DOC-Einträge in die Talsperre Sosa - eine zeitliche und räumliche Prozessanalyse

Spatial and temporal variability of dissolved organic matter across the terrestrial−aquatic continuum

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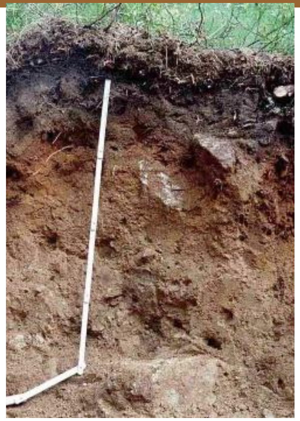
Globally increasing DOC concentrations – also in Saxony

Fotos: A. Stephani, S. Krüger

Environmental conditions promoting high DOC fluxes from soils into water

- ❑ Large carbon stocks (forest floor horizons, peatlands, mineral soils)
- ❑ High proportion of peatlands in the catchment + degrading peatlands
- ❑ High frequency of heavy rainfall /extreme events - reduced passage of the mineral soil
- ❑ Reducing conditions in the soil

Terrestrial „world“



Aquatic „world“

Combine
To monitor / experiment
Joint data processing

DOC sources in streams of forested catchments in mountainous areas

Soils of the catchment – high stocks of soil organic matter

DOC: < 1% soil organic carbon

- ❑ Peat
- ❑ Forest floor
- ❑ Mineral soil

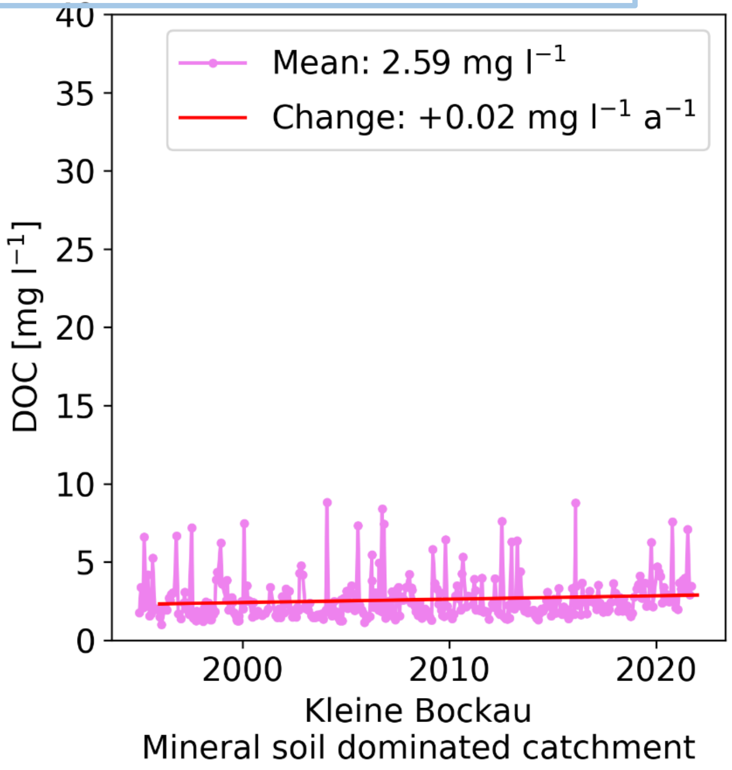
} Potential DOC sources

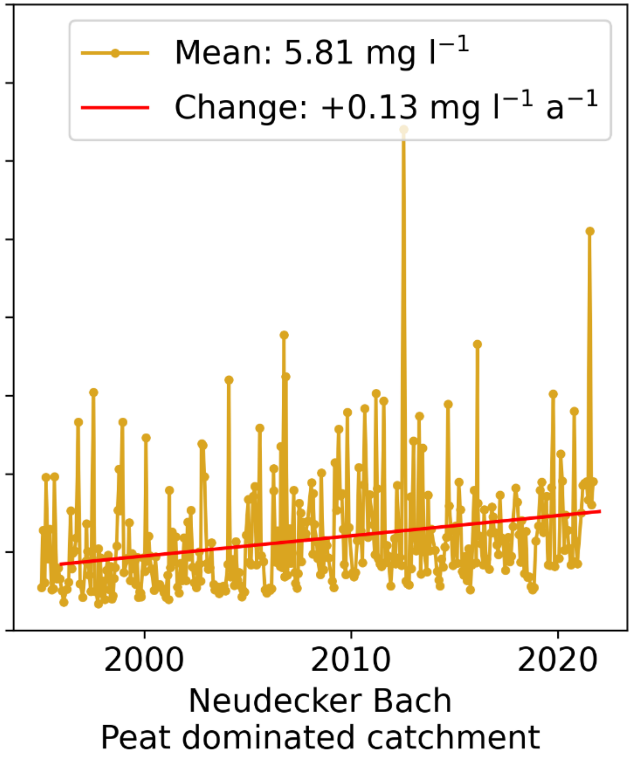
Background and objectives

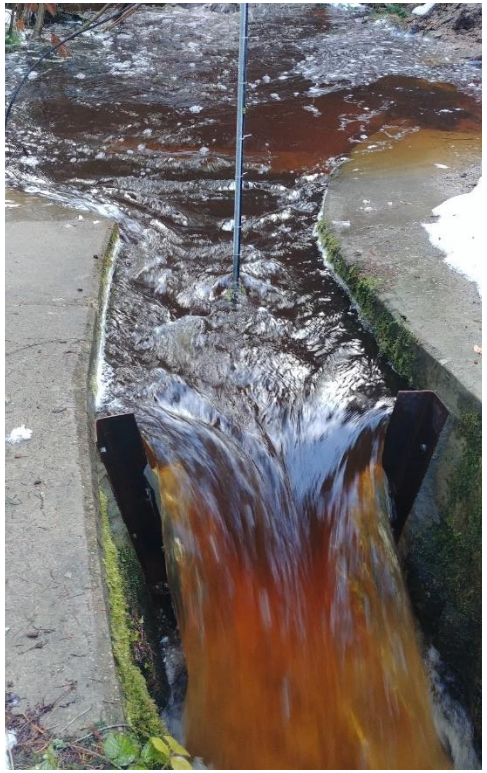
- Assessment of spatial and temporal variations in DOC export from soils to surface waters
- Which areas have highest DOC export potential? And when?

- Drivers and controls of increasing DOC concentrations
- Secure water quality

Kleine Bockau Feb 2021: 12 mg C L^{-1}

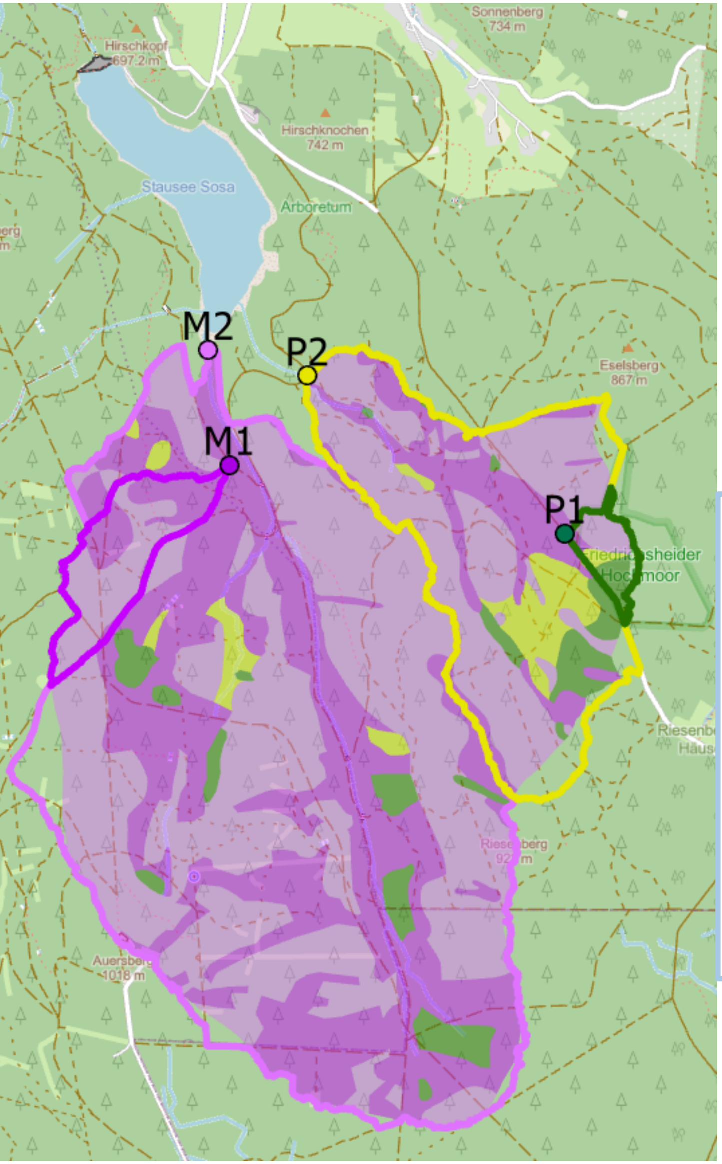


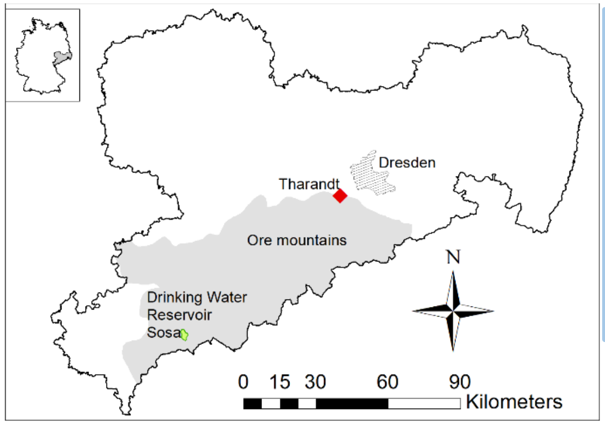




Neudecker Bach Feb 2021: 25 mg C L^{-1}

Study site - headwater catchment Sosa (German Ore mountains)





- Focus on two main DOC sources: organic (peat) und mineral soils
- Use of 2 sub catchments with different proportions of organic soils

Soil sites

4 representative soil types

- Podzol
- Cambisol
- Peat
- Highly degraded peat

Stream sites

2 × 2 sub catchments

- M1 mineral soil dominated
- M2 mineral soil dominated
- P1 peat dominated
- P2: peat and mineral soil dominated

Soil- and stream water sampling and analyses

Soil sites

Suction plates

Soil water:
DOC
DON = TN − NH_4^+-N − NO_3^--N
DOM composition

Suction cups +
tensiometers

Soil water + water potential

Suction cups +
tensiometers

Soil water + water potential

Stream sites

weir + water level sensor

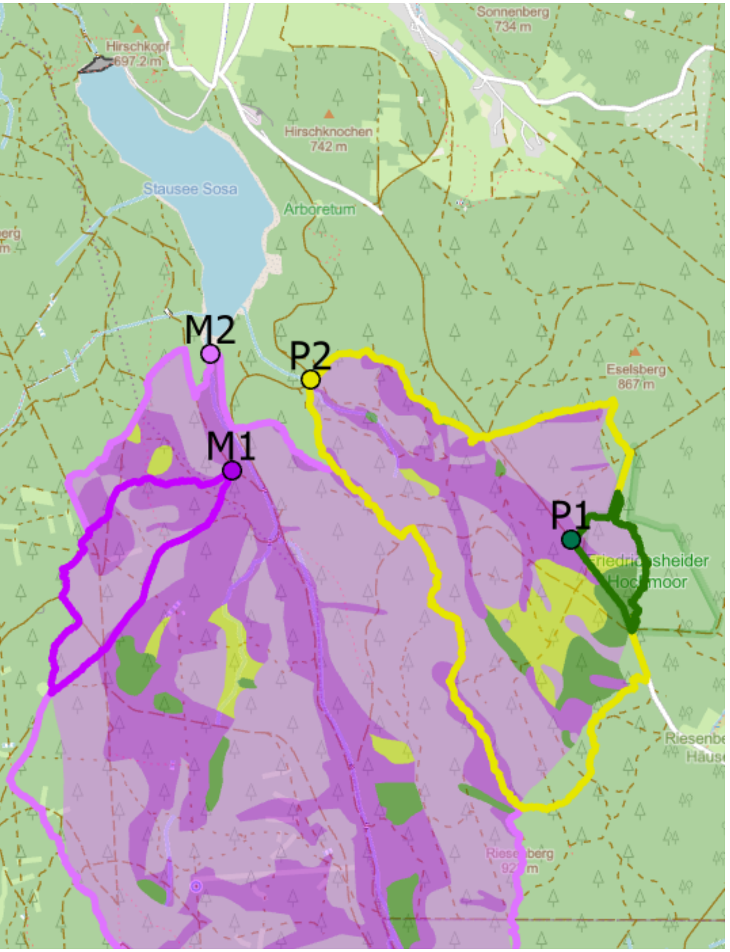
discharge

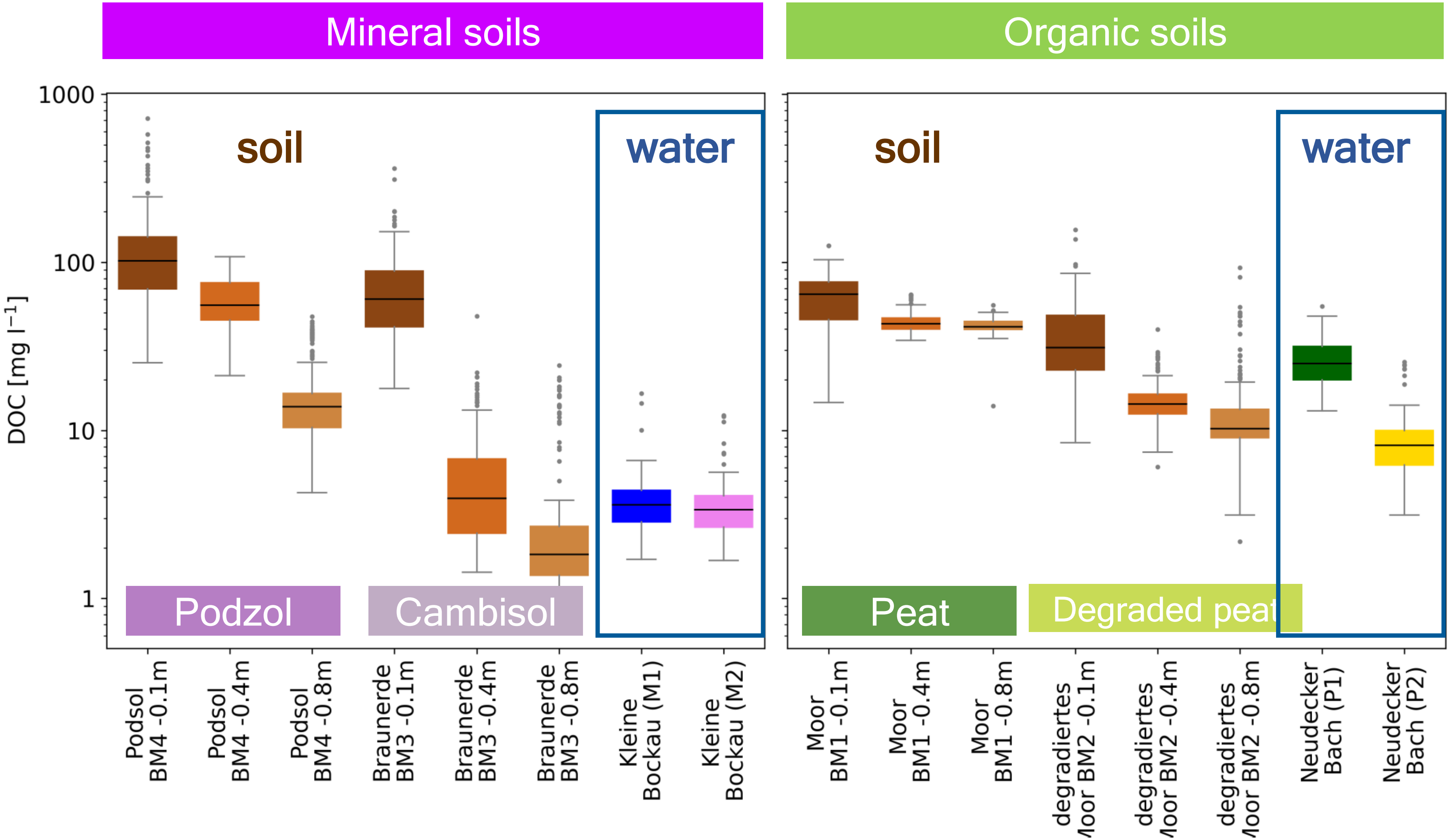
Fluorescence probe, automatic sampler

Continuous measurements, event-based sampling

Biweekly sampling + analyses

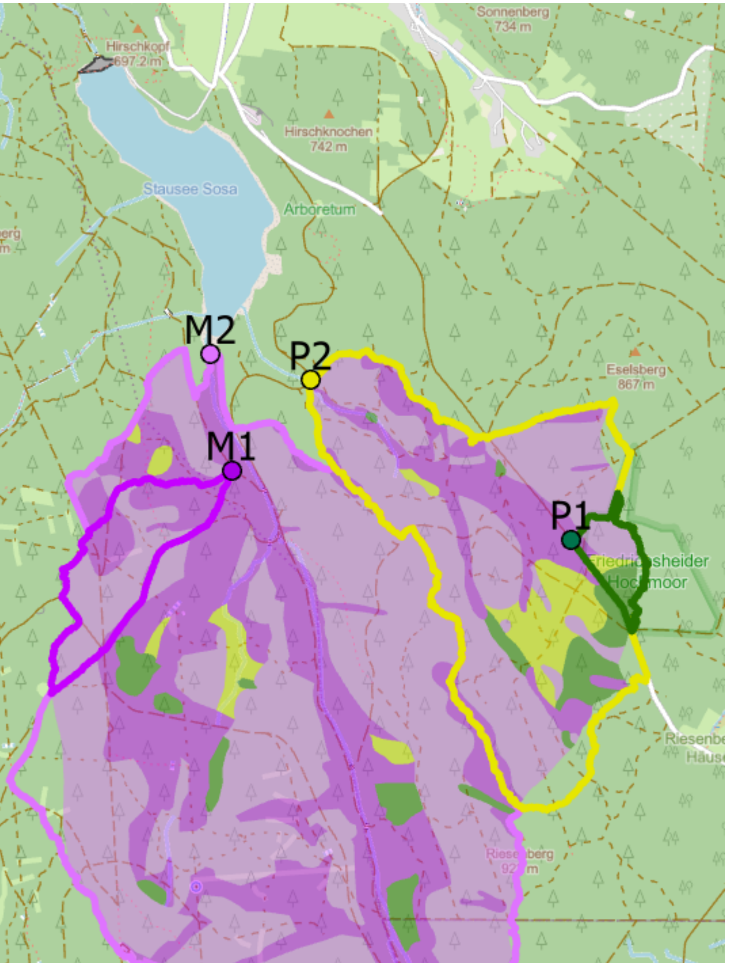
DOC in soil and water (connected streams)

