2nd TERENO-OZCAR Conference

from 25 – 28 September 2023, Bonn

TERENO

TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

Deforestation alters stream water dissolved organic carbon and sulphate dynamics - a wavelet analysis

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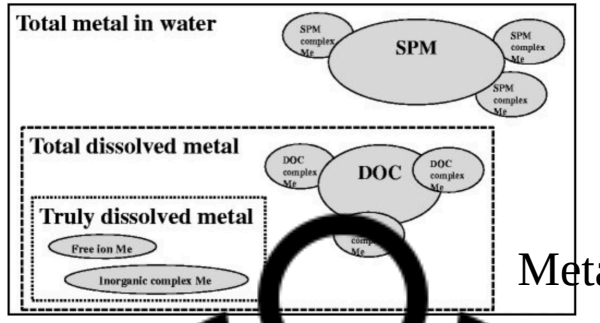
Atmospheric S deposition

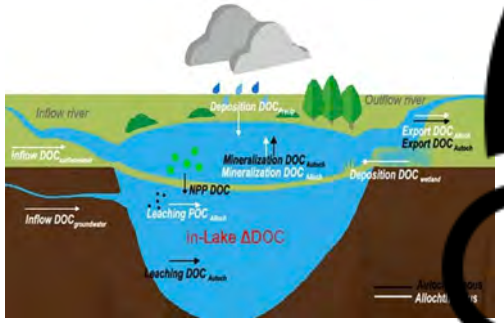
Climate, S deposition and management effect streamwater DOC

