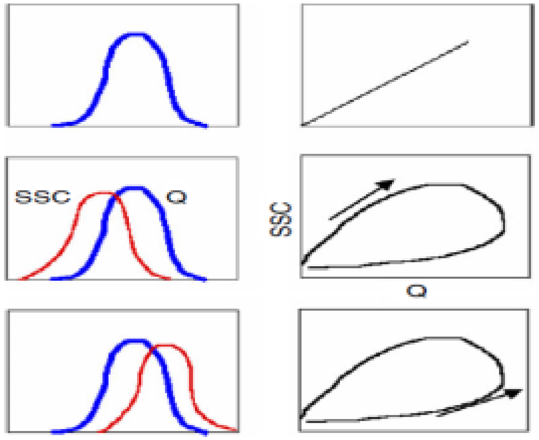
- Gather insight about the **spatial origin** and **transport pathways** of P from water quality monitoring data in a headwater agricultural catchment
- Investigate the **coupling/decoupling** between soluble reactive phosphorus (SRP) and particulate phosphorus (PP)
- Report on **seasonal variability** of origin/pathways and coupling/decoupling between SRP and PP

Previous research

Concentration-discharge hysteresis

1. Annual scale

- Monthly aggregation of data
- Indicate annual evolution of availability *(Aubert et al., JoH, 2013)*



Williams, JoH, 1989

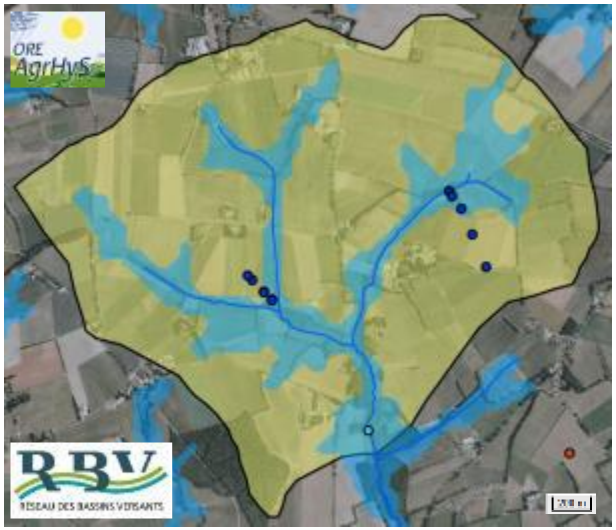
2. Flood events

- Hysteresis shape and direction inform on the **relative contribution of diffuse and within-channel** P sources *(Bowes et al., WR, 2005)*
- Most common pattern: **clockwise hysteresis** -> P supply controlled by resuspension of streambed sediment *(Stutter et al., JoH, 2008)*
- Generally: **same hysteresis shape for SRP and PP**

Few studies on coupling/decoupling between SRP-PP

Environmental research observatory ORE Agrhys

http://www7.inra.fr/ore_agrhys_eng



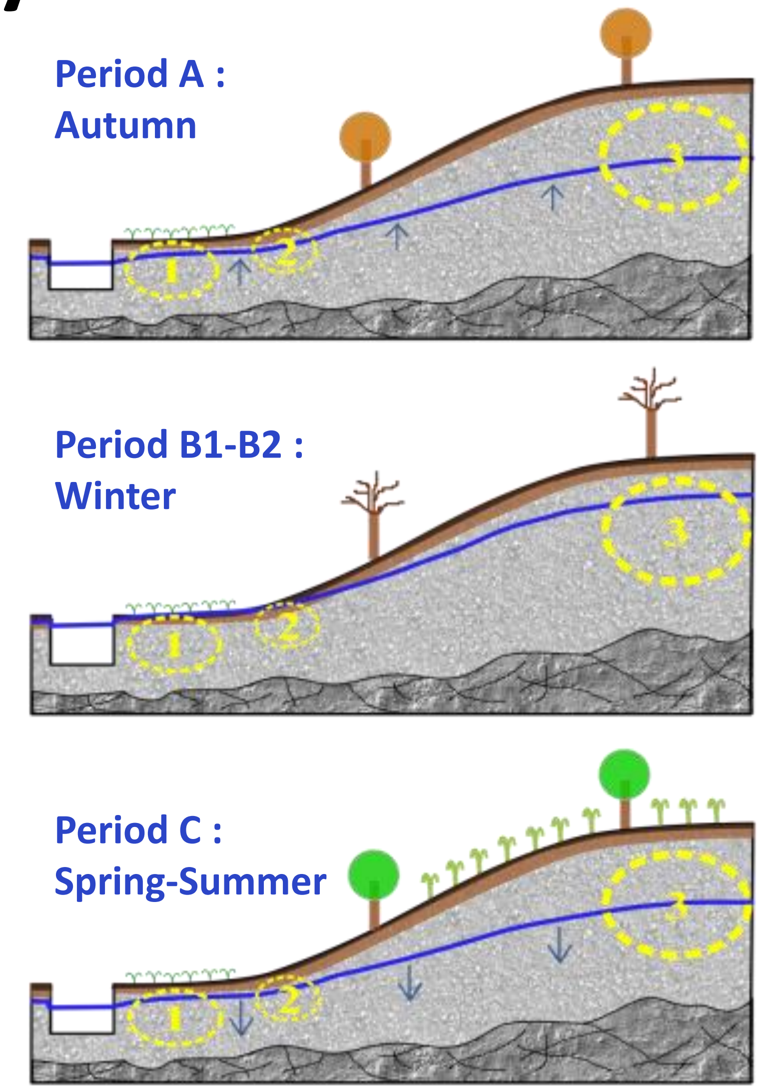
- Outlet
- Piezometer
- Meteorological station
- Stream
- Potential wetlands

