Assessing the role of colloidal phosphorus delivery processes in groundwater-fed agricultural catchments

Maelle Fresne[abc], Phil Jordan[b], Karen Daly[c], Owen Fenton[c], Per-Erik Mellander[ac]
[a]Agricultural Catchments Programme, Teagasc, Johnstown Castle Environment Research Center, Wexford, Co. Wexford, Ireland
[b]School of Geography and Environmental Sciences, Ulster University, Coleraine, UK
[c]Crops, Environment and Land Use Programme, Teagasc, Johnstown Castle Environment Research Center, Wexford, Co. Wexford, Ireland

Maelle.Fresne@teagasc.ie **@FresneMaelle**

Ulster University
AGRICULTURAL CATCHMENTS PROGRAMME
Teagasc
Agriculture and Food Development Authority
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Introduction

- Globally:
  - need to **increase food production** in a sustainable way;
  - need to **achieve** the WFD **“good status”** for surface water

    In Ireland, 35% of streams are not achieving this “good status”

→ Reduce phosphorus losses from soils to water

- Lot of efforts on reducing phosphorus in overland flow but **little consideration** on role of **belowground pathways** (time lags)

  In some Irish streams during baseflow long-term P concentrations are increasing

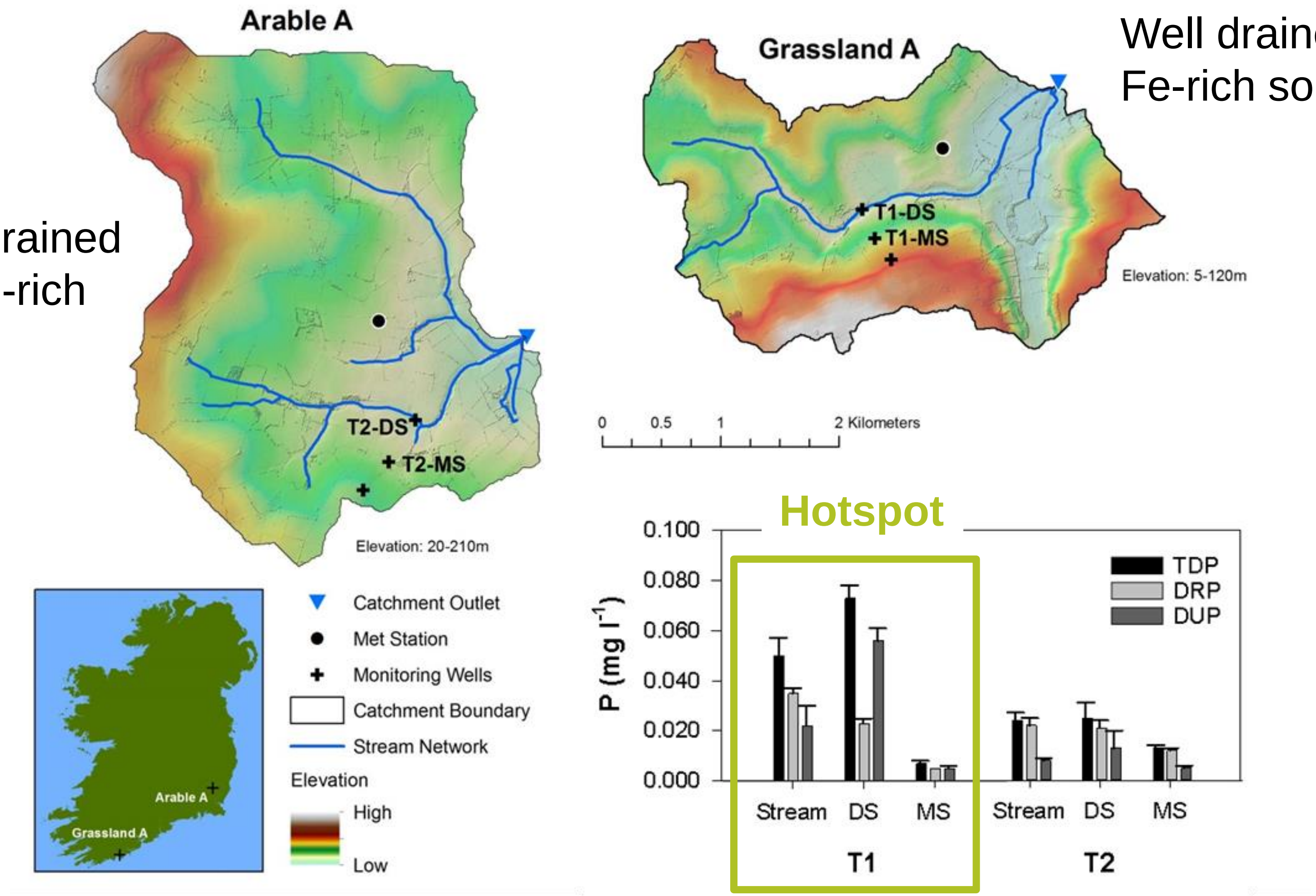
- **Colloids** (1 µm - 1 nm; Fe, Al, clay…) can be **important carriers of phosphorus** and accelerate its transfer from soils to groundwater and surface water