Environmental factors
Temperature, acid deposition

Anthropogenic disturbance
Land change, logging, surface fire

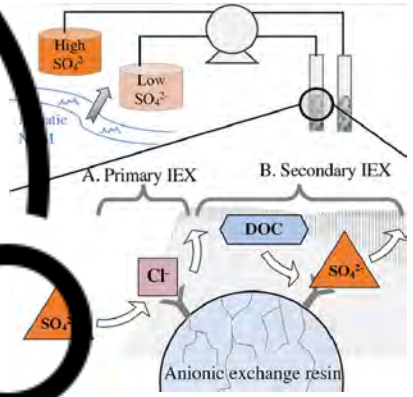


Metal export, mobility



Carbon budgets

DOC

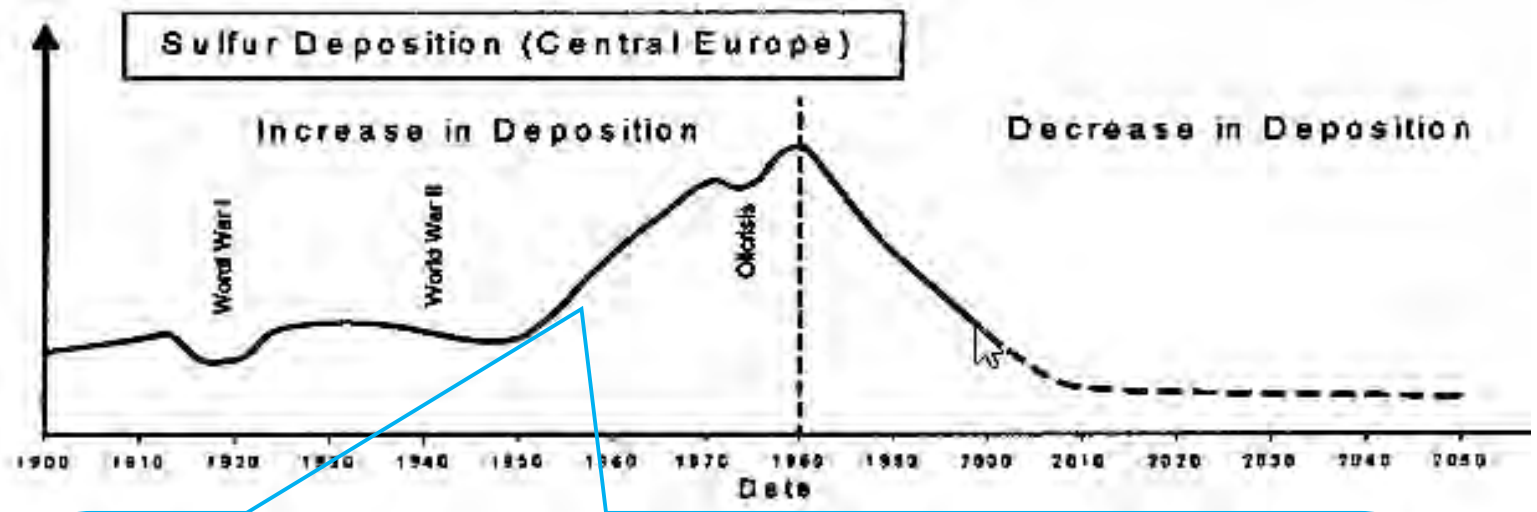


Acid-base chemistry