Area: 5 km²
Rainfall: 820 mm
PET: 710 mm
Annual runoff: 474 mm

Loamy soils (1 m)
Regolith & schist

2/3 arable crops
(wheat, maize)
1/3 temporary grassland

Indoor animal breeding
(pigs and dairy)



Molenat et al., JoH, 2008
Aubert et al., HESS, 2013

Material & methods

SS & P monitoring 2007-2013

Long-term monitoring

- Continuous monitoring of:
  - Discharge
  - Turbidity
  - GW table in piezometers
  - Rainfall, PET
- Solutes daily: NO_3^-, DOC, Cl^-, SO_4^{2-}

P regular sampling

- Manual
- Each 6 days
- Immediately filtered, refrigerated

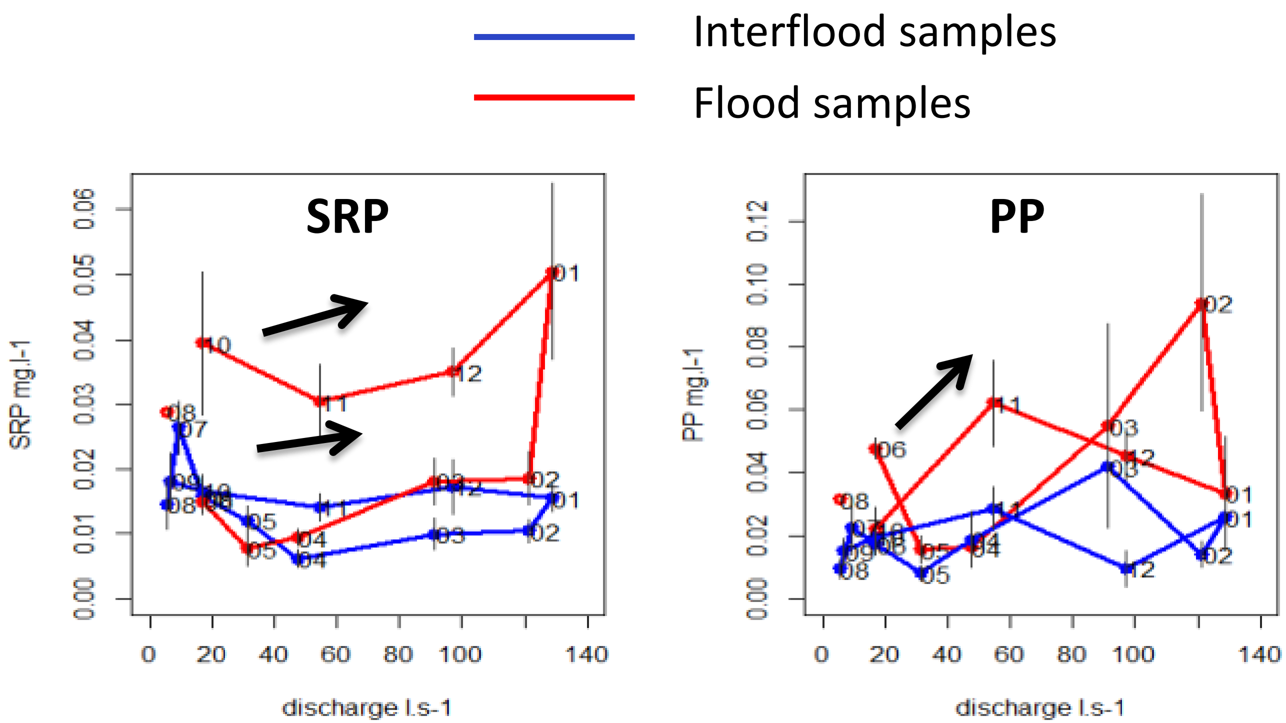
P flood monitoring

- Non-refrigerated autosampler
- 24 samples collected over 12h, an average of 12 samples analysed
- 2007->2013: 52 floods monitored

Analyses

- *SRP=molybdate reactive P (<0.45µm)*
- *TP=$K_2S_2O_8$ digestion + molybdate reaction (unfiltered)*
- *PP=TP-SRP*