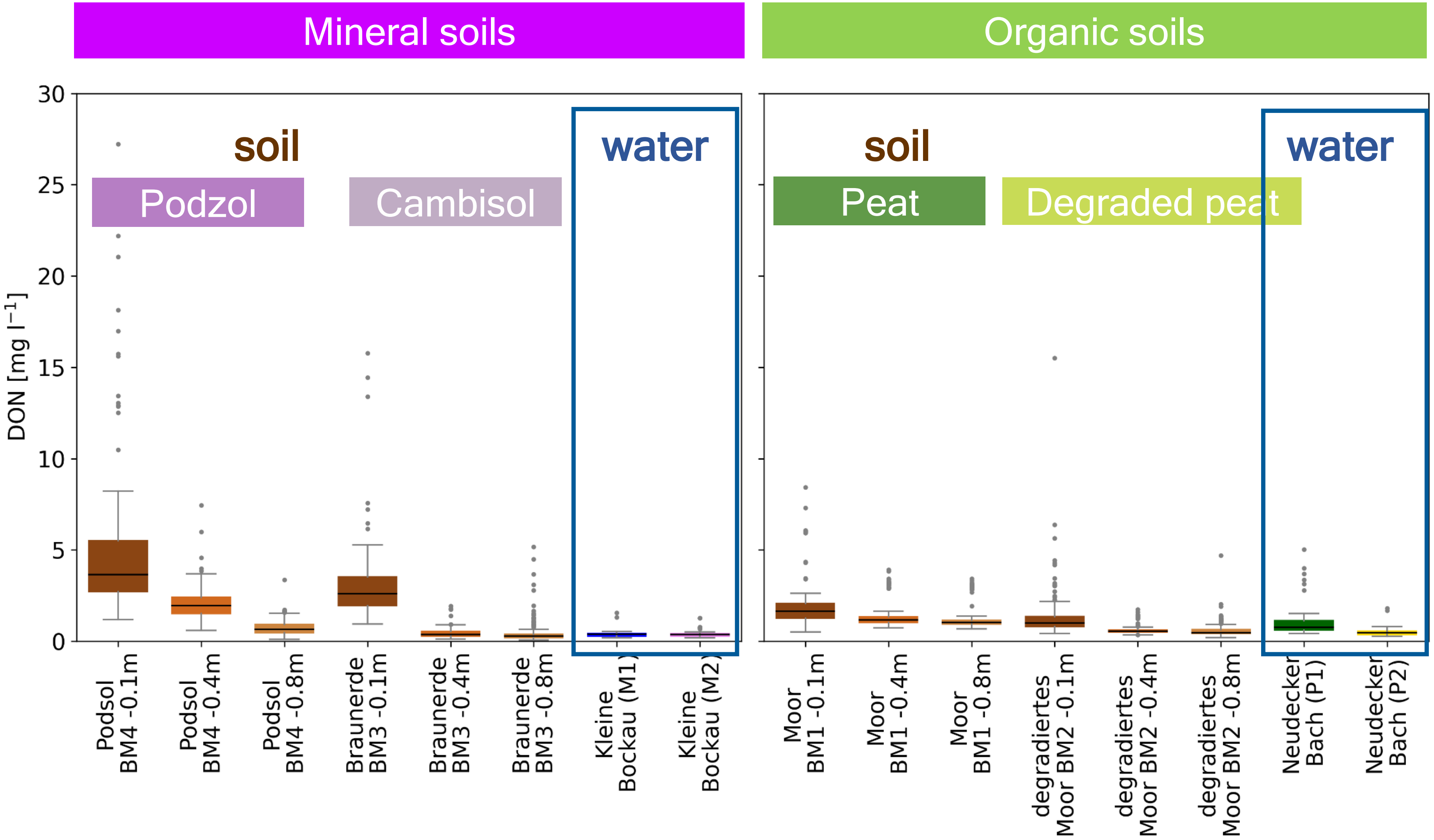




- highest DOC concentrations in upper parts of mineral soils but strong retention in deeper soil layers (high DOC concentrations in all Podzol horizons)
- Peat: high DOC concentrations in all depths

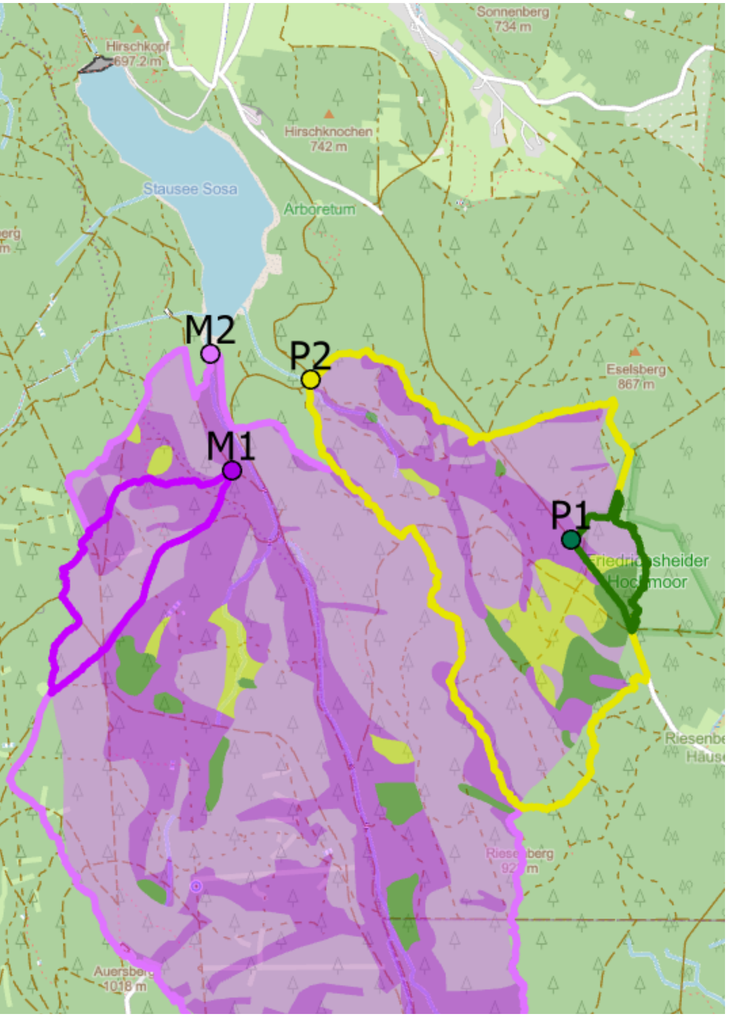
DON in soil and water (connected streams)

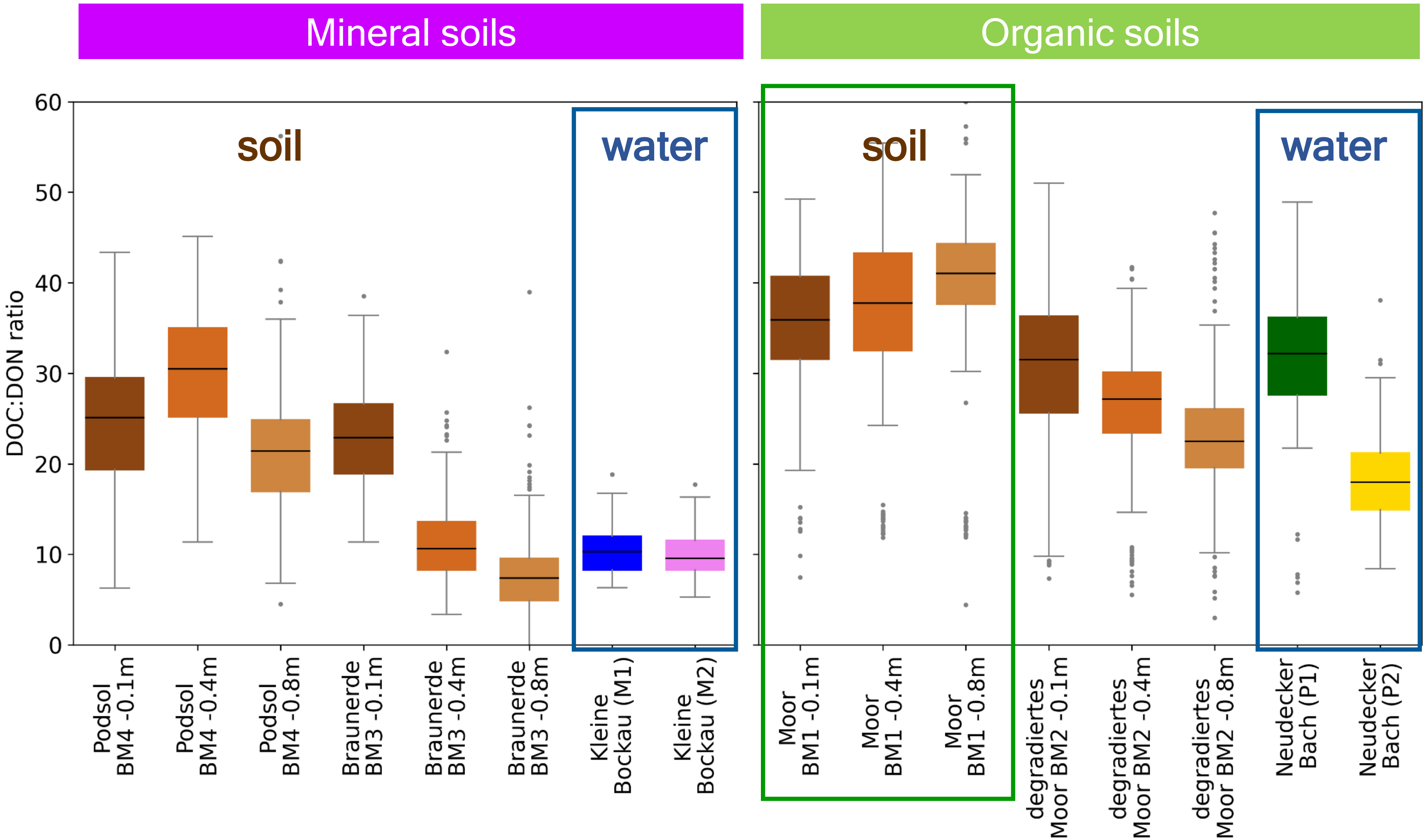




- highest DON concentrations in upper parts of mineral soils
- Peat: relatively low DON concentrations in all depths

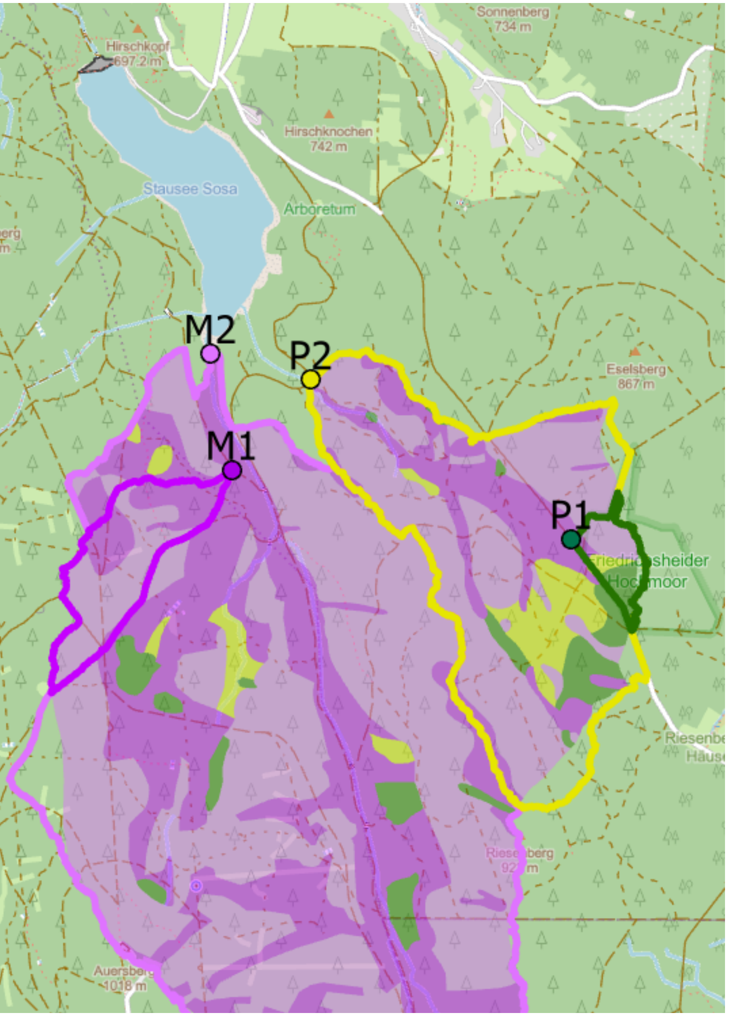
DOC:DON ratios in soil and water (connected streams)