(Li et al., 2022; Dong et al., 2018; Zimmermann et al., 2021)

Trend S deposition

Atmospheric S deposition declined since 1980s, with DOC increasing in European and North American waters



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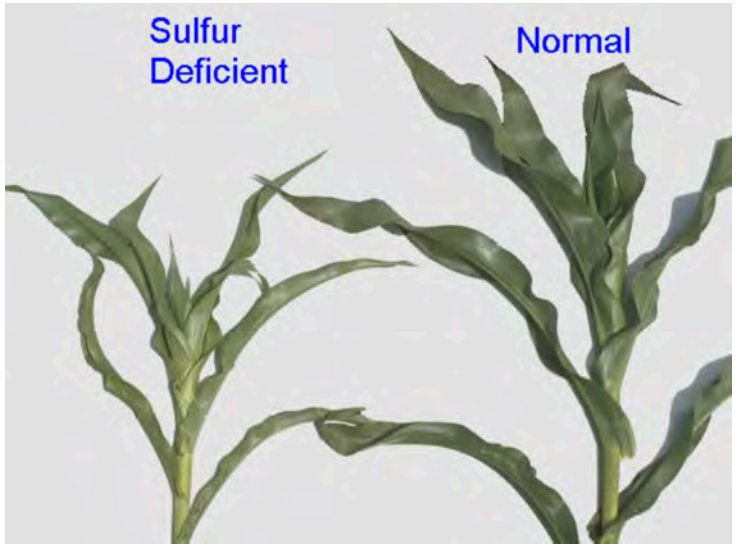
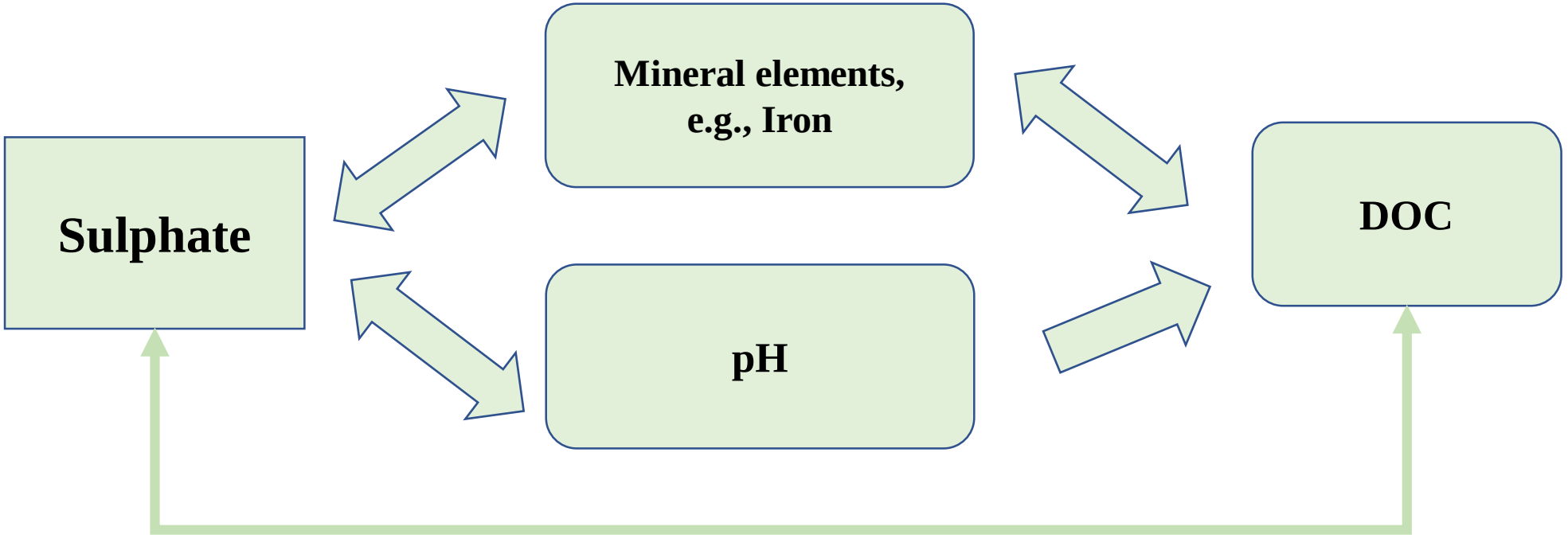