1. Annual hysteresis



- Clockwise hysteresis
  - ➢ Decrease of P source availability
- Flood/interflood similar
  - ➢ Mobilization of the same compartment during flood/inteflood?

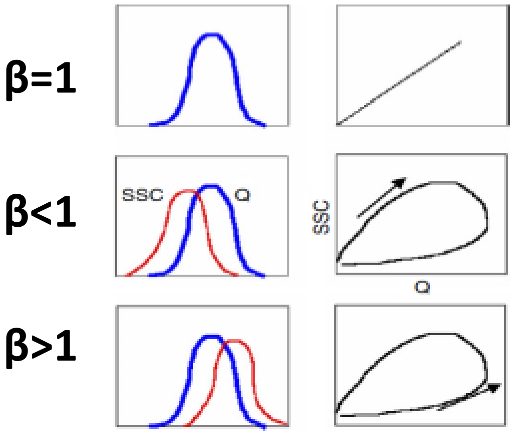
- 8-shaped
  - ➢ 2 P sources
- Flood/interflood similar
  - ➢ Mobilization of the same compartment during flood/inteflood?

Seasonal decoupling between SRP & PP

Meterial & methods

2. Flood hysteresis

- Flood description:
  - Concentration peaks of SRP, PP, SS (SRP/PP/SS_max)
  - Hysteresis direction (β_SRP/PP/SS)
    - fitting $F(x)=x^{\beta}$, F(x)= fraction of the total mass flux of a determinant, x=fraction of the total cumulated water flow ***(Rossi et al., 2005)***

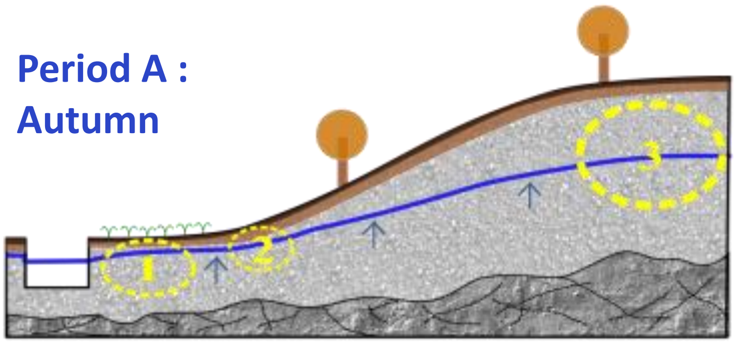


- Hydroclimatic context: antecedent conditions & flood characteritics (antecedent discharge/watertable level/rainfall, dQ/dt, Qmax)