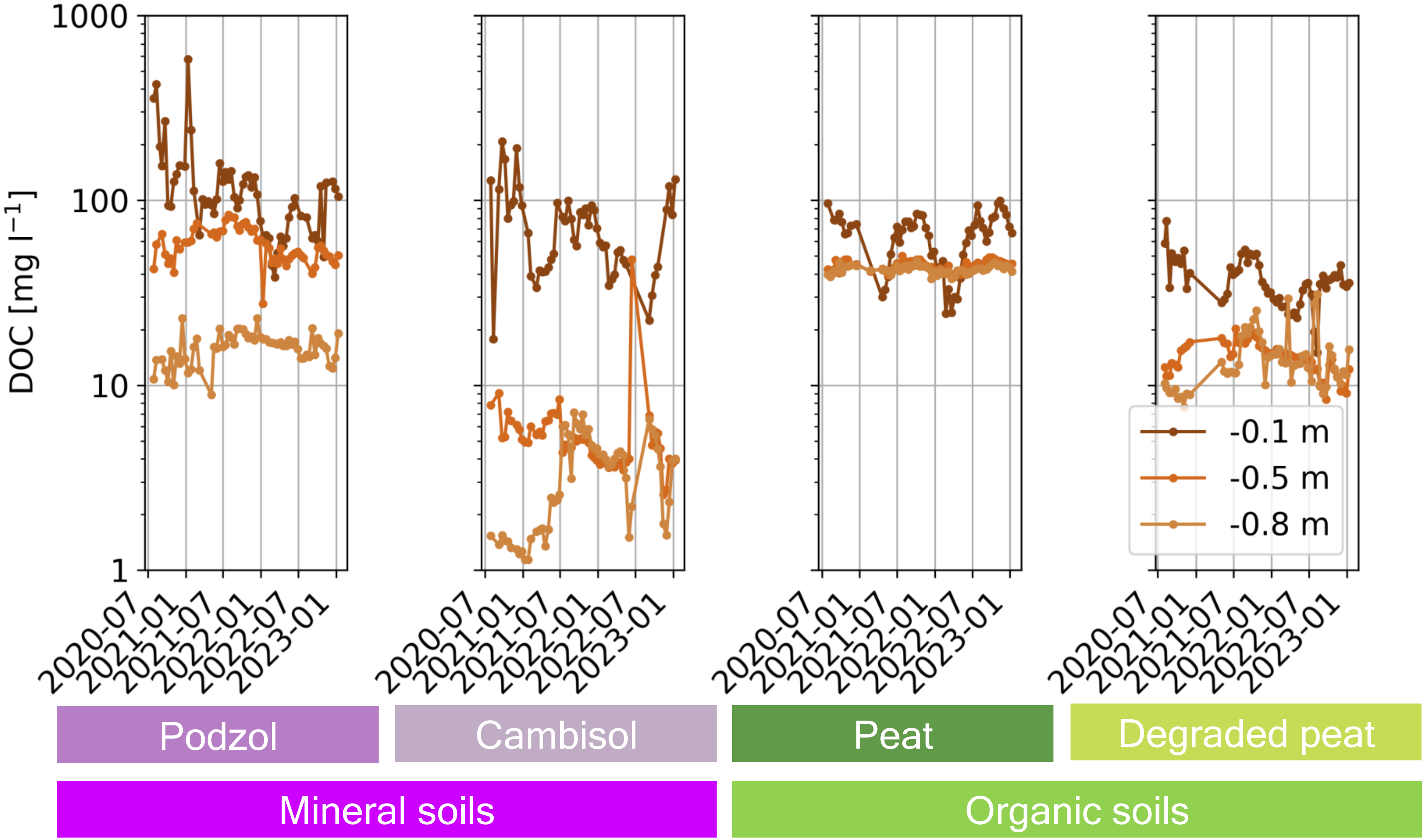




- Peat DOM: plant-derived; less microbial processing & sorptive retention/fractionation
- Mineral soil DOM: more microbially processed & sorptive retention/fractionation

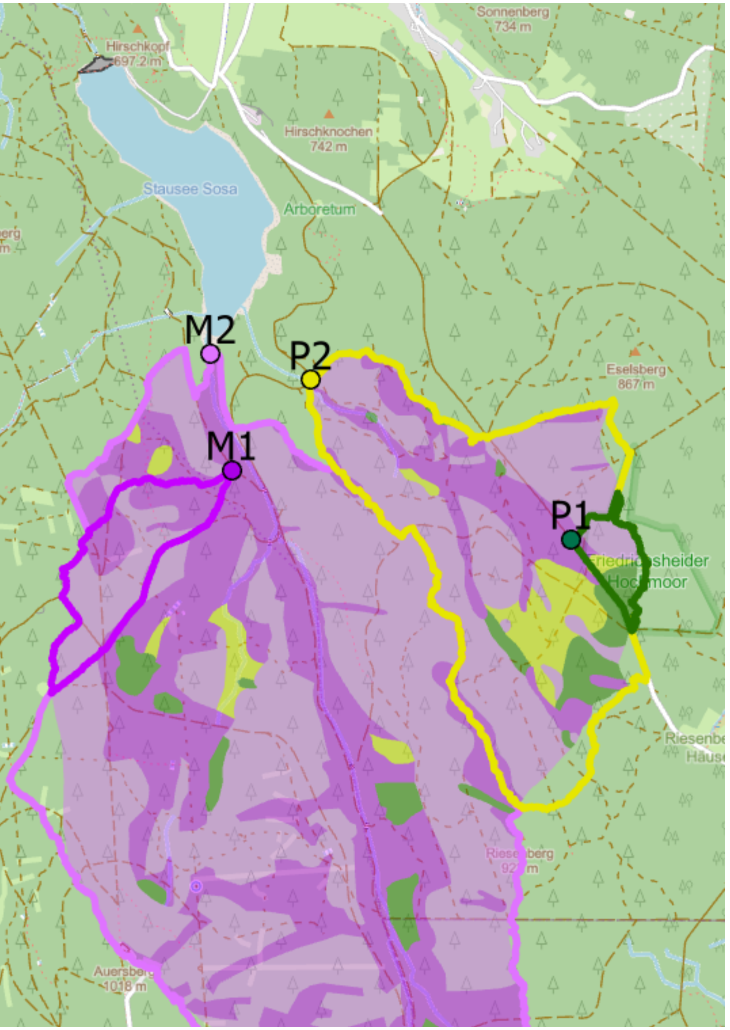
Temporal variability of DOC concentrations in soil

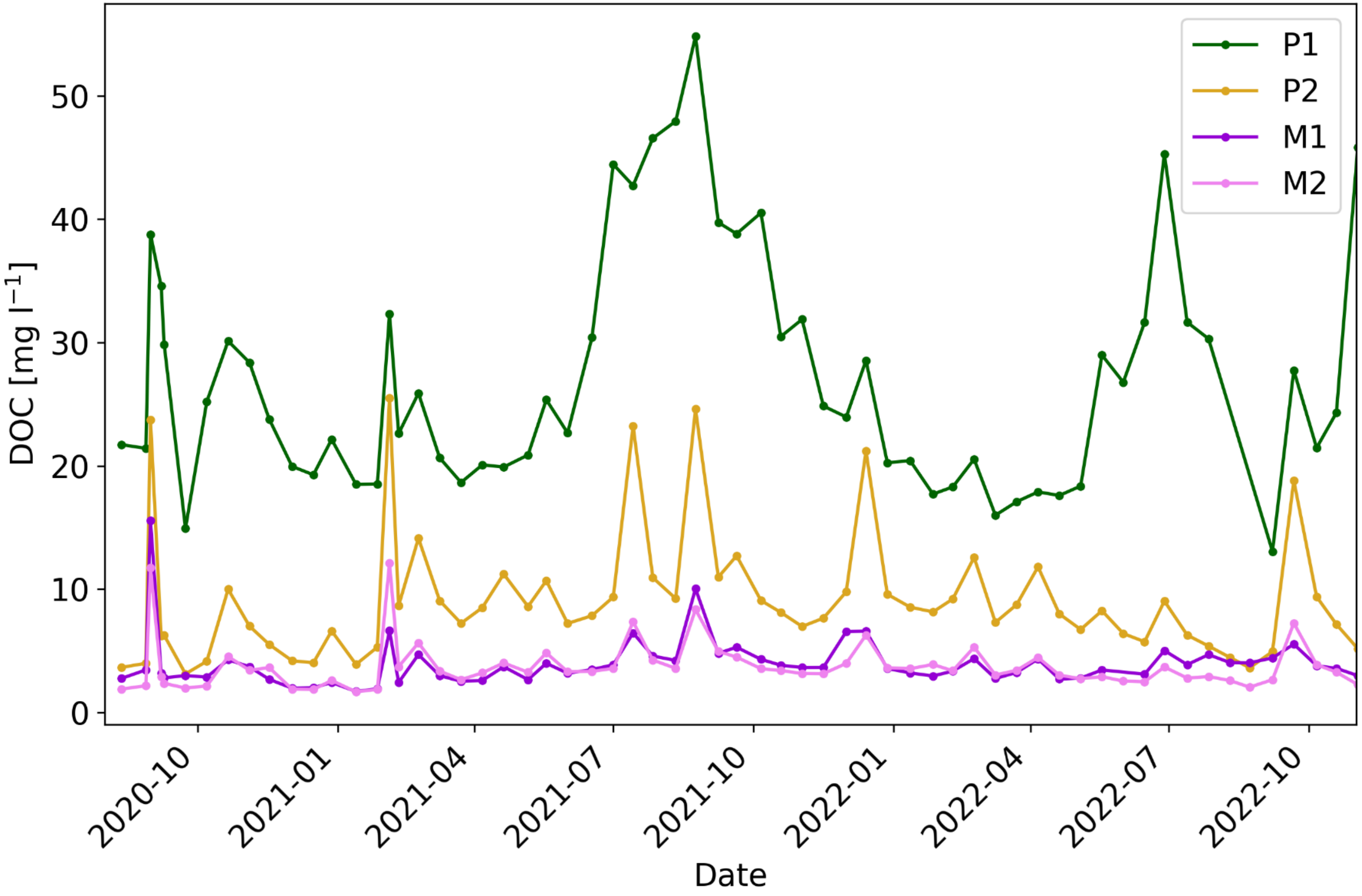




- High variability in the forest floor and in surface peat horizons with peaks mainly in Spring and Summer
- Peat: snowmelt – dilution in the upper part (lower DOC concentrations)

Temporal variation of DOC concentrations in streams

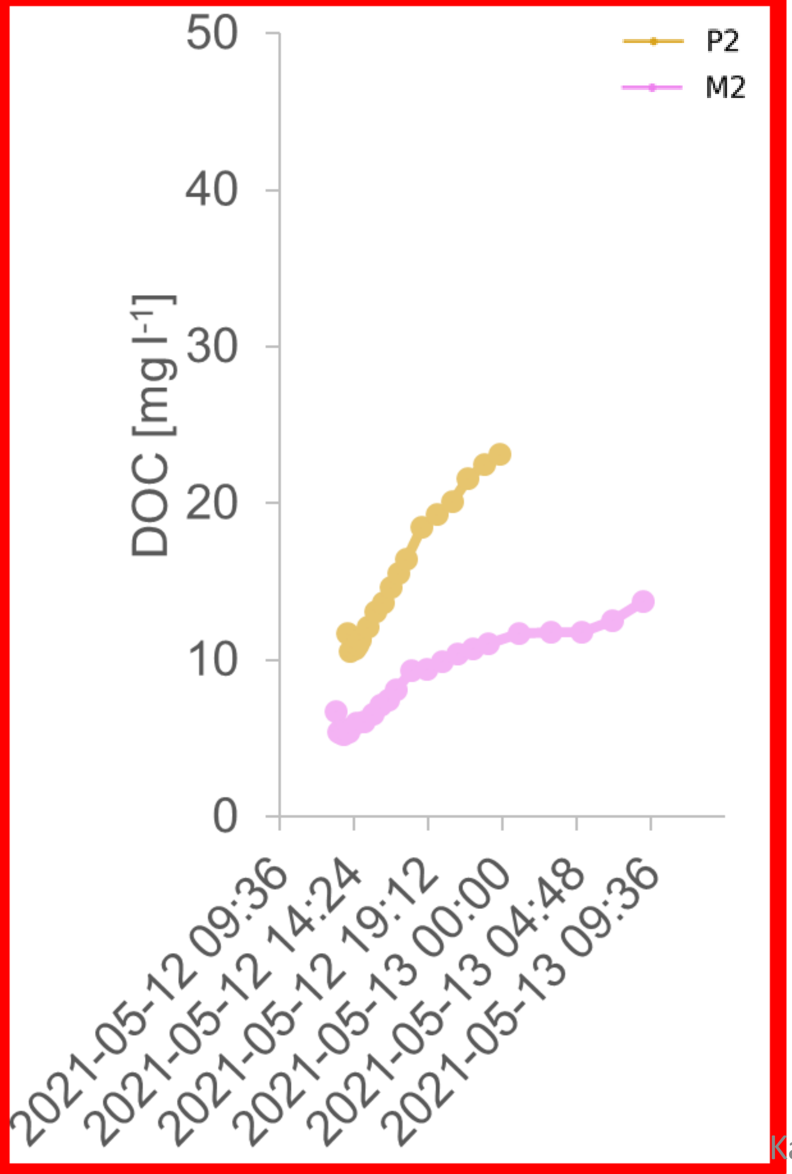


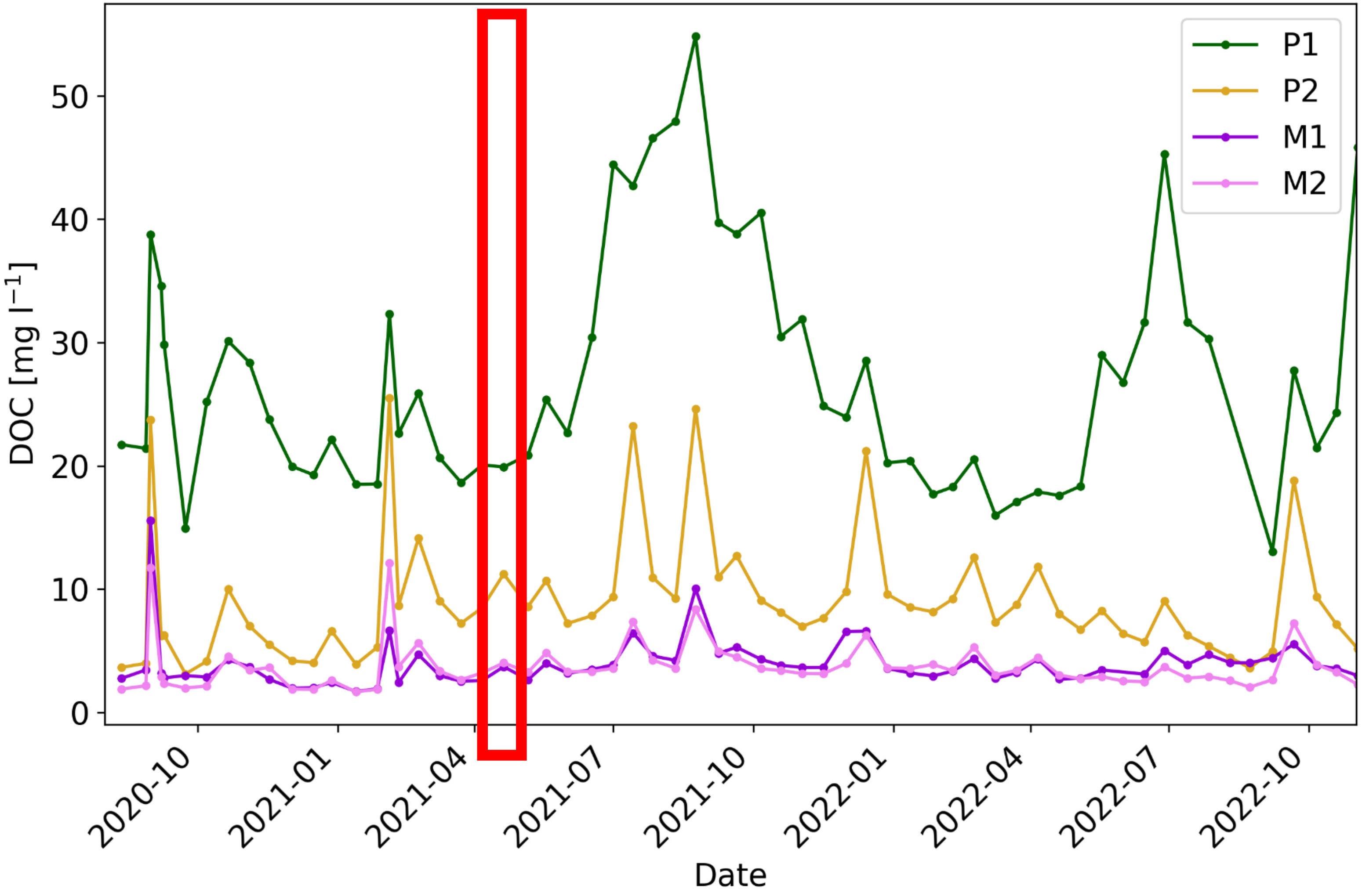


- Peaks after snowmelt and heavy rainfall events in all streams
- Relative increase in DOC concentrations highest in streams less affected by peat

Temporal variation of DOC concentrations in streams

Heavy rainfall event





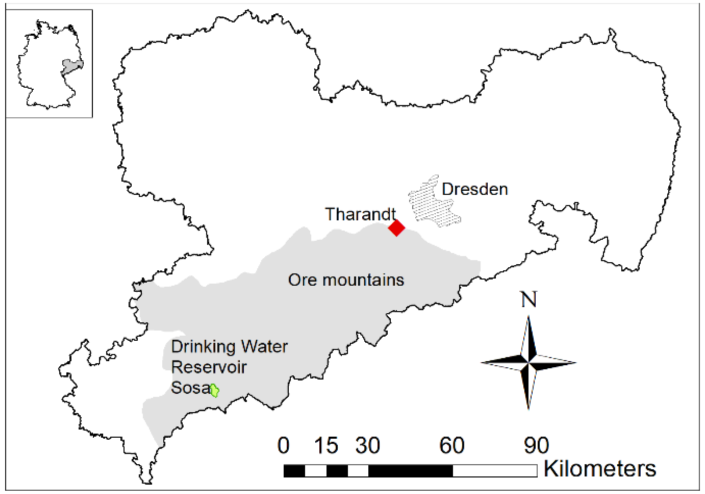
- Very fast change in DOC concentrations - doubling within a few hours