(Erlandsson et al., 2008; Xu et al., 2020)

Sulphate and DOC

- **Sulphur deposition and pH** (Goller et al., 2006),
- **Long term effect of sulfate** (Lepistö et al. 2021, Ledesma, et al., 2016).
- **Role of iron** (Bhattacharyya et al., 2018a, 2018b).



Deforestation

Clearcutting

Undisturbed

After forest clear-cutting

- **Runoff** tends to increase (Schelker et al., 2013)
- **Nutrient loads increase** (Webb et al., 2012).
- **Stream temperature** tends to increase (Griffith and Kiffney, 2022; Oanh et al., 2021)

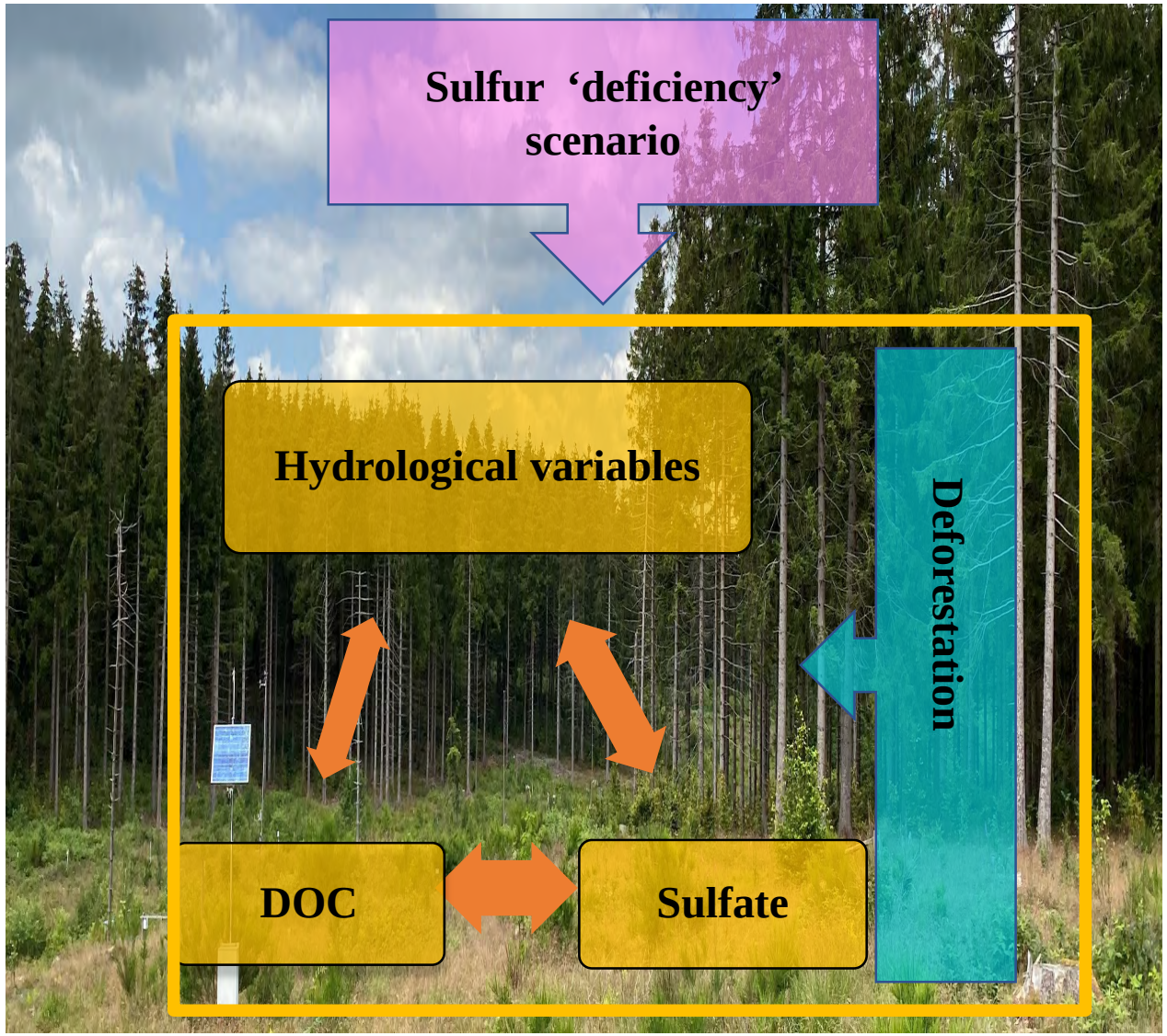
Deforestation vs. streamwater C and S dynamics under declining S deposition