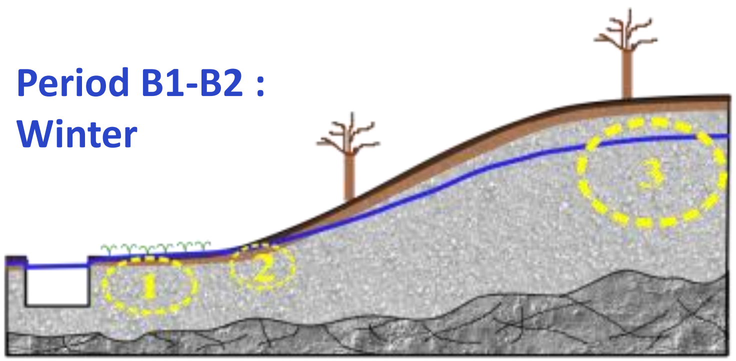
Results

Concentration peaks

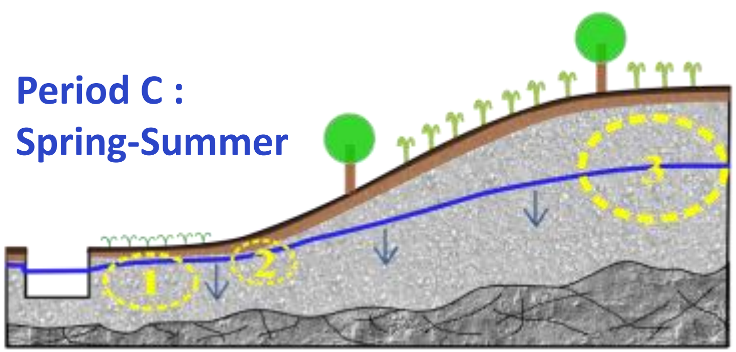
Period A :
Autumn

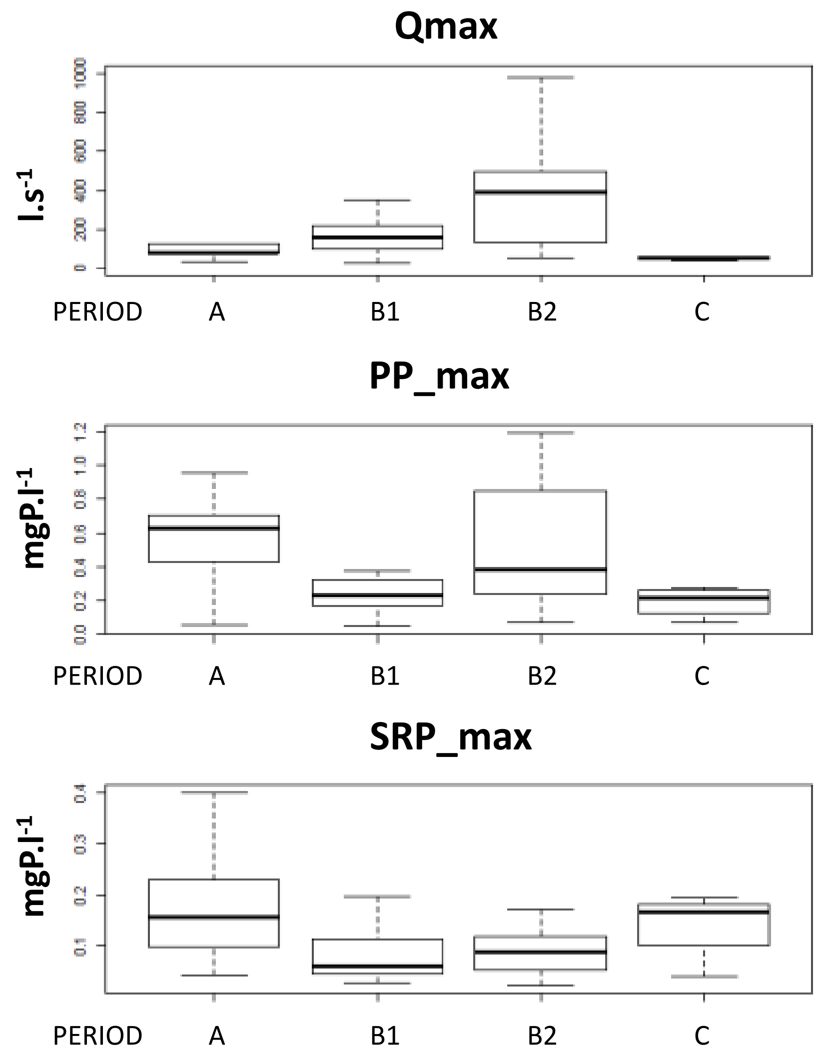


Period B1-B2 :
Winter



Period C :
Spring-Summer



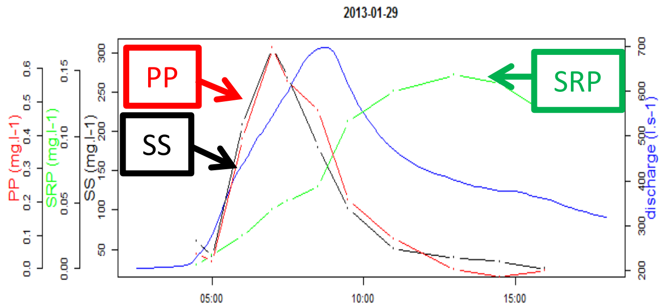


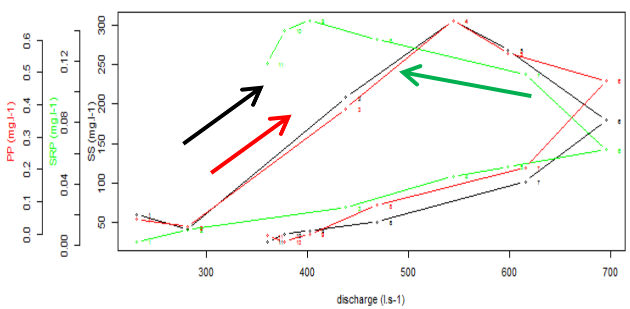