→ *What is the **role of colloidal phosphorus delivery** processes in **groundwater**-fed agricultural catchments?*

Methods – Study catchments

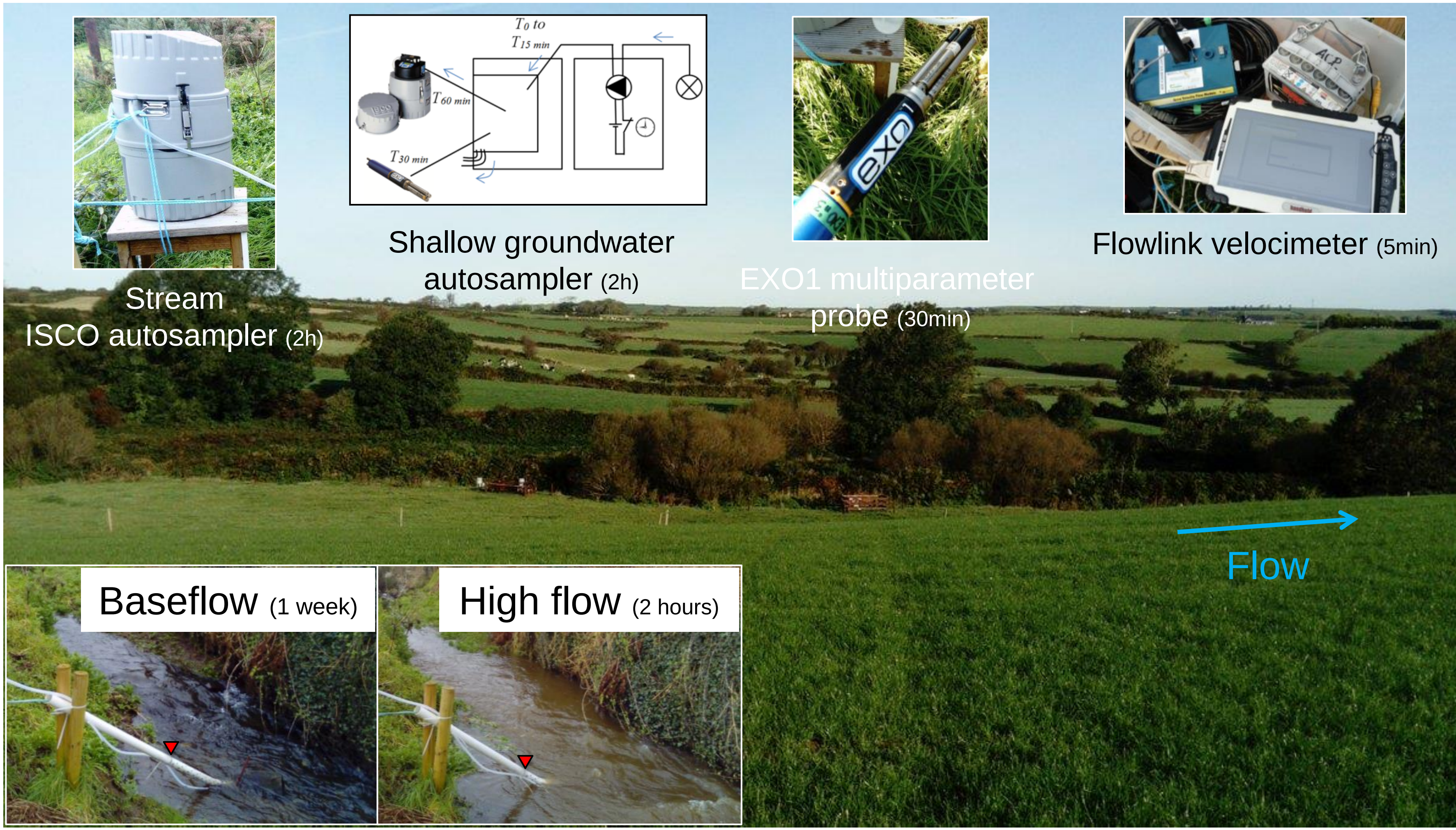