Objectives

1. Examine spatio-temporal relationships of sulphate, DOC runoff & stream temperature
2. The deforestation effect on the relationship among DOC, sulphate, runoff and temperature in streams.

Hypothesis

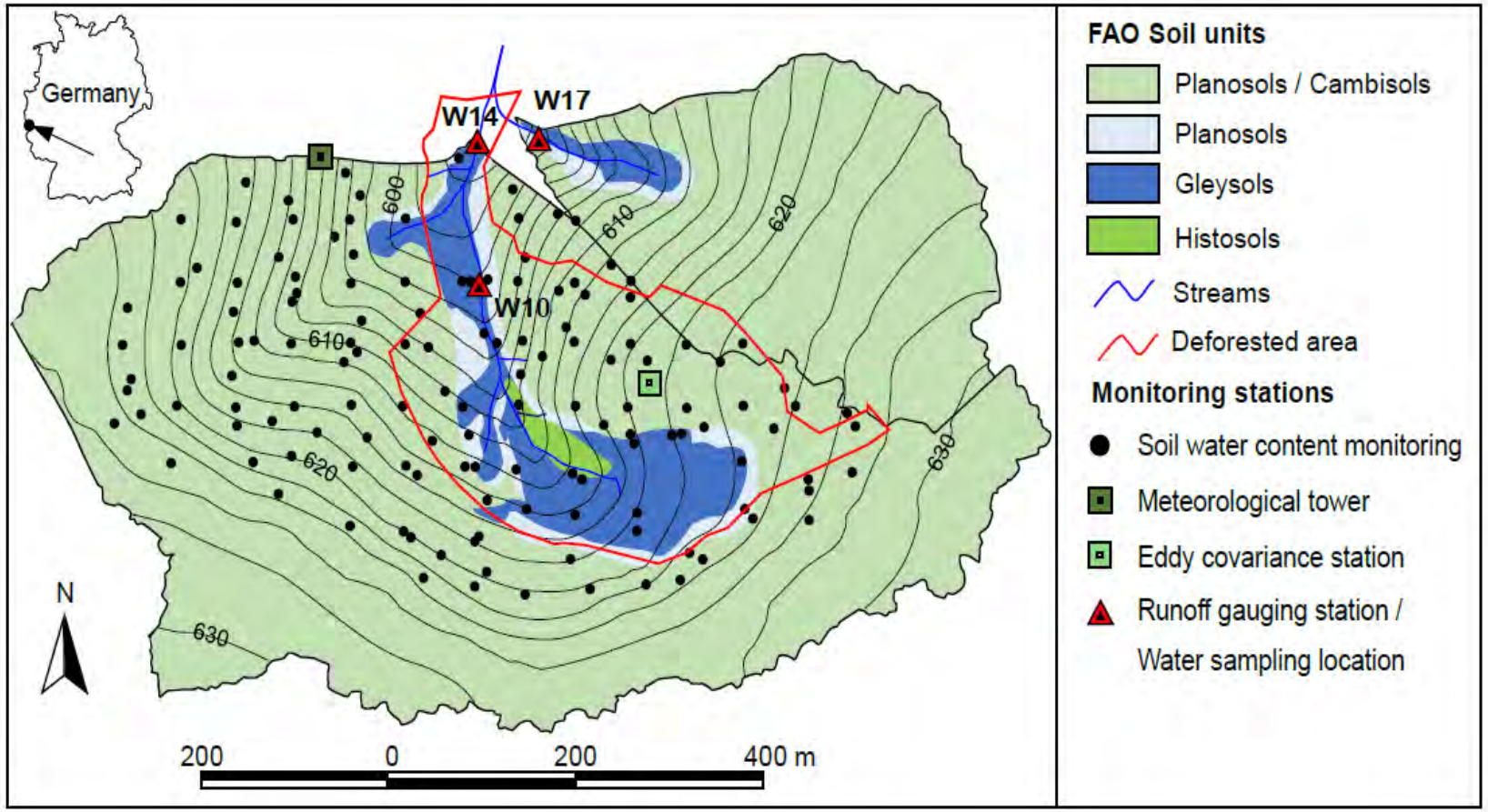
The relationship between DOC and sulphate is non-stationary, and varies with spatial and temporal scales, especially after the clear-cut.