Seasonal distribution of concentration peaks SRP ≠ PP

Results

Hysteresis shape

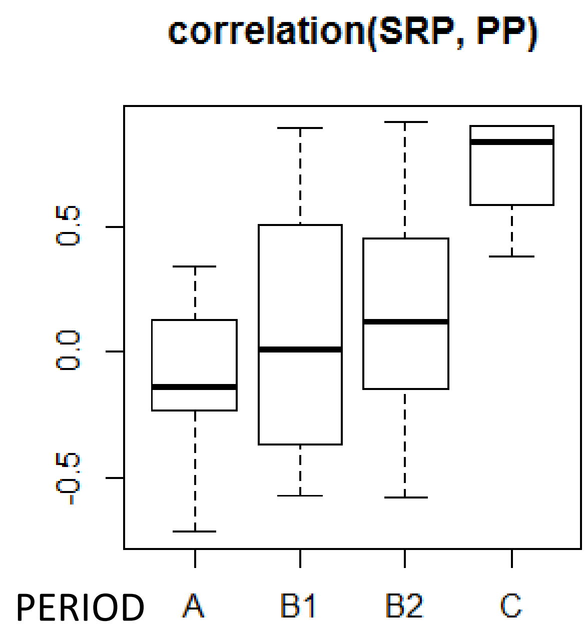
Most common pattern





- SRP anticlockwise hysteresis β>1 : 77%
- PP & SS clockwise hysteresis β<1 : 80%
- ➢ **Most common flood pattern: time decoupling between PP & SRP**