Well drained and Fe-rich soils

Well drained and Al-rich soils

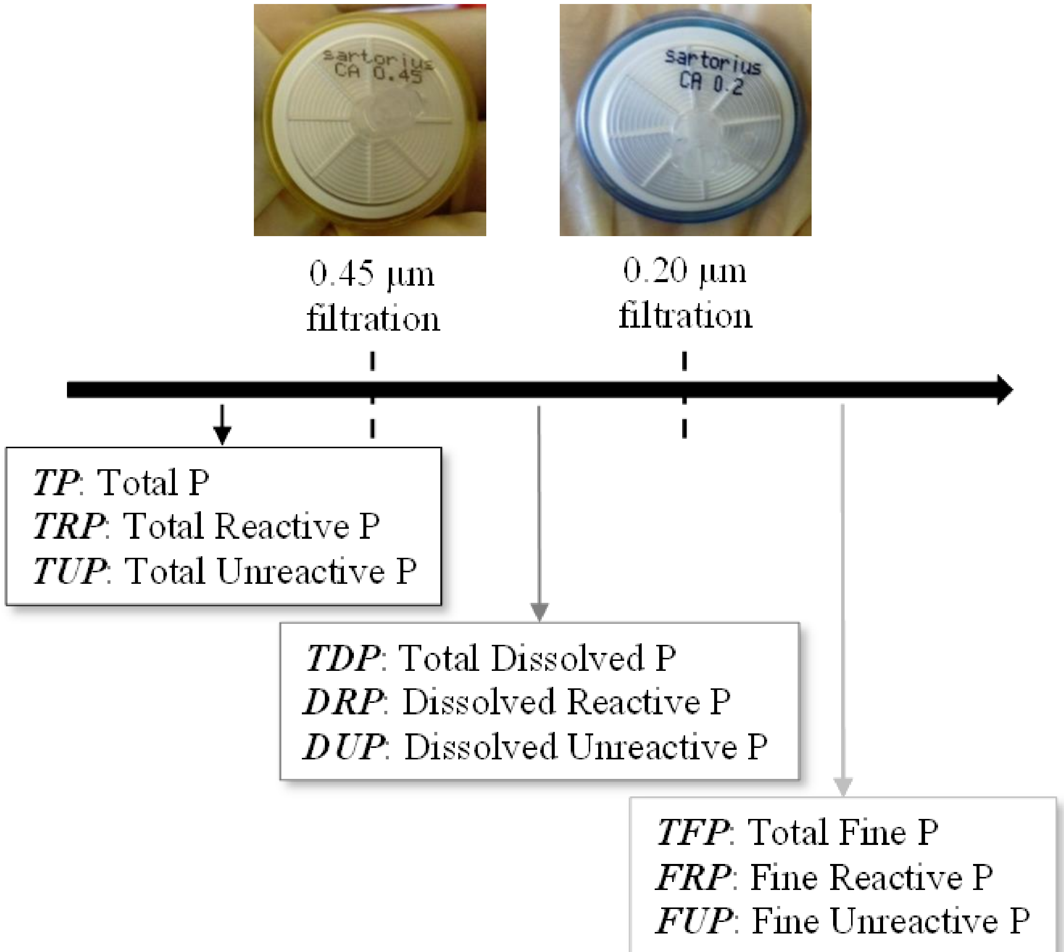


Study hillslopes T1 (Grassland) and T2 (Arable) and long-term (2010-2017) phosphorus concentrations