Datasets

TERENO Wüstebach catchment (Eifel, Germany) deforestation in 2013

Proportions of deforested area (W10: 31%, W14: 25%, W17: 3%)



10-year time series

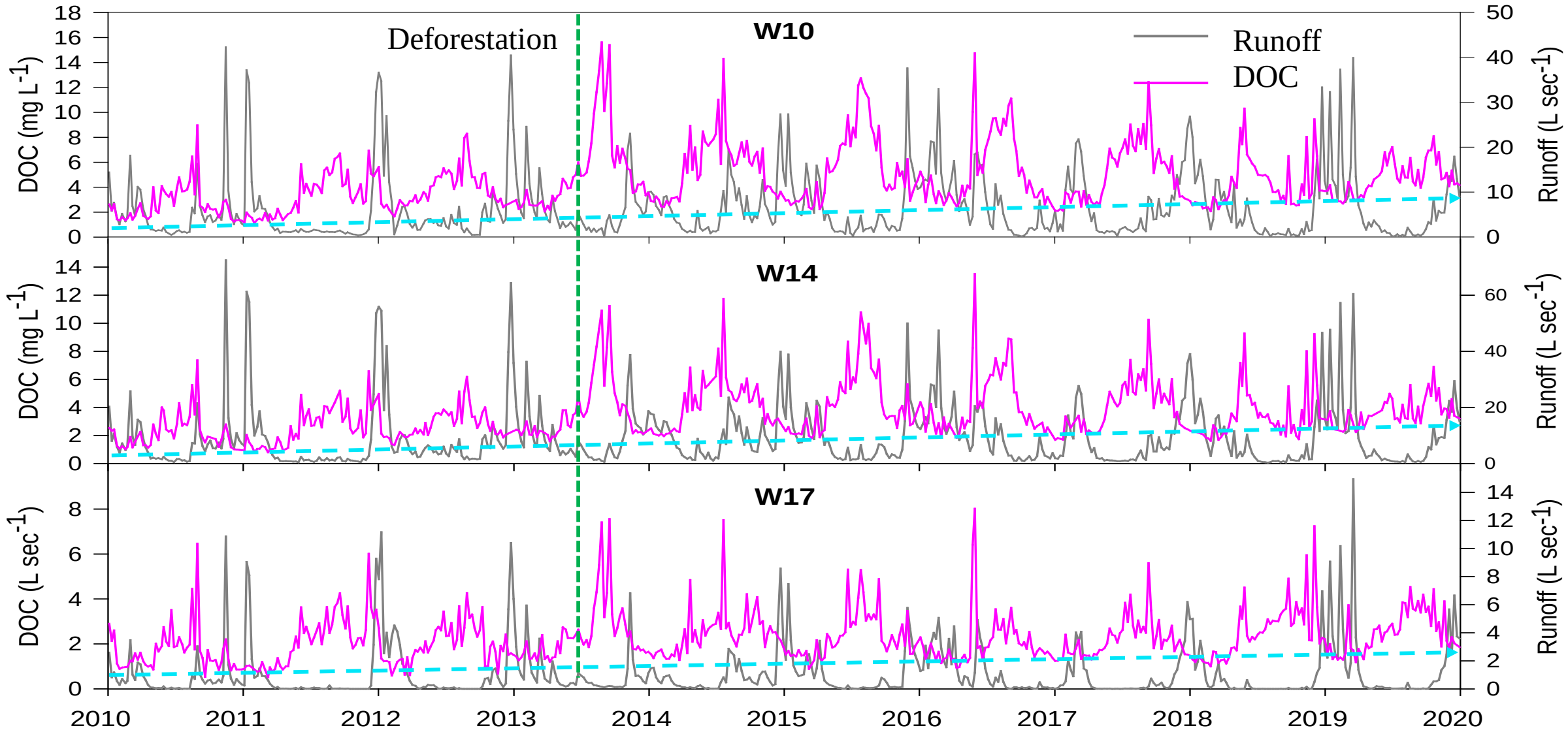
04/01/2009-30/12/2019 (522 weeks)