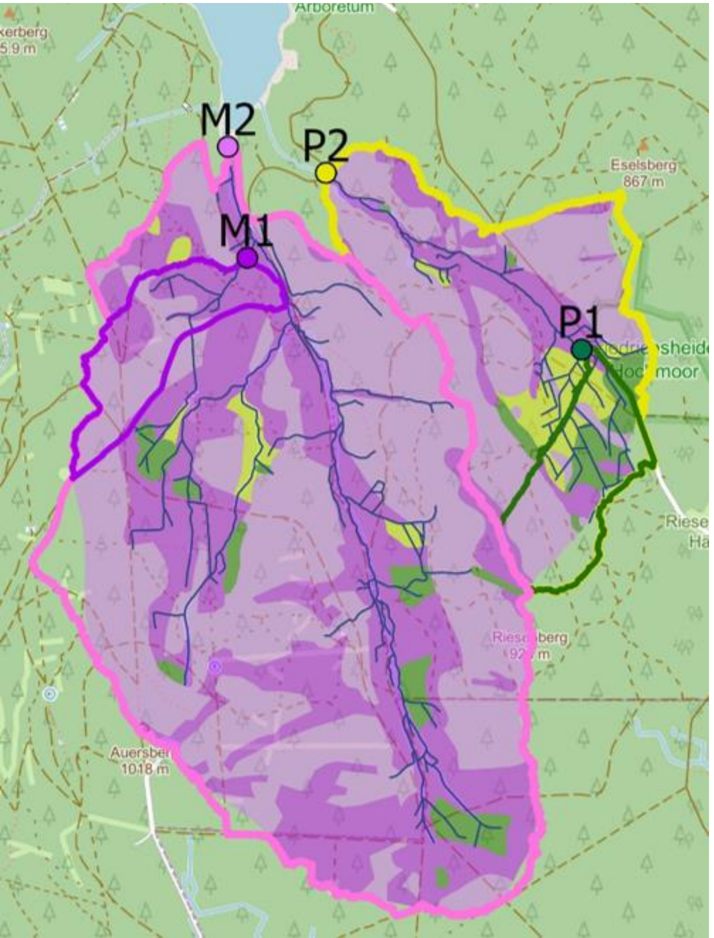
Temporal variation of DOC concentrations in streams

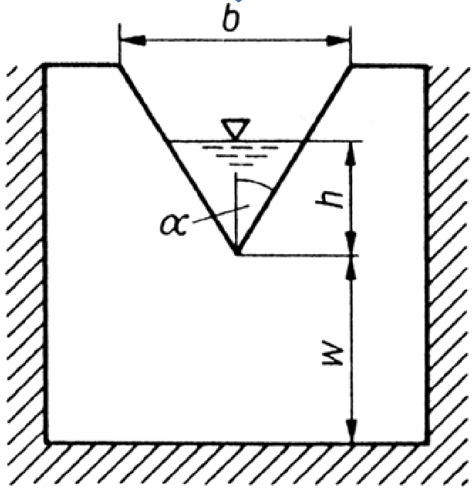
What does it mean for DOC fluxes from soils into the Sosa reservoir?

- Specific DOC loads from different source areas
- Effects of high water fluxes

Let's get some high-resolution data





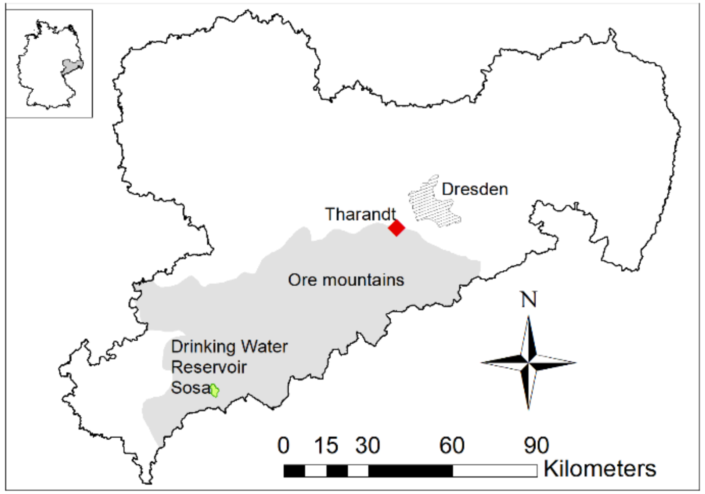


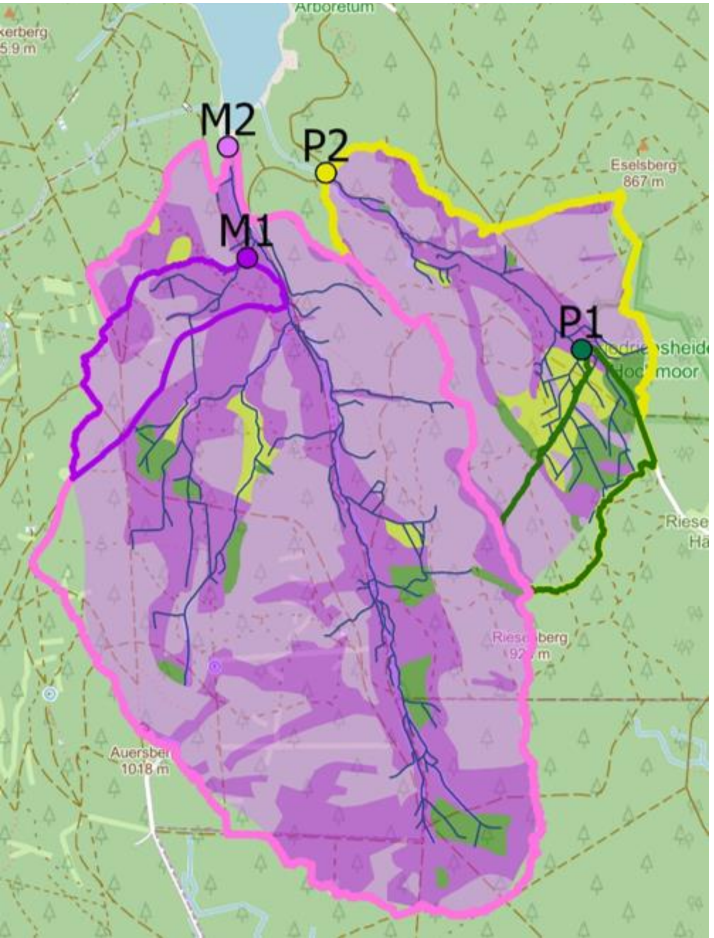
$$Q\left[\frac{m^3}{s}\right] = \frac{8}{15}\cdot\mu\cdot(2\ g)^{\frac{1}{2}}\cdot\tan\frac{\theta}{2}\cdot h_1^{5/2}$$

g = gravity acceleration [9.81 m/s²]
μ = runoff coefficent [-]
ϑ = angle [-]
h_1 = weir head [m]

(Morgenschweiß, 2018)

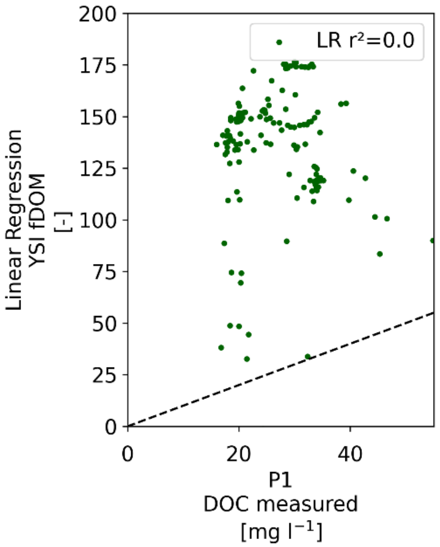
Let’s get some high-resolution data

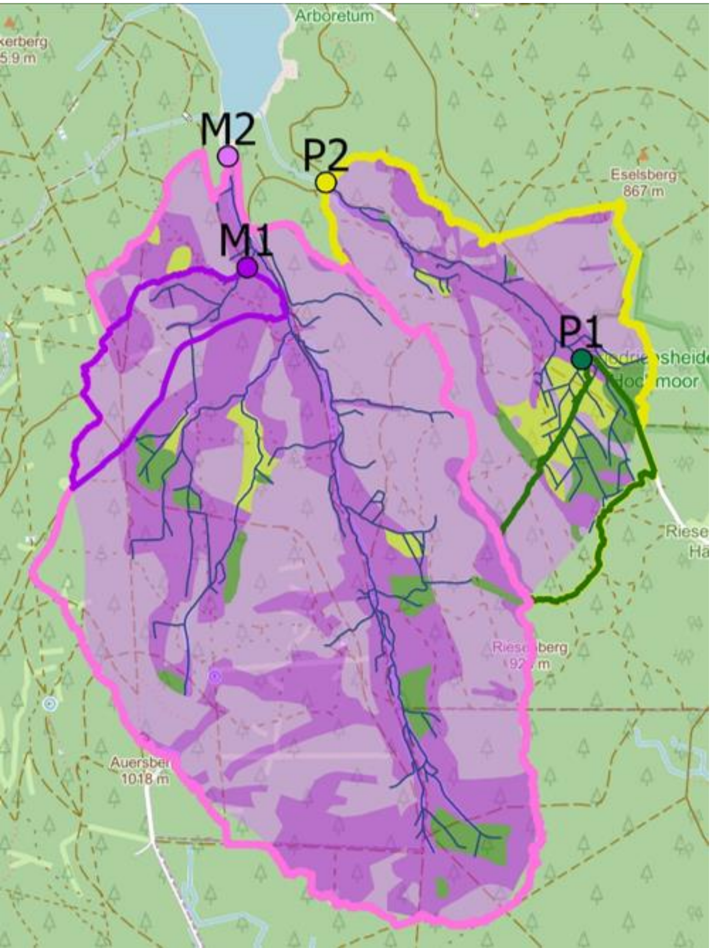




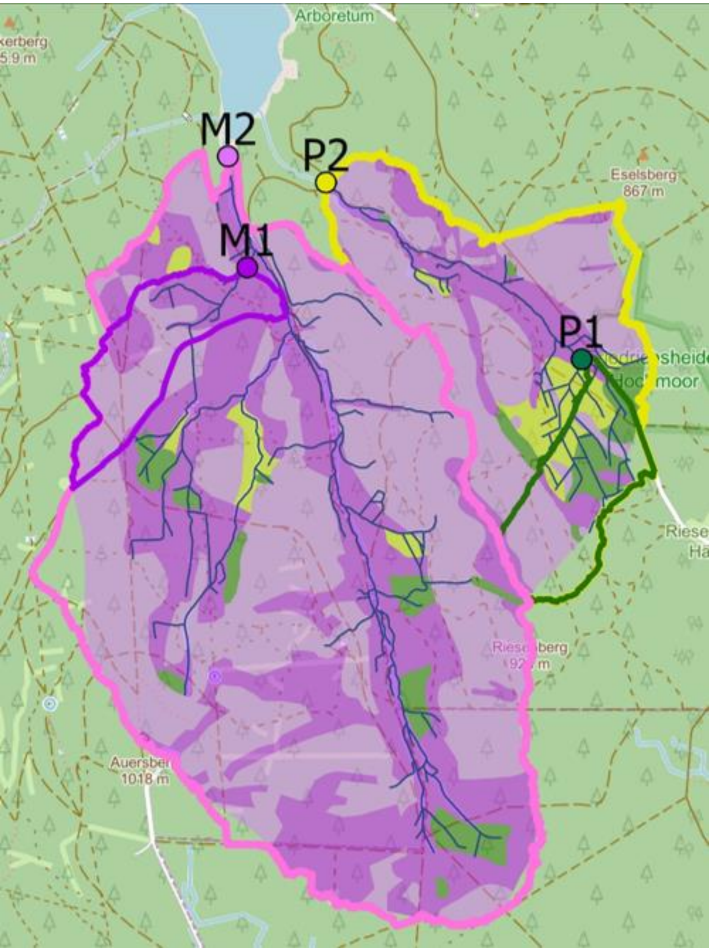
YSI-EXO2


YSI-EXO2

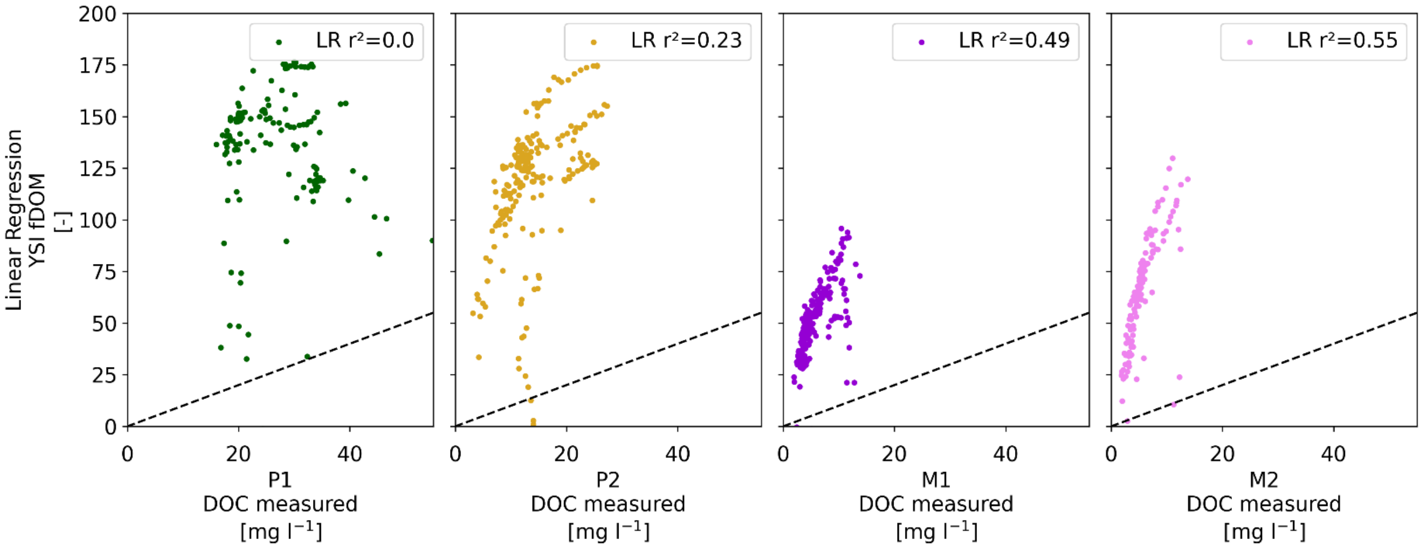

LR r²=0.0
Linear Regression
YSI fDOM
[-]
P1
DOC measured
[mg l⁻¹]
0
25
50
75
100
125
150
175
200
0
20
40