Methods – Field set up

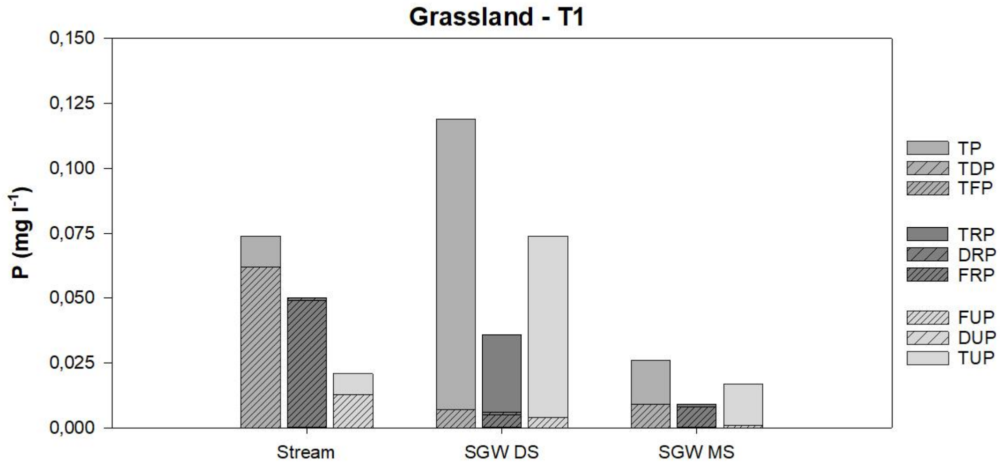


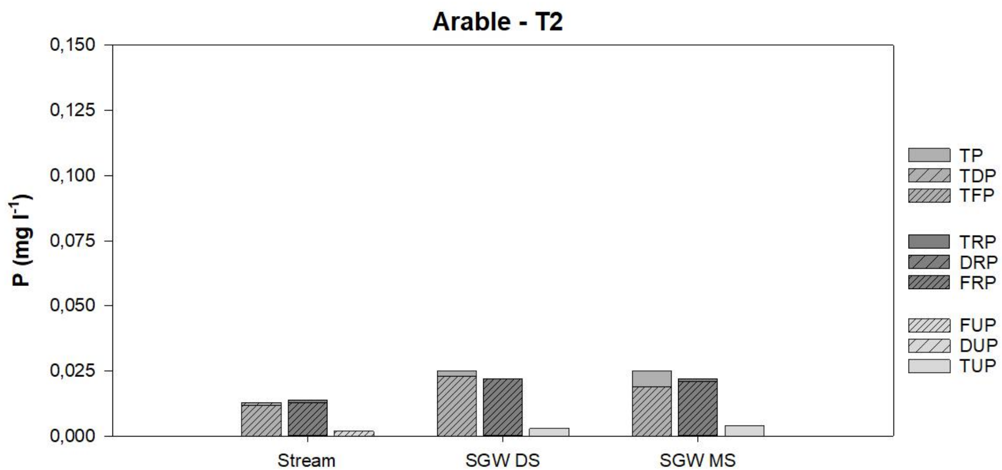
Methods – Fractionation



Fractionation and terminology used for the different fractions and species

Results – Baseflow conditions





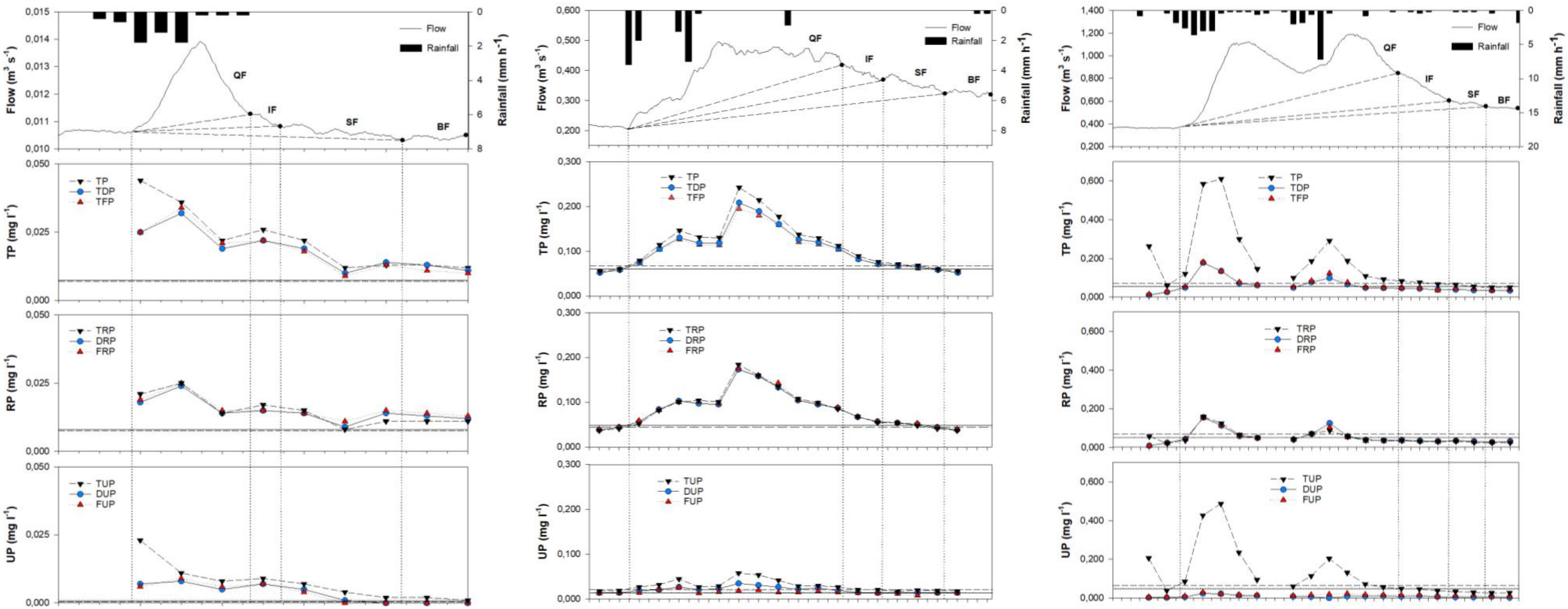
Phosphorus average concentrations in stream, shallow groundwater (SGW) at DS and MS
(fine P is included in dissolved P which is included in total P)

- Grassland T1: *August - March*
  Higher concentrations
  Dominance of **unreactive P** in the **particulate P fraction** in **GW**
  Dominance of **reactive P** in the **fine P fraction** in **stream**

- Arable T2: *February - June*
  Lower concentrations
  Dominance of **reactive P** in the **fine P fraction** in **GW** and **stream**

Results – Flow events

A-1: 12th **June** 2019	**G-1**: 14-15th **October** 2019	**G-2**: 8-10th **February** 2020
6.4 mm in 8h	11.6 mm in 17h	28.6 mm in 19h
Peak 1.8 mm h^{-1}	Peak 3.6 mm h^{-1}	Peak 7.2 mm h^{-1}
SMD 25.2 mm	SMD 0 mm	SMD 2.2 mm