- 184 weeks before clear-cut
- 338 weeks after clear-cut

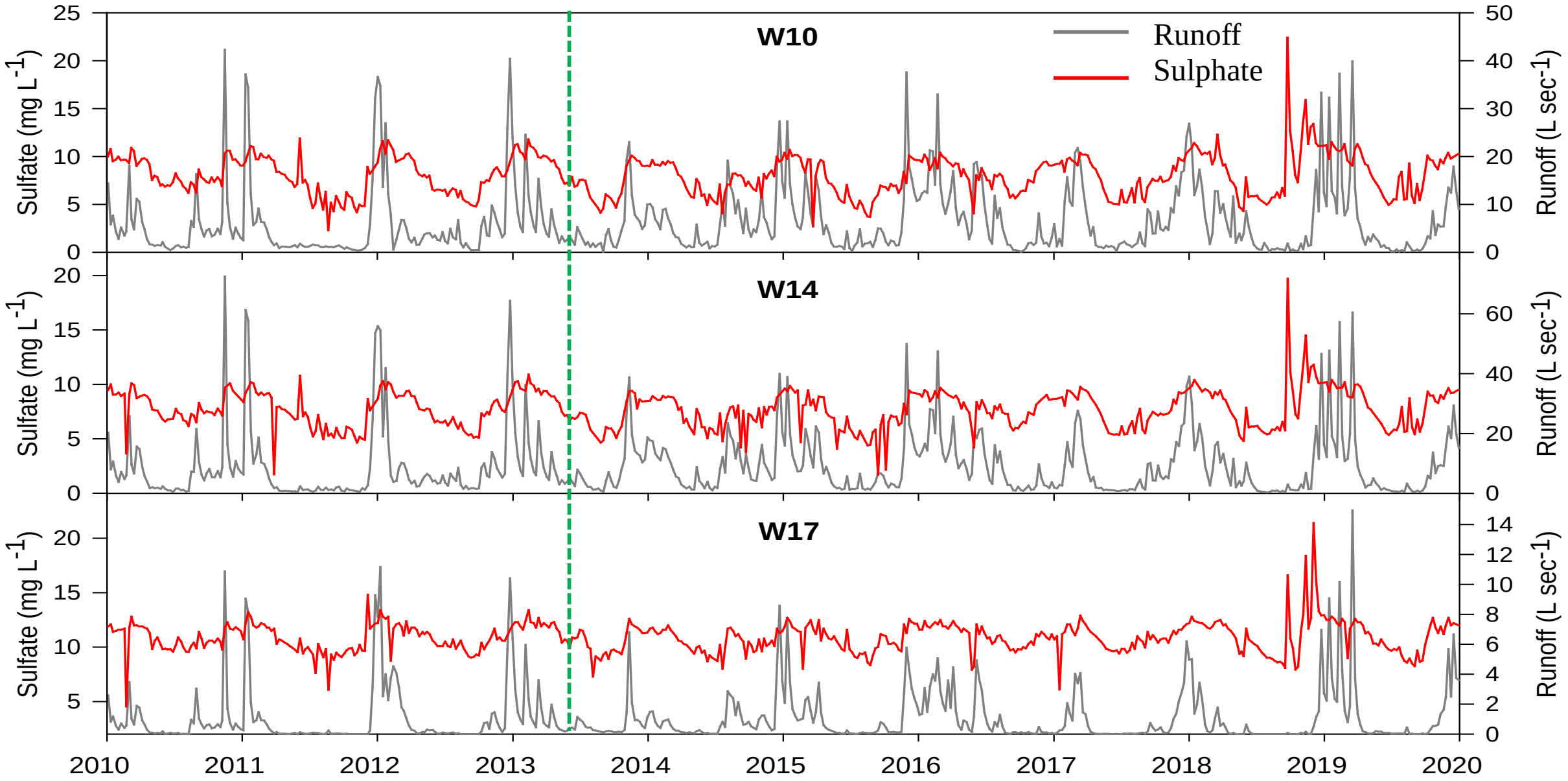
Variables

- Runoff (Q) - Every 20 min
- DOC - Weekly measured
- Sulphate (SO_4^{2-}) - Weekly measured
- DOC/Sulphate ratio - Calculated