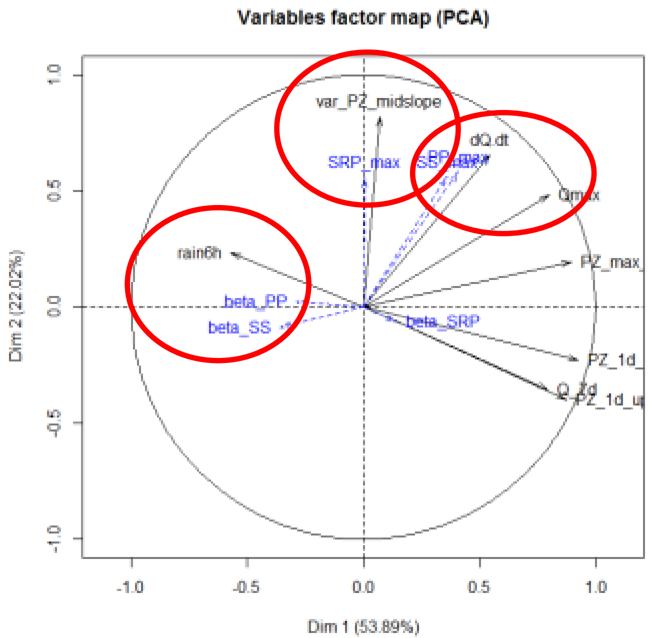
Seasonal variation

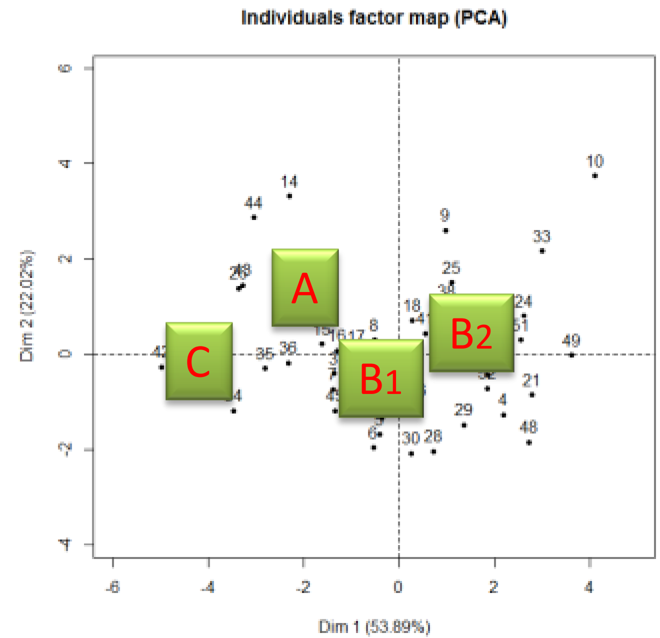


- **Time decoupling** between PP & SRP during period A, B1 & B2
- **Time coupling** in period C

Coupling/decoupling between PP & SRP -> different origins & pathways except during period C

Relating flood features to hydroclimatic conditions





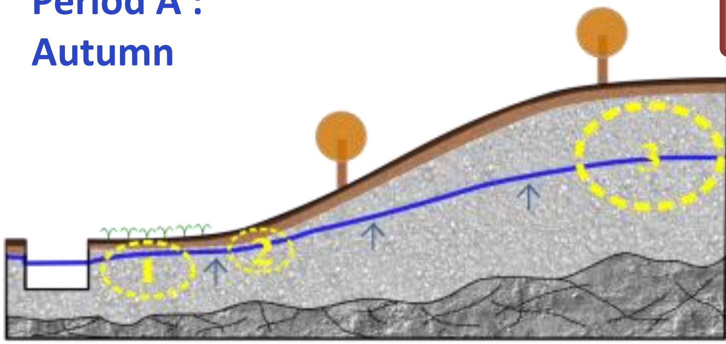
- **PP/SS_max associated with flood energy**: flood magnitude (*Qmax*) and rate of change in discharge (*dQ/dt*). **High during B1 & B2**.
- **SRP_max associated with water table fluctuation** at the limit between the wetland & midslope domain (*var_PZ_midslope*). **High during A**.
- **Beta_PP/SS associated with rainfall intensity**. PP/SS peaks coincide with discharge peak-> erosion (**period C**)

Different hydrologic control between PP & SRP

Conclusion

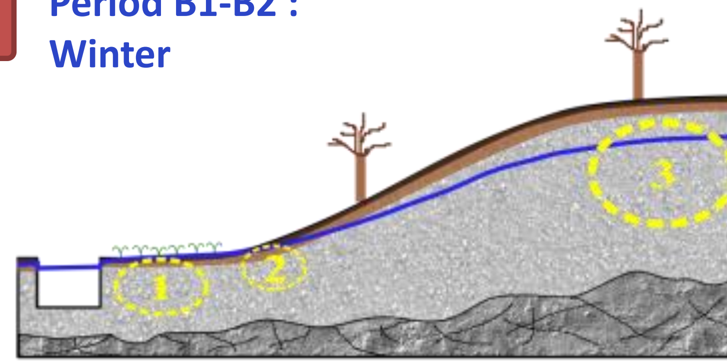
P sources and pathways

Period A : Autumn



decoupling

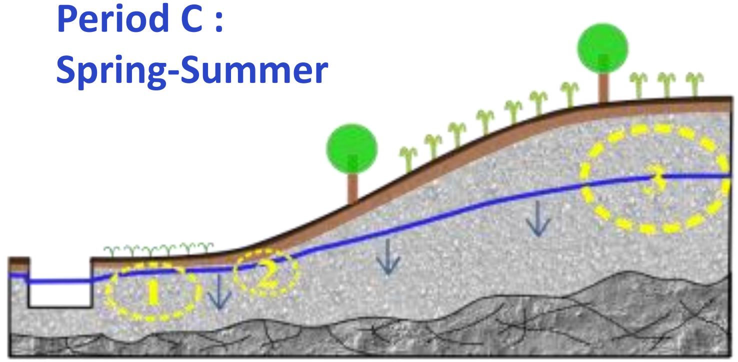
Period B1-B2 : Winter



- ✓ Large availability of stream sediment
  - ✓ **high PP**
- ✓ Water table fluctuation in wetland
  - ✓ **high SRP (production)**