Rainfall and hydrograph with inflection points and delivery pathways (quickflow QF, interflow IF, shallow baseflow SF, deeper baseflow BF). Total, reactive and unreactive phosphorus concentrations (the lines represents the baseflow concentrations)

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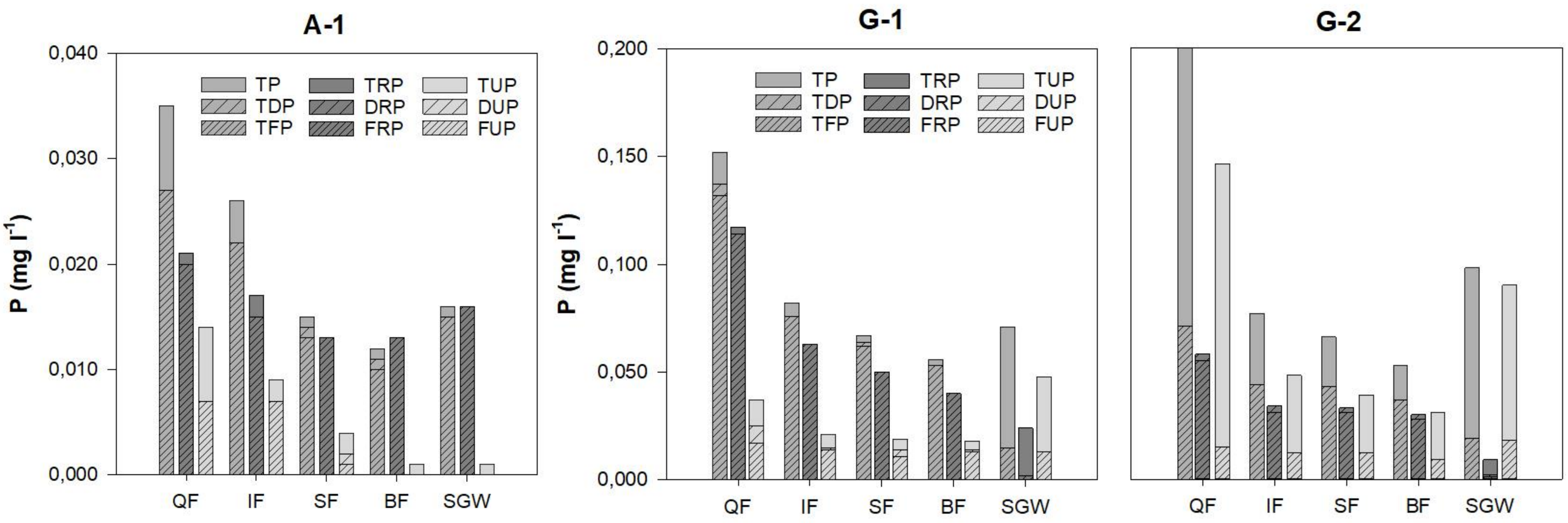
Results – High flow conditions

Stream: **reactive P in fine P fraction**
Shallow GW: **reactive P in fine P fraction**

Stream: **reactive P in fine P fraction**
Shallow GW: **unreactive P in particulate P fraction**