Arboretum
M2
P2
M1
P1
Eselsberg
867 m
Auersber
1018 m


YSI-EXO2

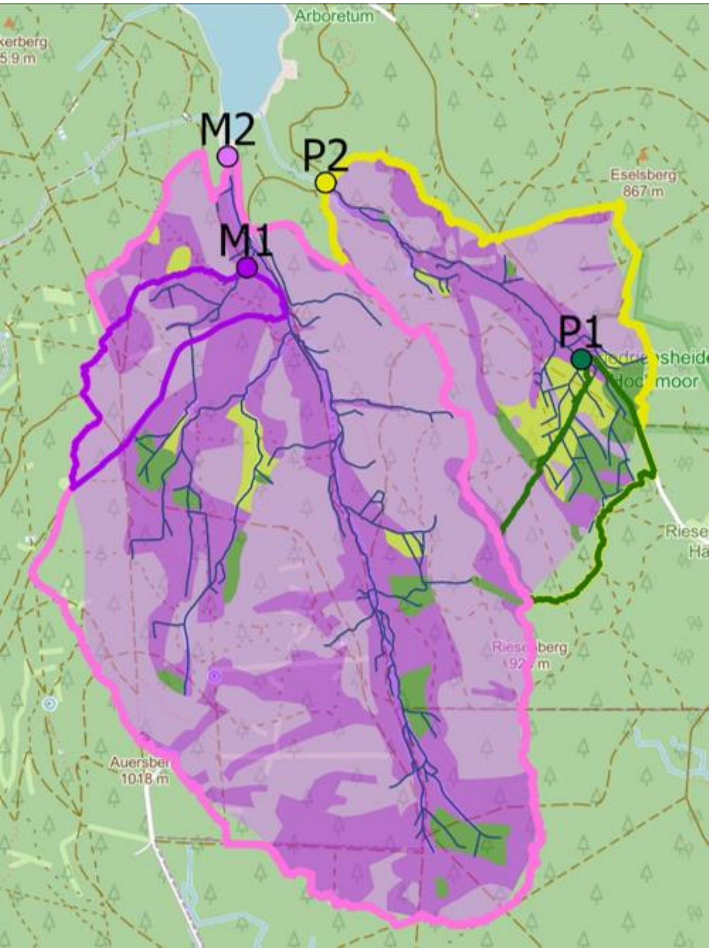


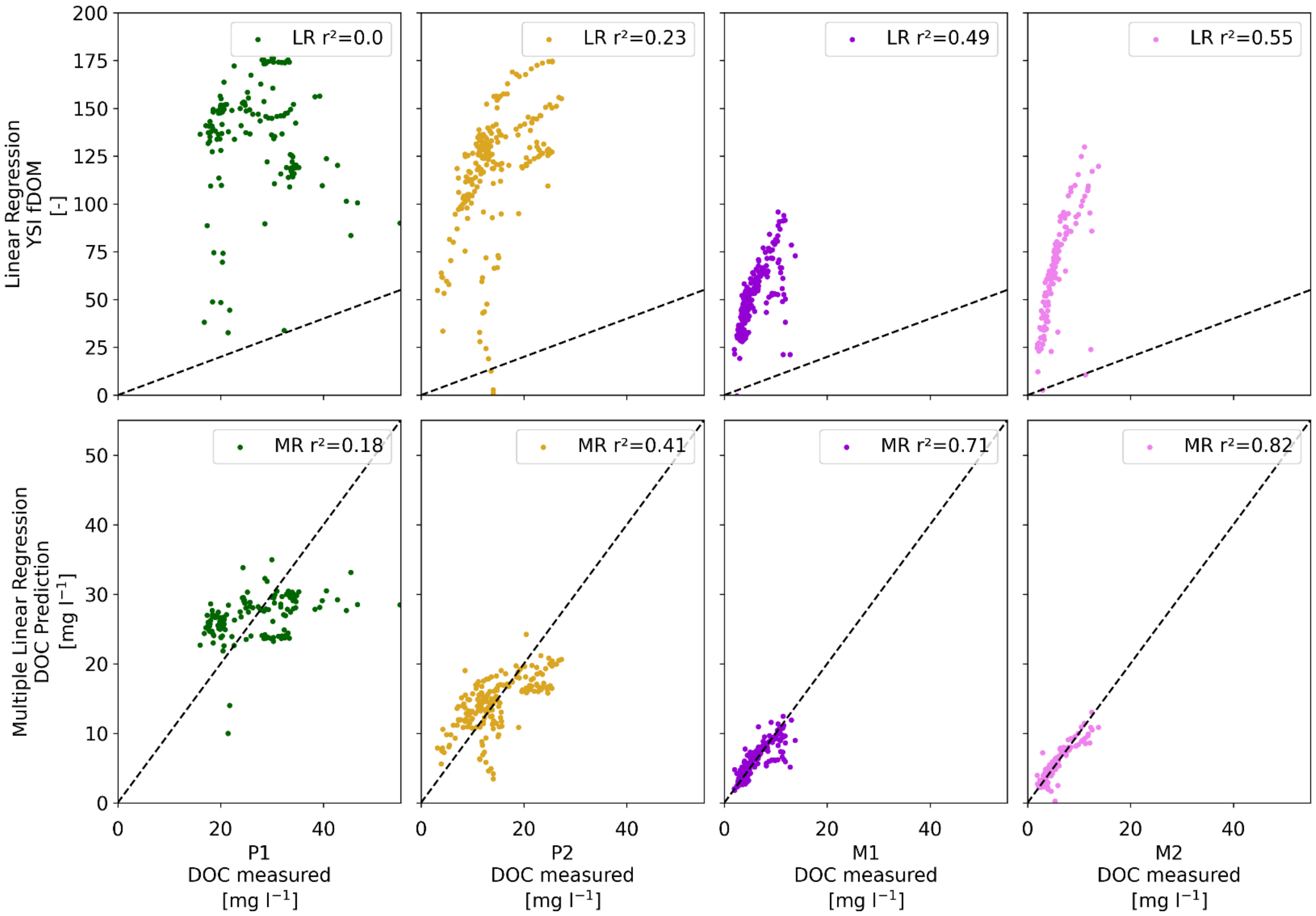
Arboretum
M2
P2
M1
P1
Eselsberg
867 m
Auersber
1018 m



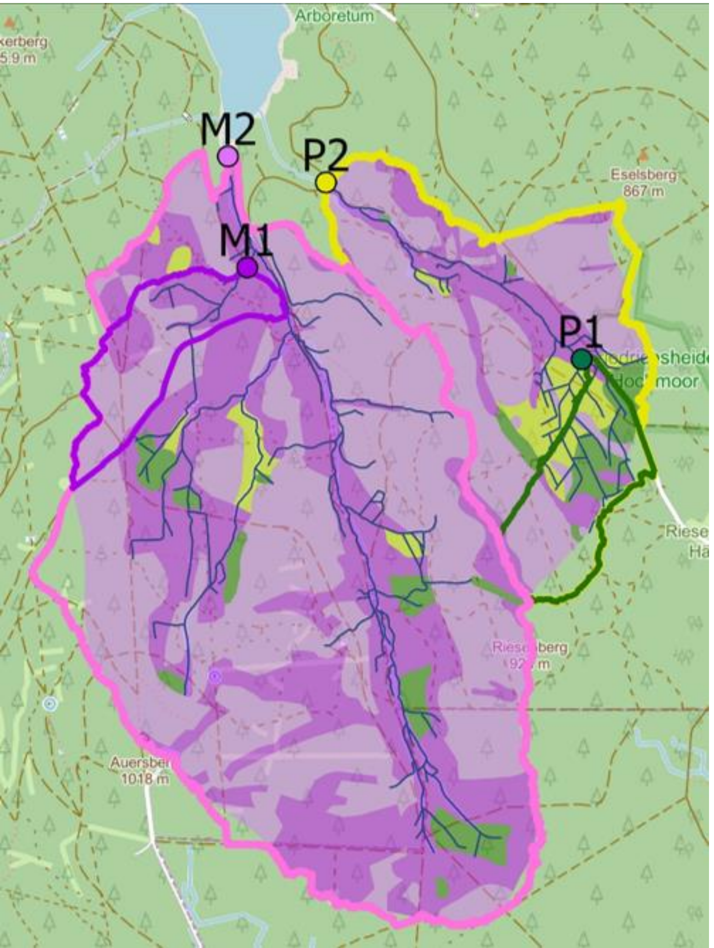
Linear Regression
YSI fDOM
[-]
LR r²=0.0
LR r²=0.23
LR r²=0.49
LR r²=0.55
P1
DOC measured
[mg l⁻¹]
P2
DOC measured
[mg l⁻¹]
M1
DOC measured
[mg l⁻¹]
M2
DOC measured
[mg l⁻¹]

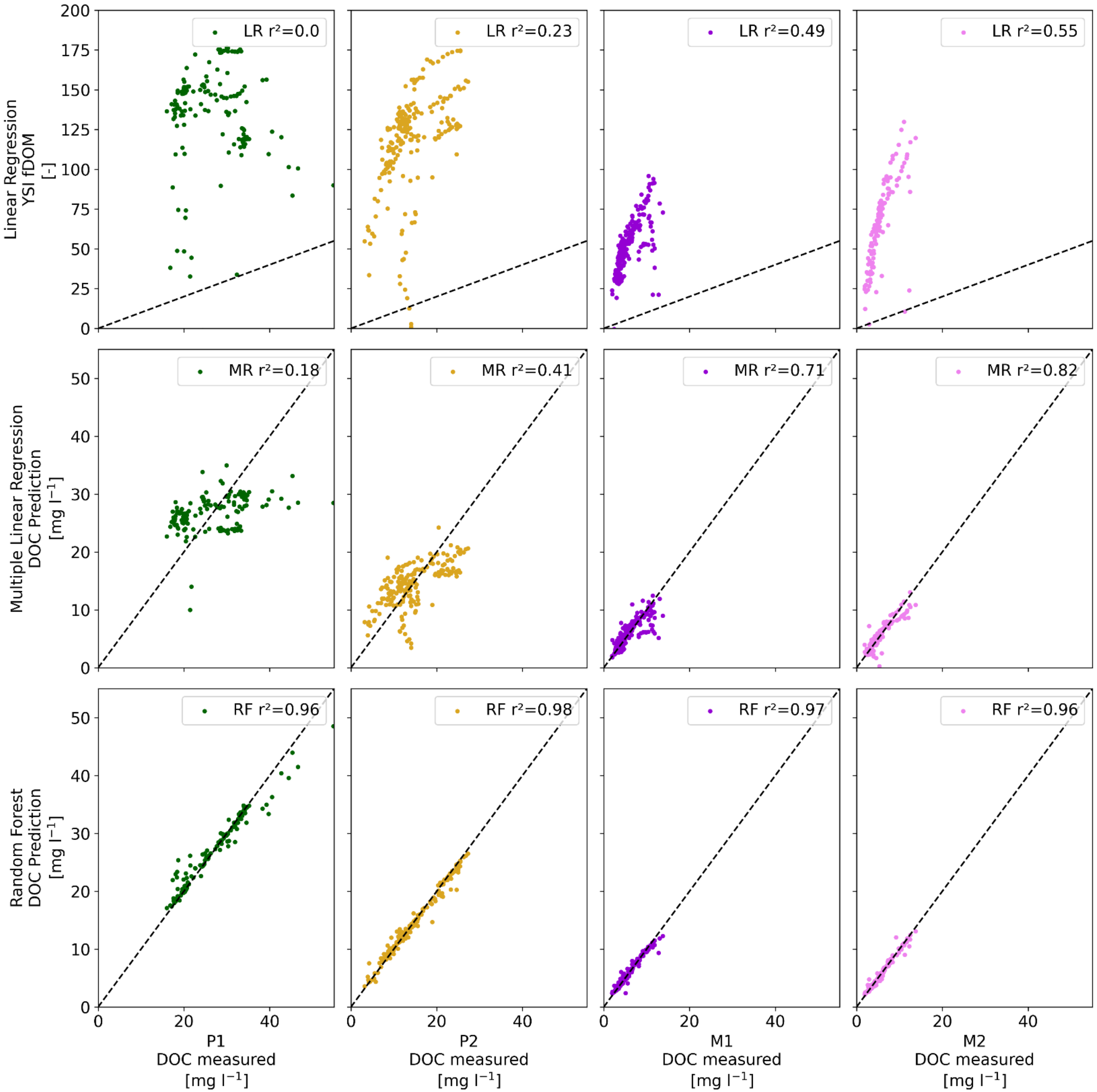
YSI-EXO2


Arboretum
M2
P2
M1
P1
Eselsberg
867 m
Auersberg
1018 m


LR r²=0.0
LR r²=0.23
LR r²=0.49
LR r²=0.55
MR r²=0.18
MR r²=0.41
MR r²=0.71
MR r²=0.82
Linear Regression
YSI fDOM
[-]
Multiple Linear Regression
DOC Prediction
[mg l⁻¹]
P1
DOC measured
[mg l⁻¹]
P2
DOC measured
[mg l⁻¹]
M1
DOC measured
[mg l⁻¹]
M2
DOC measured
[mg l⁻¹]


YSI-EXO2


Arboretum
M2
P2
M1
P1
Eselsberg
867 m
Auersberg
1018 m


LR r²=0.0
LR r²=0.23
LR r²=0.49
LR r²=0.55
MR r²=0.18
MR r²=0.41
MR r²=0.71
MR r²=0.82
RF r²=0.96
RF r²=0.98
RF r²=0.97
RF r²=0.96
Linear Regression
YSI fDOM
[-]
Multiple Linear Regression
DOC Prediction
[mg l⁻¹]
Random Forest
DOC Prediction
[mg l⁻¹]
P1
DOC measured
[mg l⁻¹]
P2
DOC measured
[mg l⁻¹]
M1
DOC measured
[mg l⁻¹]
M2
DOC measured
[mg l⁻¹]
0
25
50
75
100
125
150
175
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50
0
20
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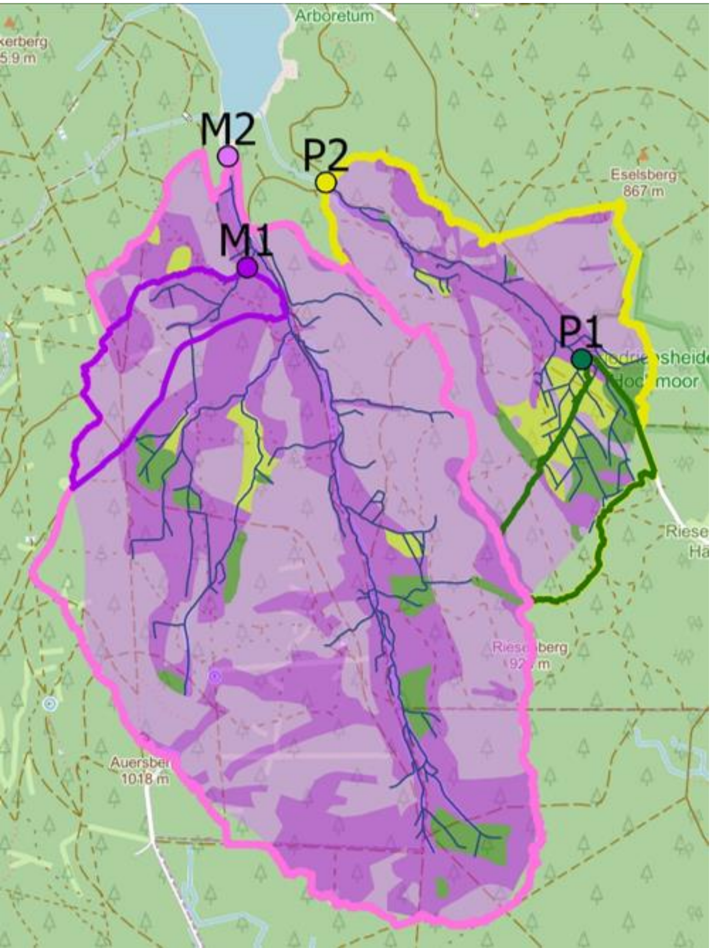
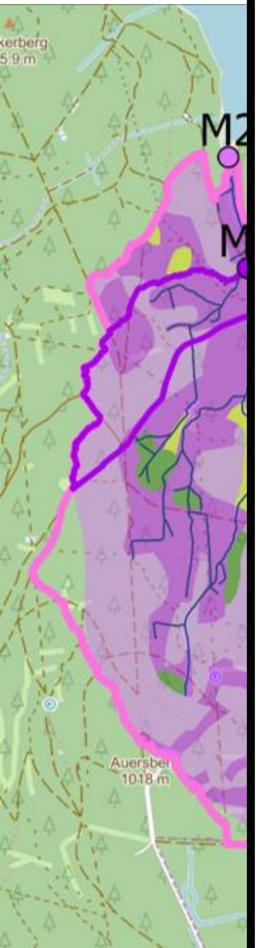
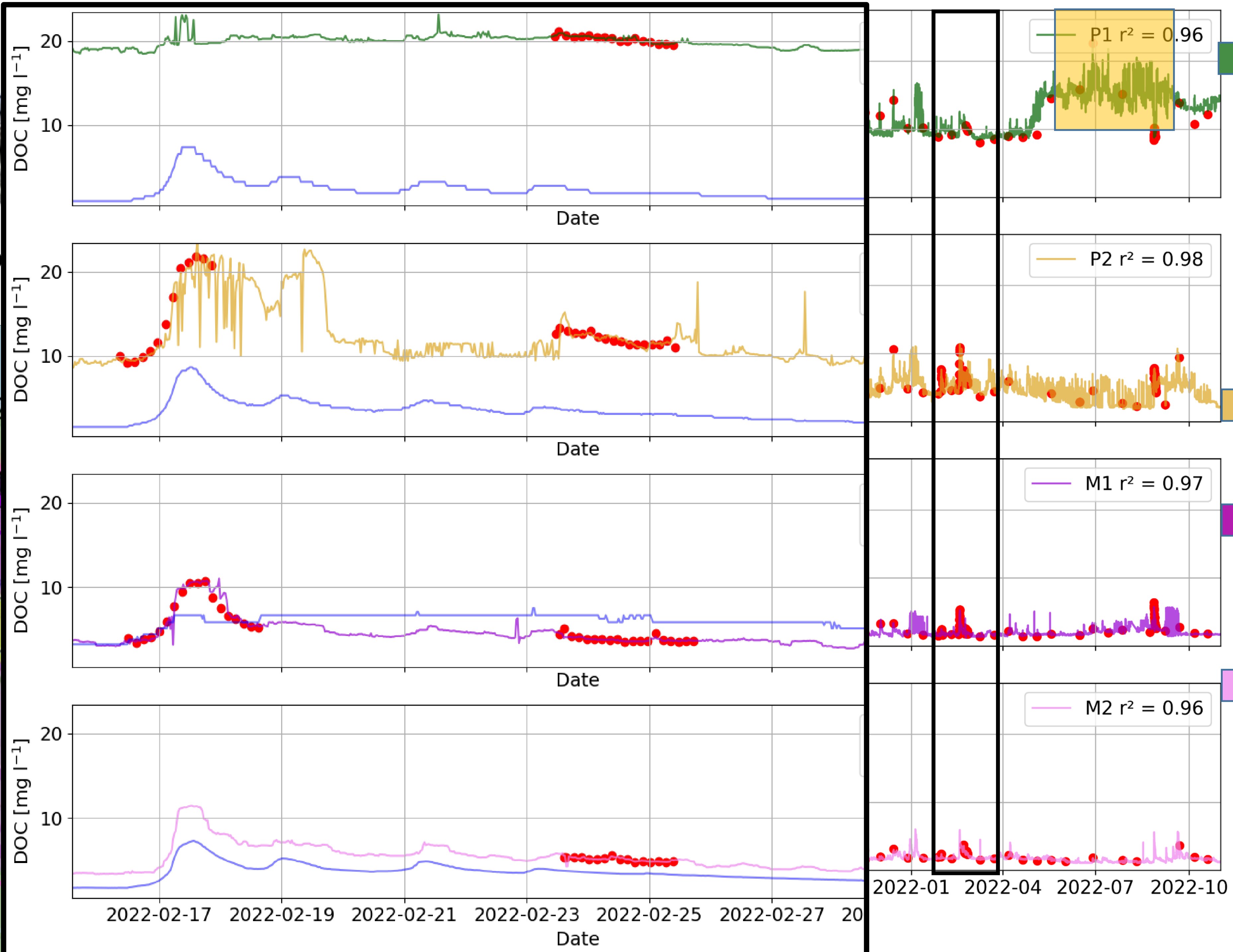