- ✓ Variable availability & transport capacity
  - ✓ **variable PP**
- ✓ Water table fluctuation upslope
  - ✓ **low SRP (dilution)**

Period C : Spring-Summer



coupling

- ✓ Erosion, overland flow
  - ✓ **high SRP & PP**

Conclusions

Conclusion

- SRP controlled by GW table
  - **GW table fluctuation in wetland domain**
    - **SRP Production & transport in autumn**
  - GW table in hillslope domain
    - **SRP dilution in winter**
- SRP & PP overland flow and erosion in spring

Temporal decoupling between PP & SRP

Perspectives

- Hillslope monitoring : C, N and P coupling
- Modelling

Thanks for your attention

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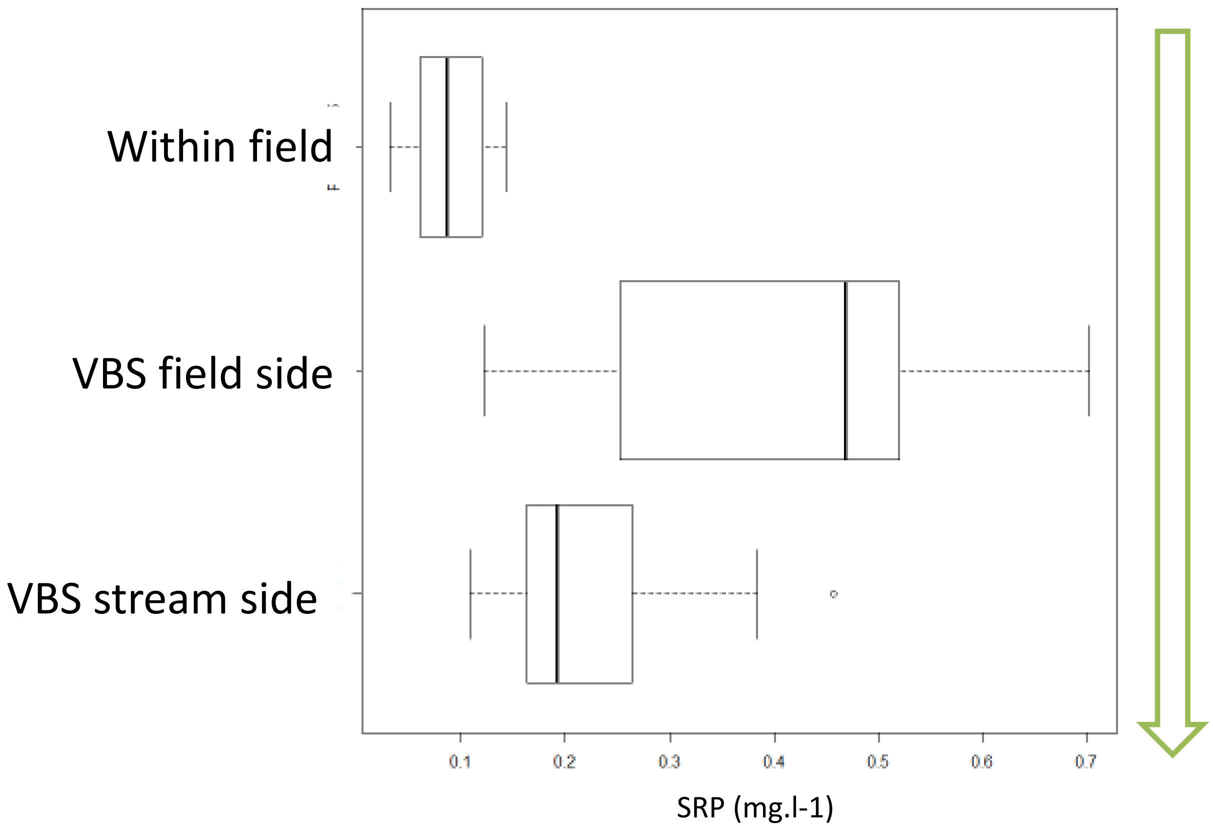
Hillslope monitoring

- Zero-tension lysimeter, 5cm deep



- Vegetated buffer trip = source of SRP. Enrichment effect? Biogeochemical reaction increases SRP solubility? ***(Stutter et al., Env Sci Tech, 2009)***