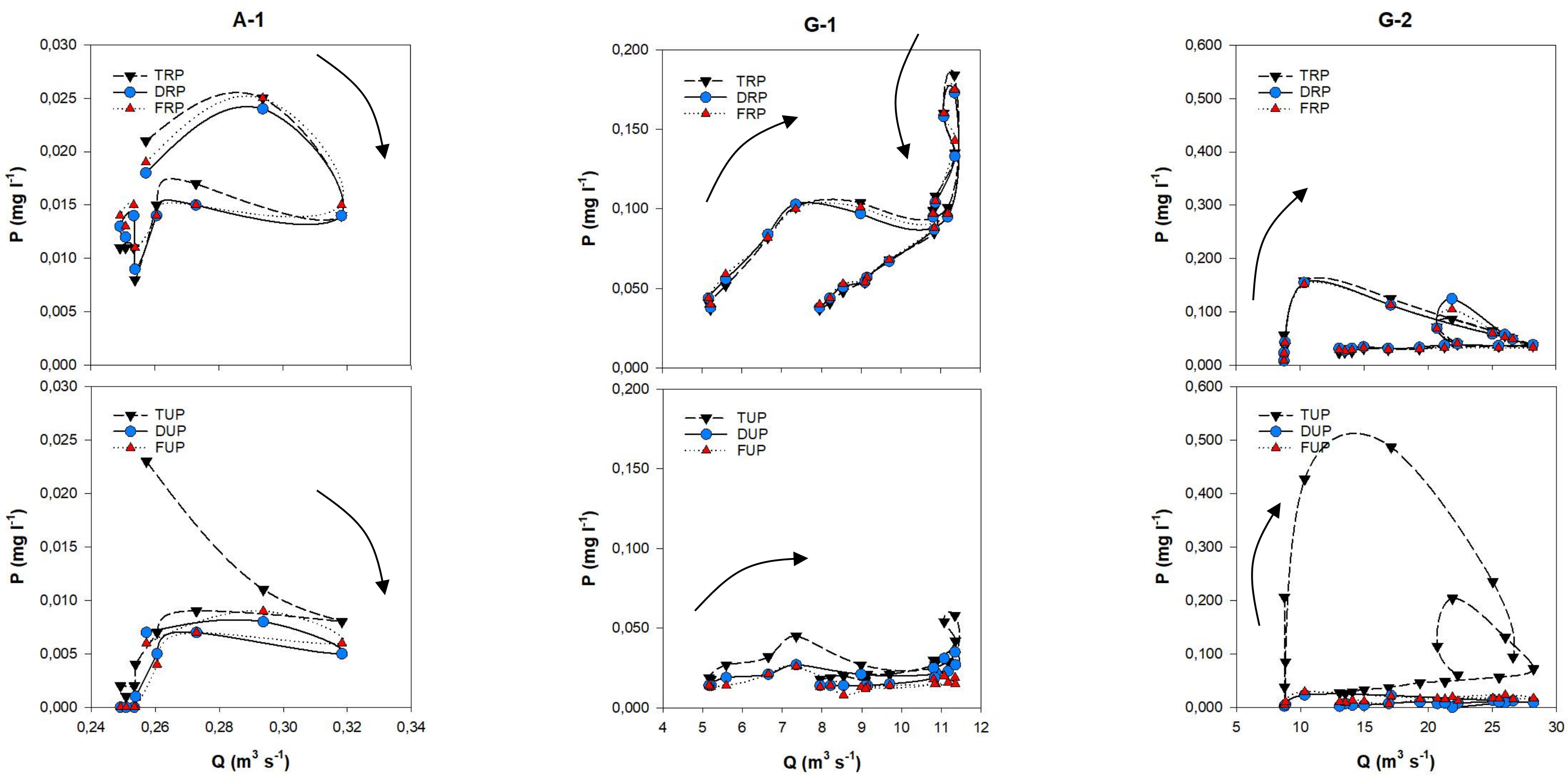
Stream: **unreactive P in particulate P fraction**
Shallow GW: **unreactive P in particulate P fraction**



Phosphorus flow weighted average concentrations in stream during quickflow QF, interflow IF, shallow baseflow SF, deeper baseflow BF and in shallow groundwater (SGW) at DS (fine P is included in dissolved P which is included in total P)

Results – High flow conditions

Source easily mobilised (reactive P in fine P fraction)	Source easily mobilised + 2nd source (reactive P in fine P fraction)	Source easily mobilised (unreactive P in particulate P fraction)



Concentration-Discharge hysteresis (reactive and unreactive P shown at the top and bottom, respectively)