Summer brings high DOC concentrations

All year constant background concentration with short peaks during discharge events

YSI-EXO





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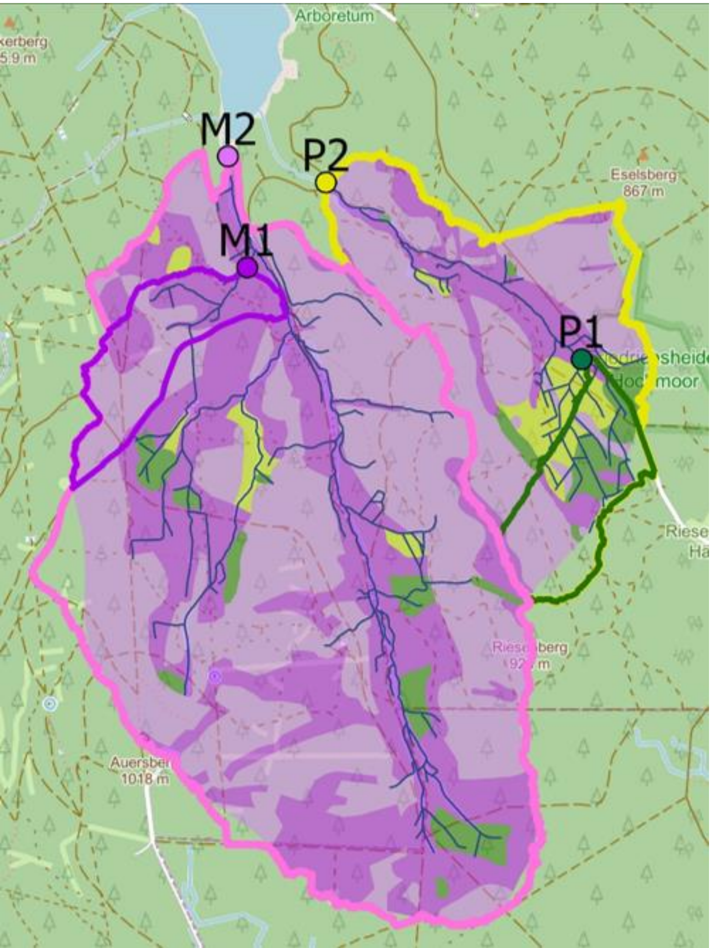
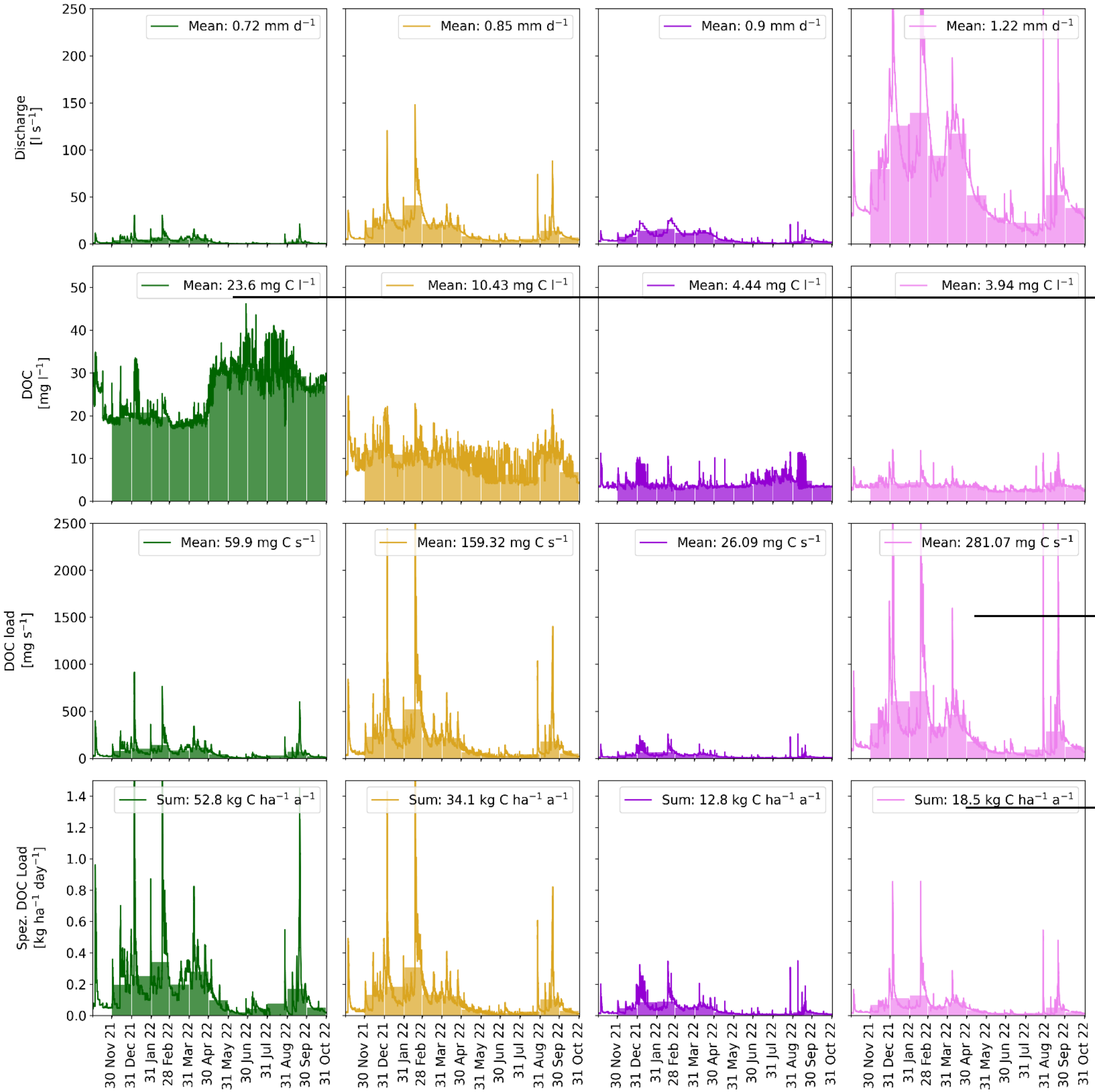
YSI-EXO2



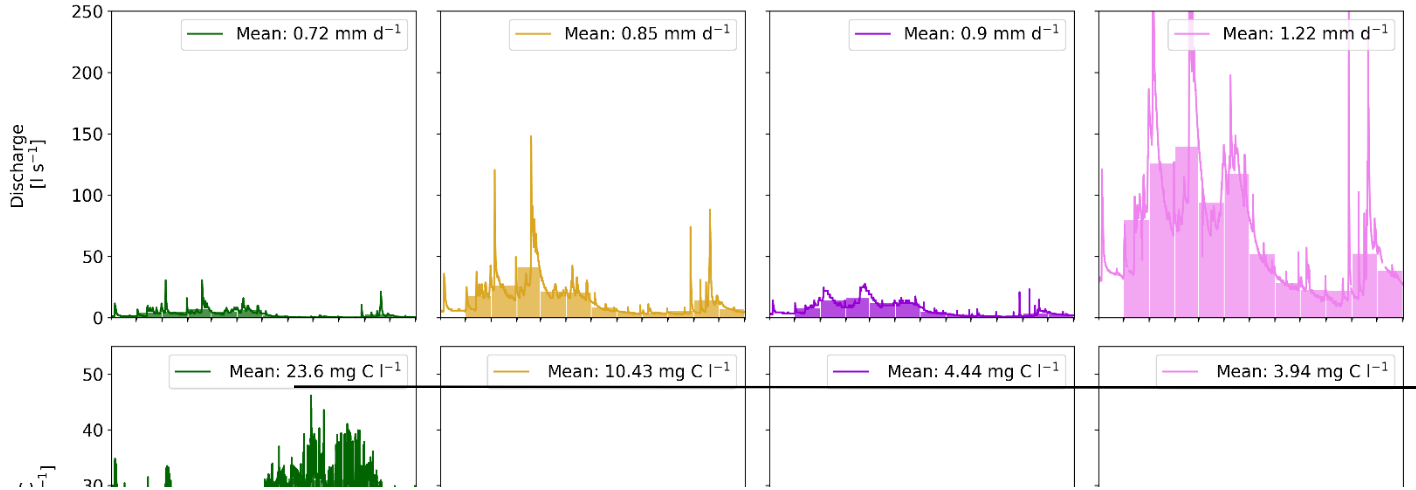


P1 has the highest DOC concentration

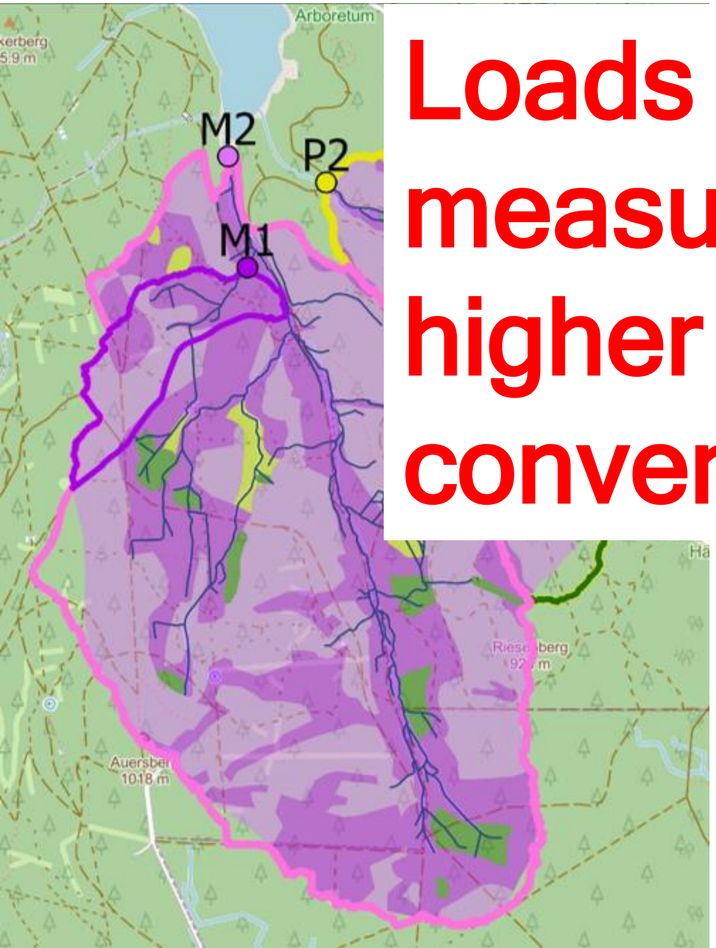
M2 has the highest DOC load

Decreasing proportion of organic soils - decreasing specific loads

YSI-EXO2

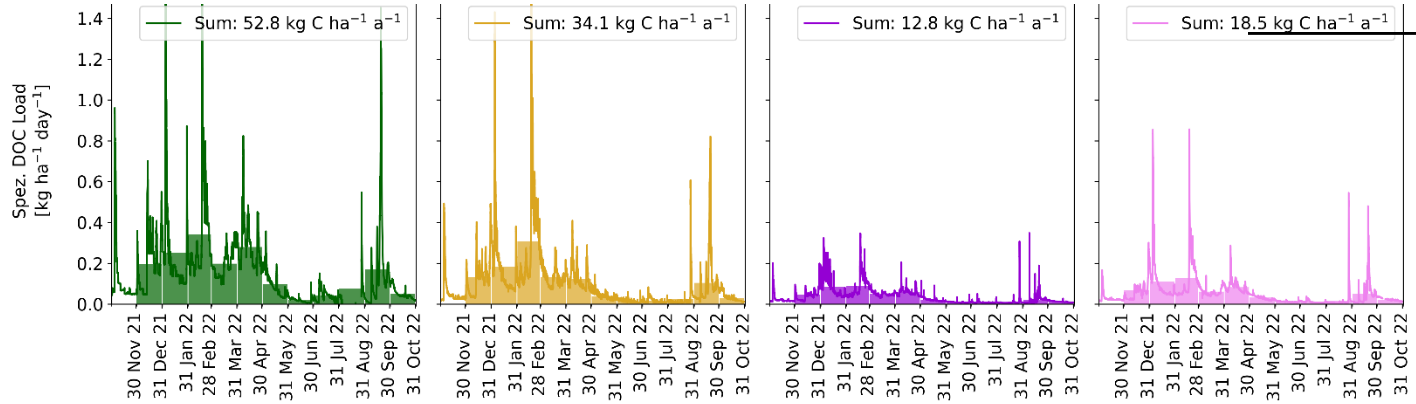


P1 has the highest DOC concentration



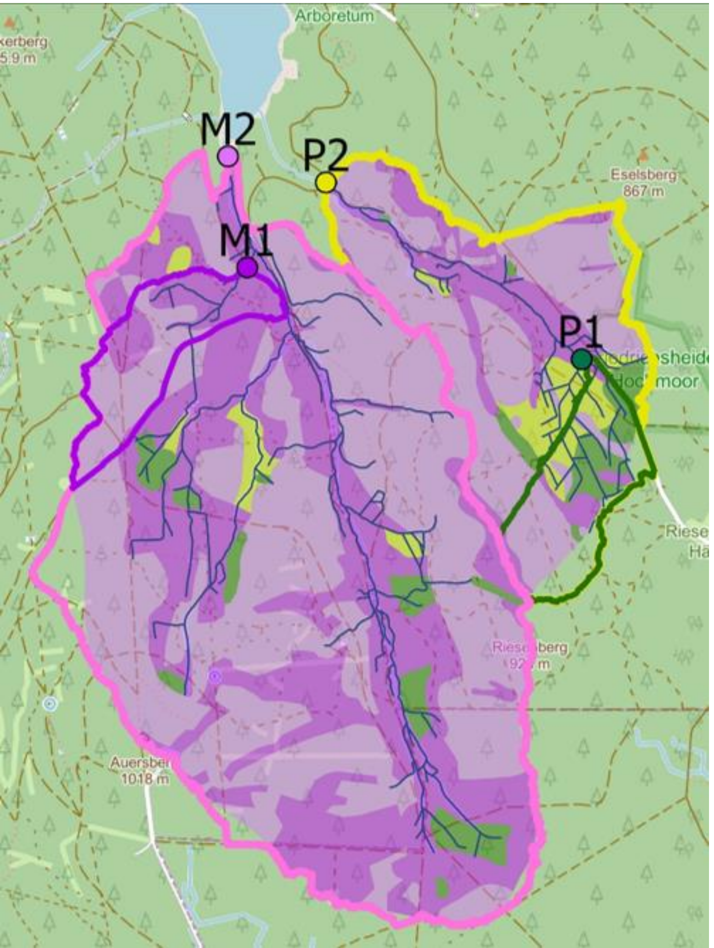
Loads determined by high-resolution measurements are almost 2 times higher than measured by conventional samplings (monthly)