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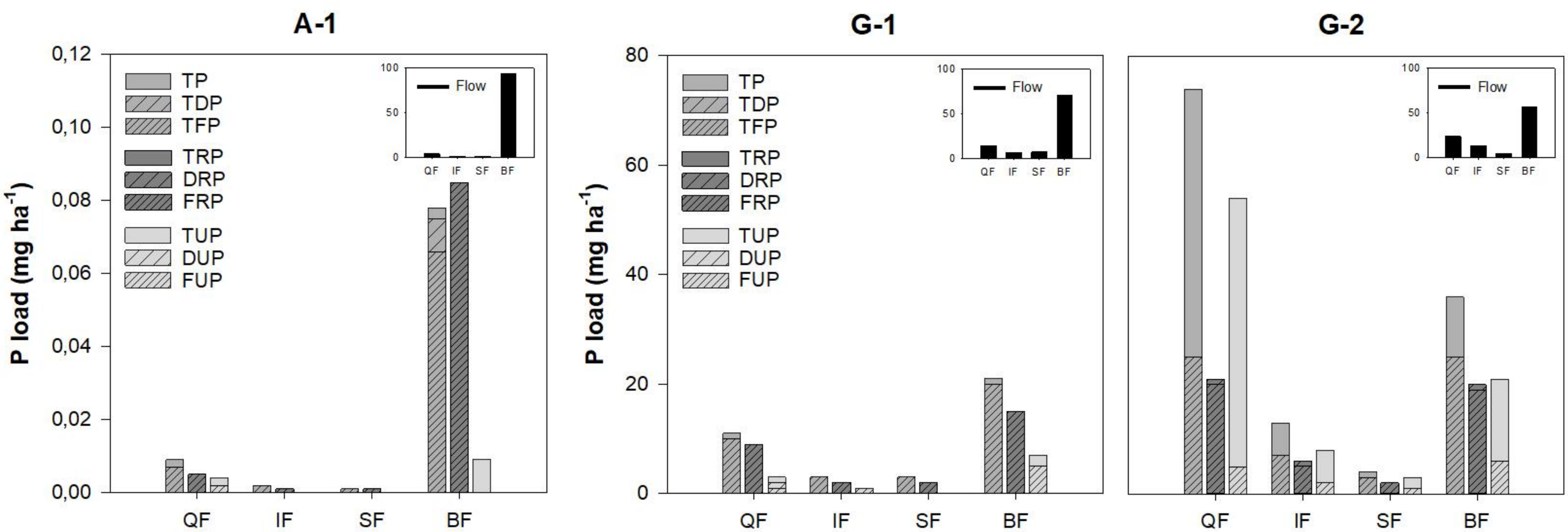
Results – High flow conditions

BF (94%): reactive P in fine P fraction **0.085 mg ha^{-1}**

BF (71%): reactive P in fine P fraction **15 mg ha^{-1}**
QF (14%): reactive P in fine P fraction **9 mg ha^{-1}**

BF (57%): reactive P in fine P fraction **19 mg ha^{-1}**, unreactive P in part. P fraction **15 mg ha^{-1}**
QF (24%): unreactive P in part. P fraction **49 mg ha^{-1}**



Stream phosphorus loads during quickflow QF, interflow IF, shallow baseflow SF, deeper baseflow BF (fine P is included in dissolved P which is included in total P)

Conclusion - Discussion

- **Fine** (< 0.20 µm) **colloidal P dominate dissolved** (< 0.45 µm) **fraction**

→ Important for overall P delivery when dissolved P is dominant

→ Need to further consider smaller colloidal fractions

- **Catchments differed in baseflow P signature**

➢ Grassland catchment: particulate unreactive P in GW, fine colloidal reactive P in stream

➢ Arable catchment: fine colloidal reactive P in GW and stream

→ *Influence of soil chemistry? Porosity?*

- **Seasonality** in the Grassland catchment

➢ source of fine colloidal reactive P in October // particulate unreactive P in February

→ *Influence of land management (slurry spreading)?*

➢ BUT near-stream shallow GW always source of particulate unreactive P

→ *Chemical processes in GW (zone of denitrification)? Soil chemistry? Texture? Porosity?*