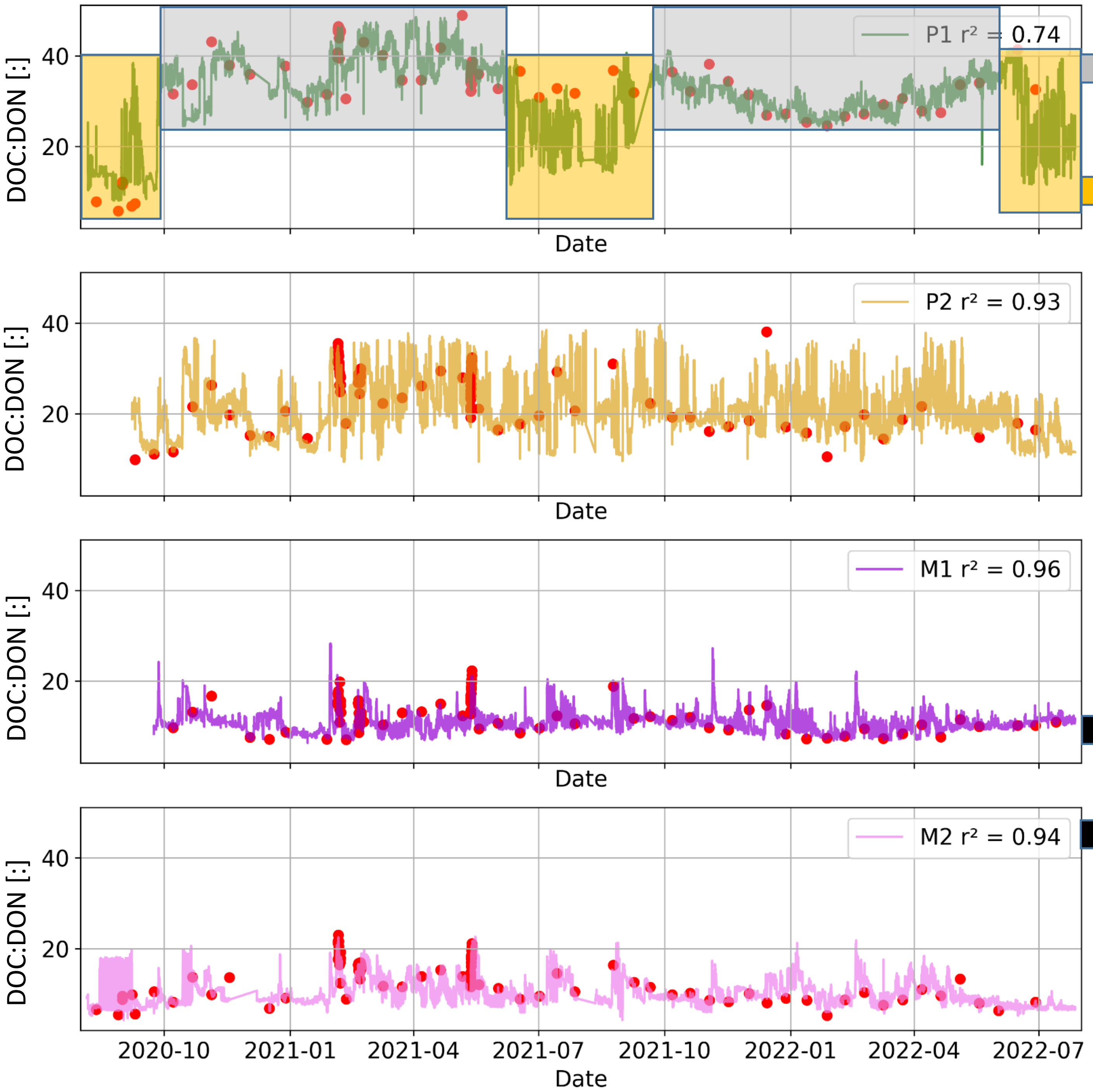
M2 has the highest DOC load



Decreasing proportion of organic soils - decreasing specific loads

YSI-EXO2





Winter brings mainly plant-derived material

Summer brings mainly microbial-derived material (mineral soil)

Peaks in DOC – mainly plant-derived (peat, forest floor)

All year mainly microbial-derived material (mineral soil)

Main DOC sources in the catchment

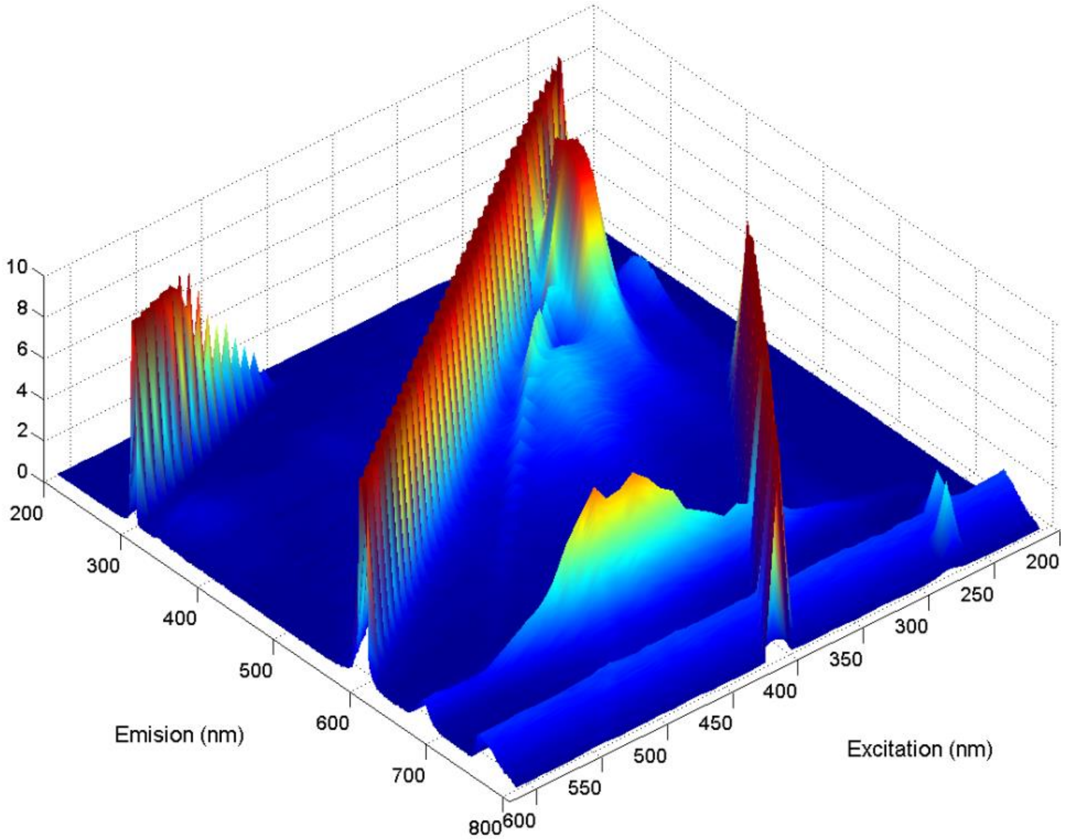
- Peat
- Forest floor
- Mineral soil

Potential DOC sources

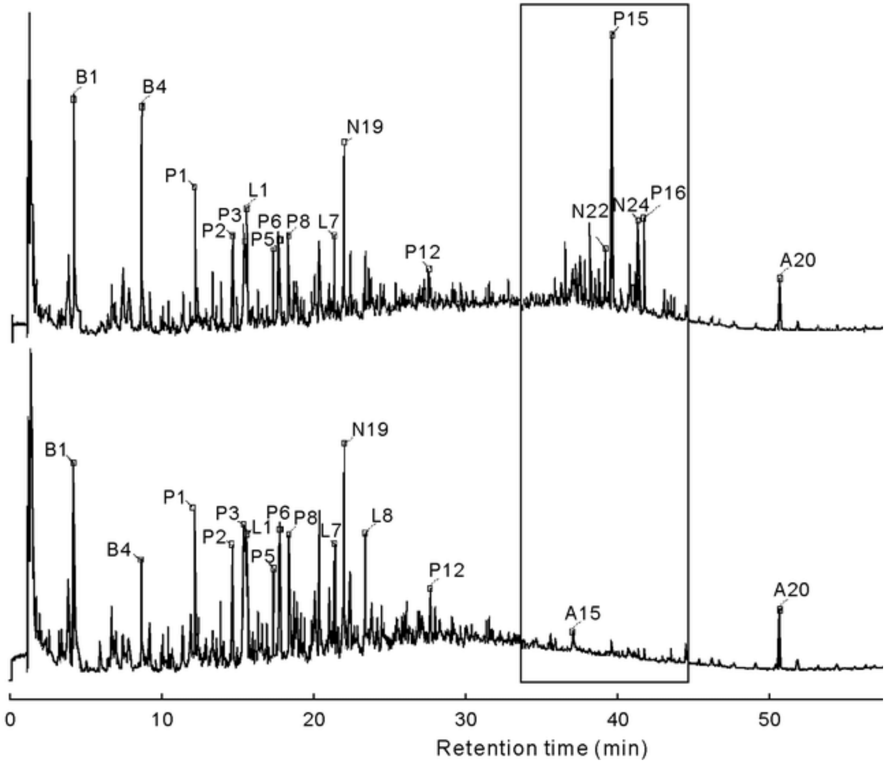
Use of the composition of DOM for characterizing different DOC sources – not just DOC/DON ratios

Main DOC sources in the catchment – DOM composition

Fluorescence spectroscopy + parallel factor analysis (PARAFAC)

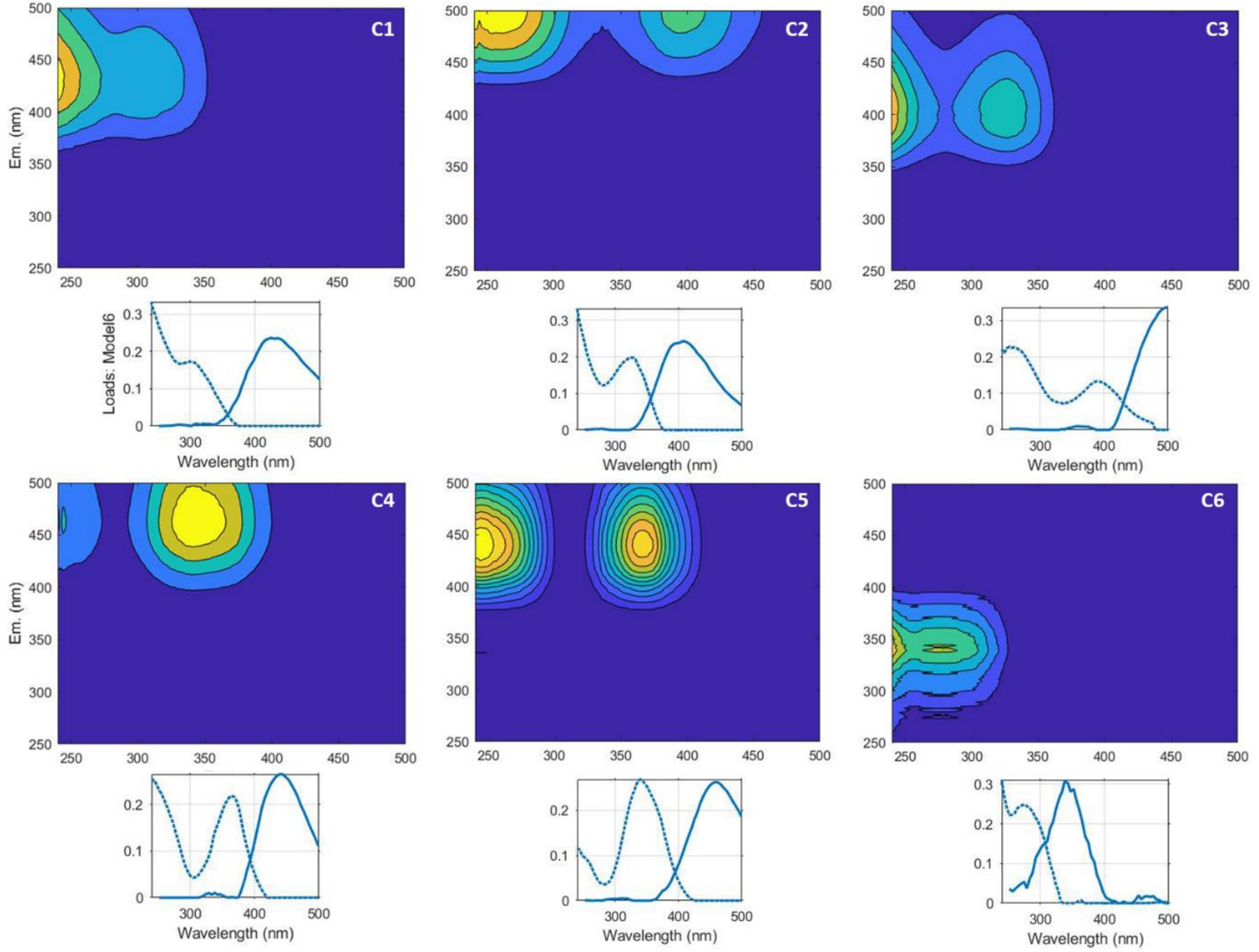


Pyrolysis gas chromatography mass spectrometry



Main DOC sources in the catchment – DOM composition

Fluorescence spectroscopy + parallel factor analysis (PARAFAC)



Soil water:

- C1 and C2: typical for organic soil horizons (peat and forest floor)
- C3: typical for mineral soil horizons

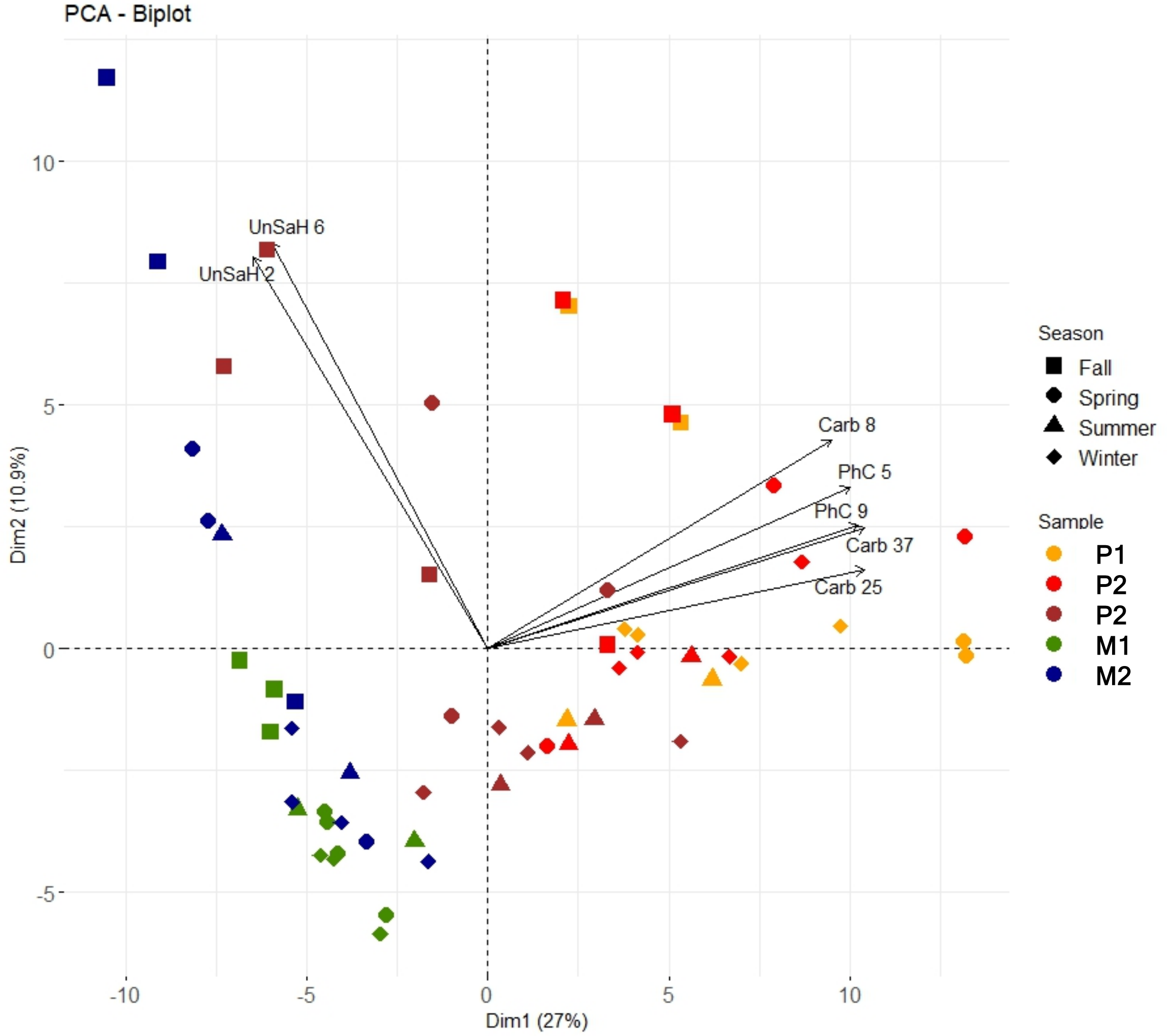
Stream water:

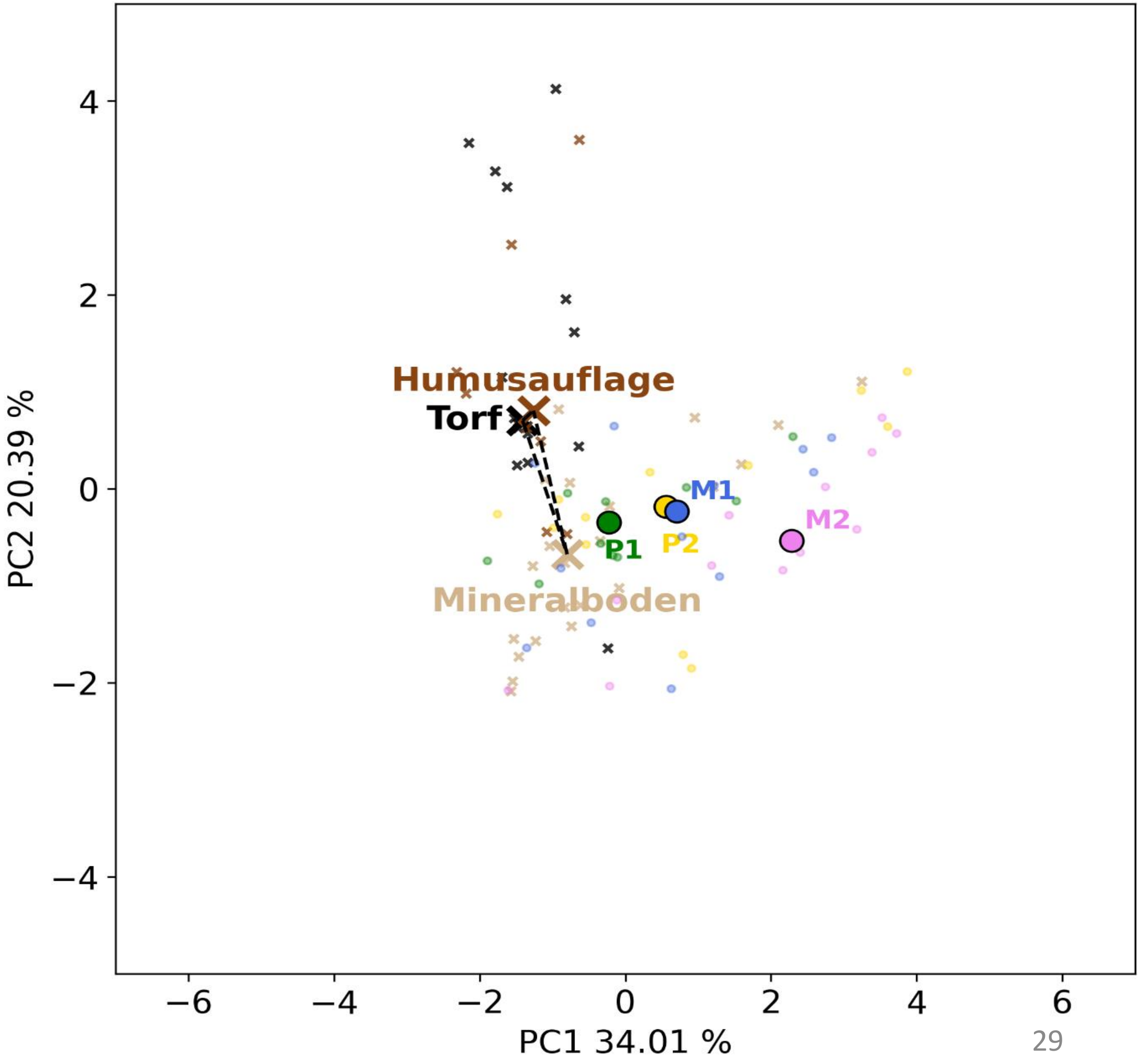
- Streams with higher proportions of organic soils (P1, P2) – higher contribution of C2
- Streams with lower proportions of organic soils (M1, M2) – higher contribution of C3

Main DOC sources in the catchment – DOM composition

Pyrolysis gas chromatography mass spectrometry (> 100 soil and water samples)

chemical analysis | Semi-automated pipeline using R | PCA and source identification





Main DOC sources in the catchment – DOM composition

- Qualitative differentiation of DOM sources (organic and mineral soil horizons but not of different organic horizons) by both approaches; even between DOM from all four soils (PyGC/MS)
- Clear differences in DOM composition of the two streams (PyGC/MS, fluorescence)
- Differences between high and low flow conditions (fluorescence)

- Quantitative estimation of the different sources by DOM characteristics not possible yet – further data analyses necessary

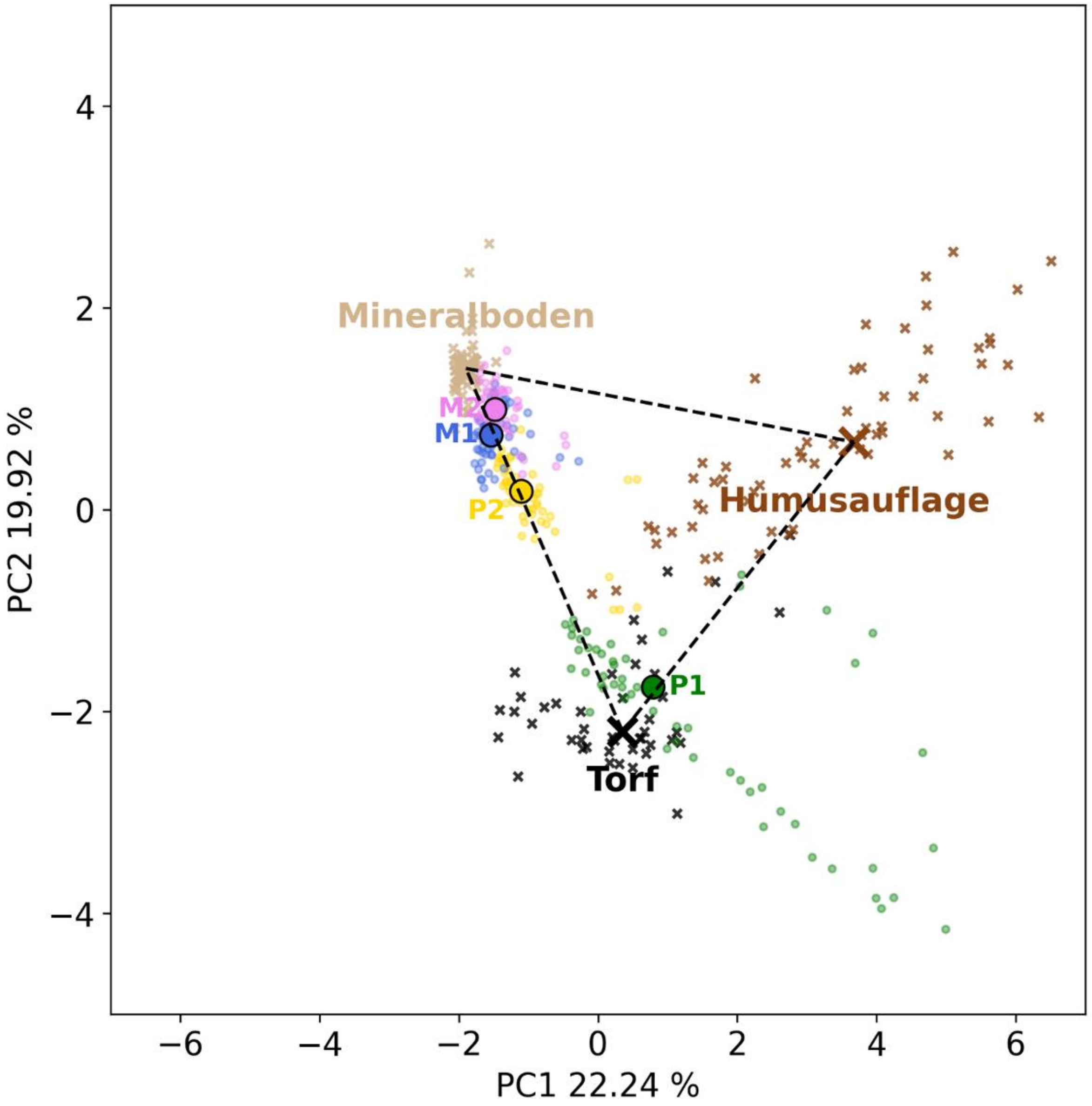
Main DOC sources in the catchment – quantification

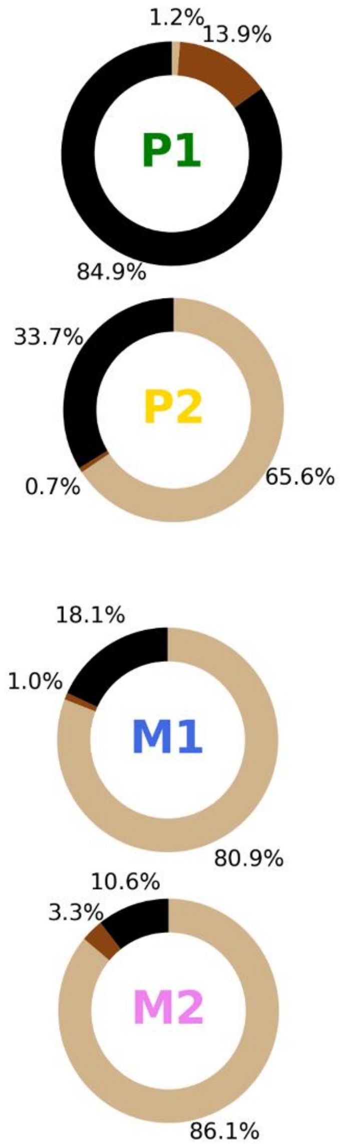
- ❑ Peat
- ❑ Forest floor
- ❑ Mineral soil

Potential DOC sources

Quantification of the potential DOC sources in the streams

Main DOC sources in the catchment





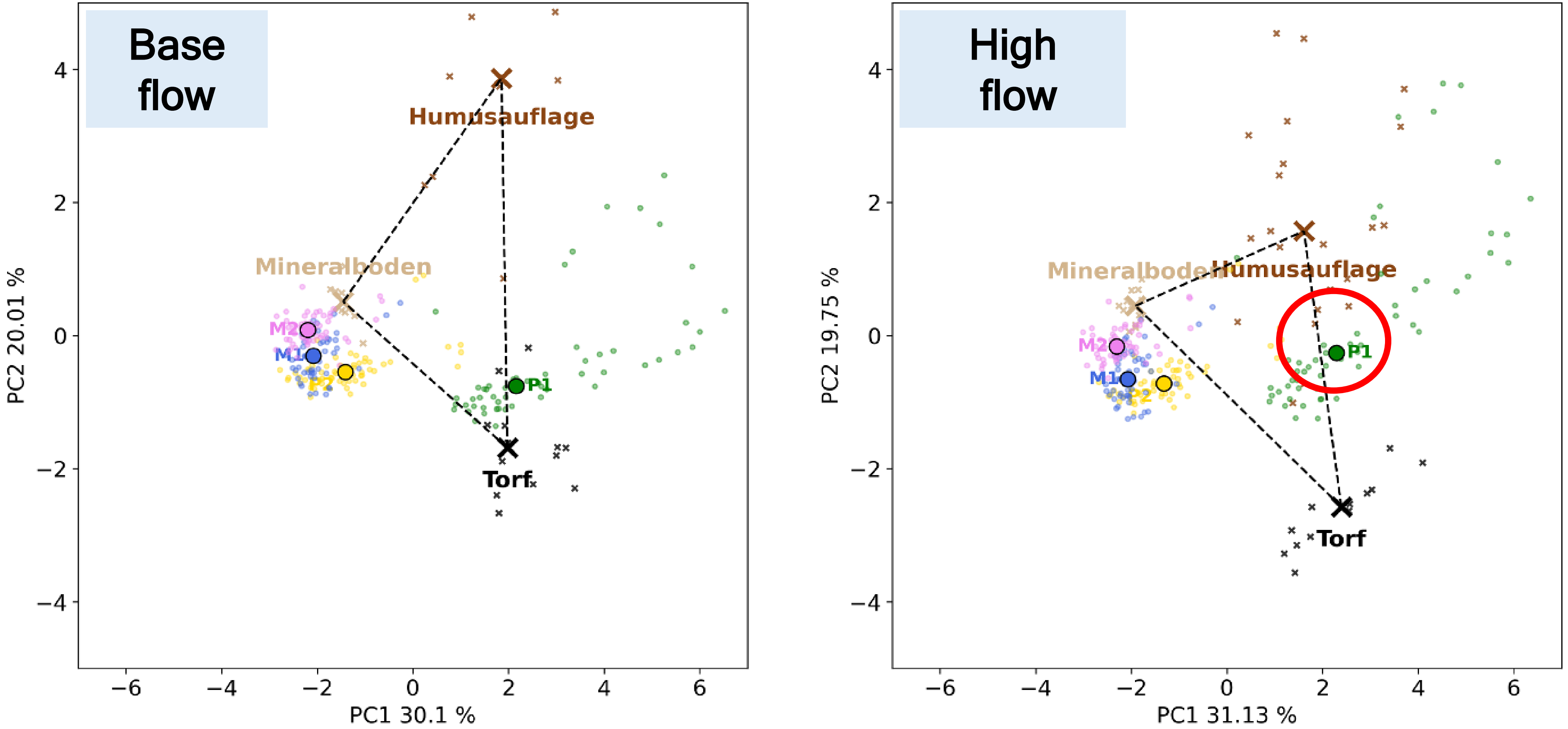
Endmember mixing analysis using geochemical data (DOC, N species, anion, cations) of two years

- Strong contribution of peat in the upper part of the catchment (P1) only
- Mineral soil = largest contributor to DOC being transported into the reservoir even in the stream heavily affected by peat (Neudecker Bach)
- Forest floor horizons - minor contributor to DOC in streams

Contribution of peat-derived DOM seems to be directly linked to the proportion of organic soils in the (sub) catchment.

Main DOC sources in the catchment – low vs. high flow

Endmember mixing analysis using geochemical data (DOC, N species, anion, cations) of two years – differentiating base flow and high flow conditions



- DOC source estimation more uncertain considering differences in water fluxes
- High water fluxes – increasing contribution from forest floor horizons in peat soils

Summary

- **General pattern:**
  - Increasing DOC concentrations and fluxes at high flow events (snow melt, heavy rainfall)
  - Without high-resolution data - large underestimation of average DOC concentrations and fluxes
  - Proportion of peatlands in the catchment - predictor of DOC loads
- **Organic soils (peat):**
  - Continuous large DOC source, highest specific DOC load (53 kg C ha^{-1} a^{-1}), but a relatively low contribution to DOC input into the reservoir (19%)
  - Decreasing importance from the upper to the lower part of the catchment
- **Mineral soils: (forest floor / mineral horizons)**
  - Largest total contribution to DOC input into the reservoir (79%), but a relatively low specific DOC load (12-18 kg C ha^{-1} a^{-1})
  - Forest floor horizons - not clear; probably less <10%; indications for increasing importance during high flow events

TECHNISCHE UNIVERSITÄT DRESDEN

LANDESTALSPERREN VERWALTUNG SACHSEN

LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE | Freistaat SACHSEN

DOC-Einträge in die Talsperre Sosa – eine zeitliche und räumliche Prozessanalyse

Spatial and temporal variability of dissolved organic matter across the terrestrial–aquatic continuum

Conclusions for the second phase of the project

- Include additional DOC sources (precipitation, throughfall)
- Include long-term trend analyses
- Study microbial processes (e.g. in the mineral soil)
- Investigate interactions between temperature and soil moisture – effects on DOC on different scales

Thank you for your attention!