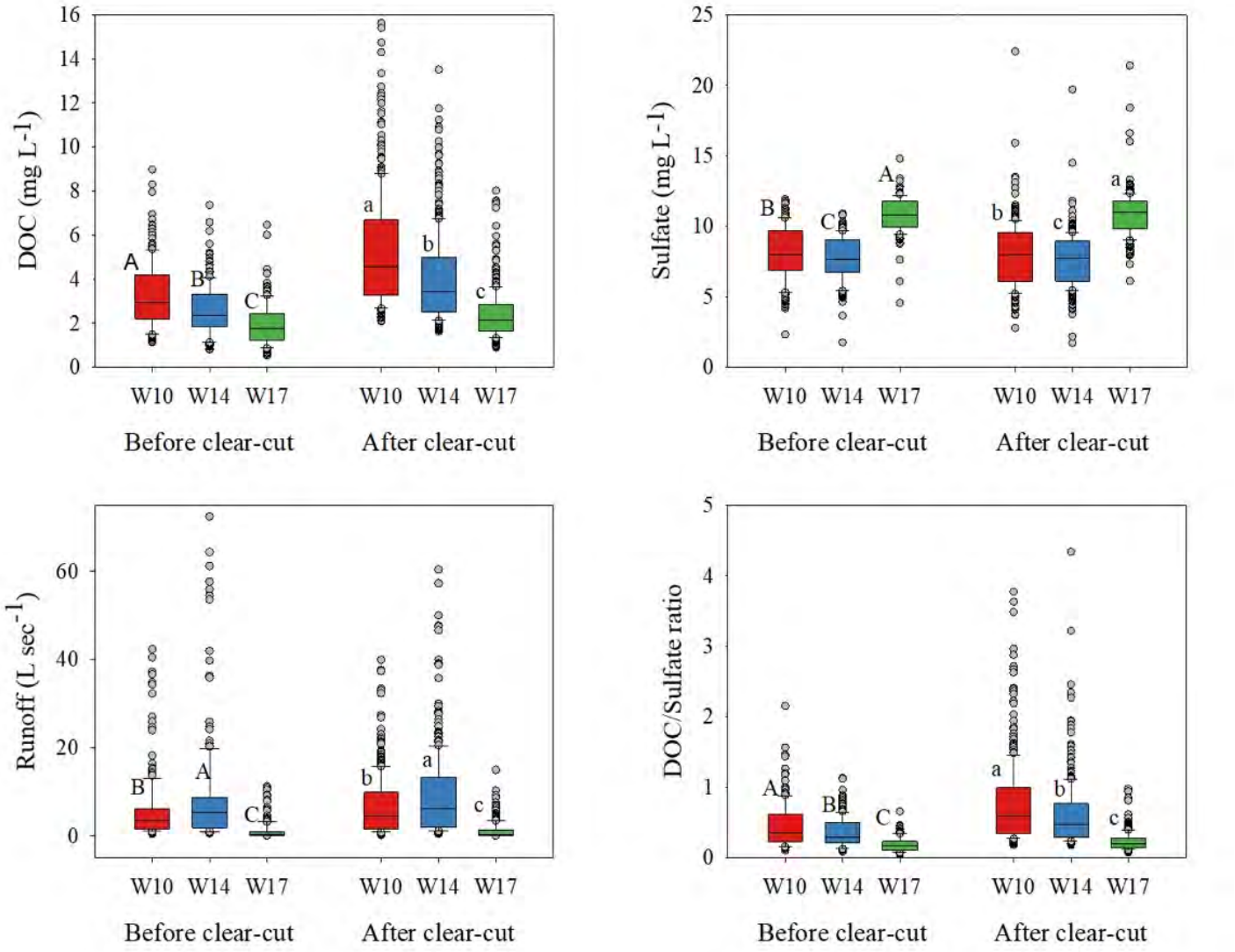
DOC dynamics



Sulphate dynamics

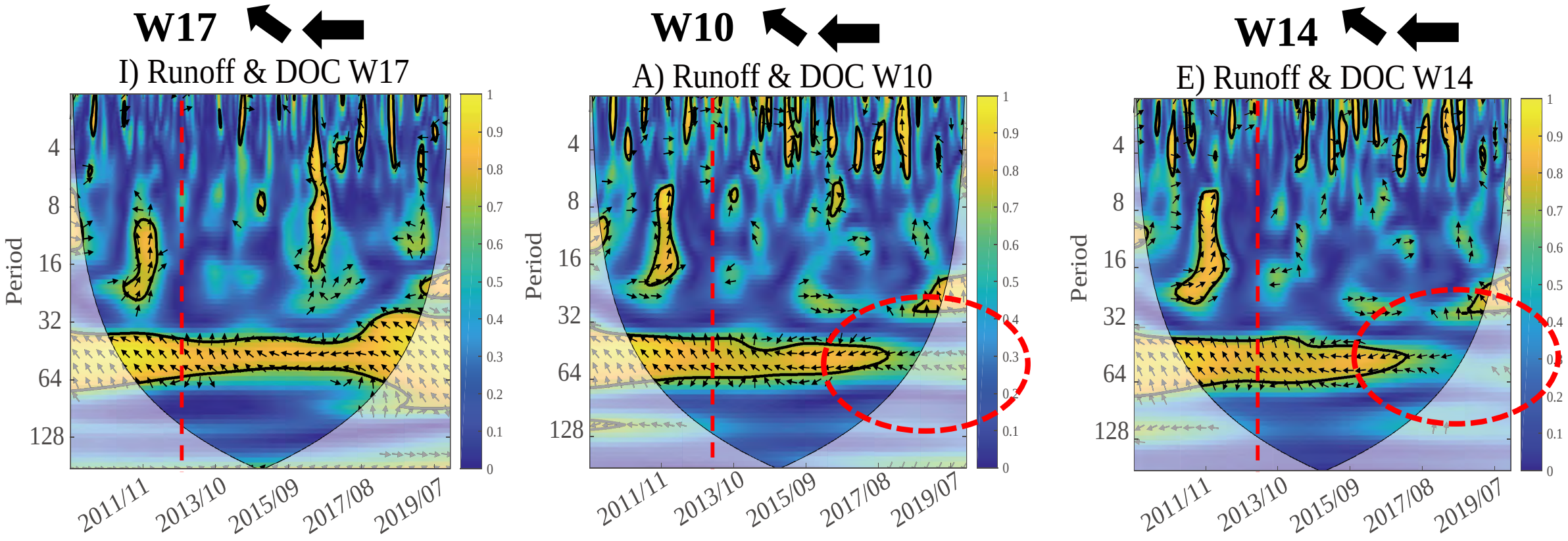


Deforestation effect



- DOC significantly increased by 59%, 58%, 26% in W10, W14, W17, respectively.
- Runoff and sulfate concentrations showed slight changes.

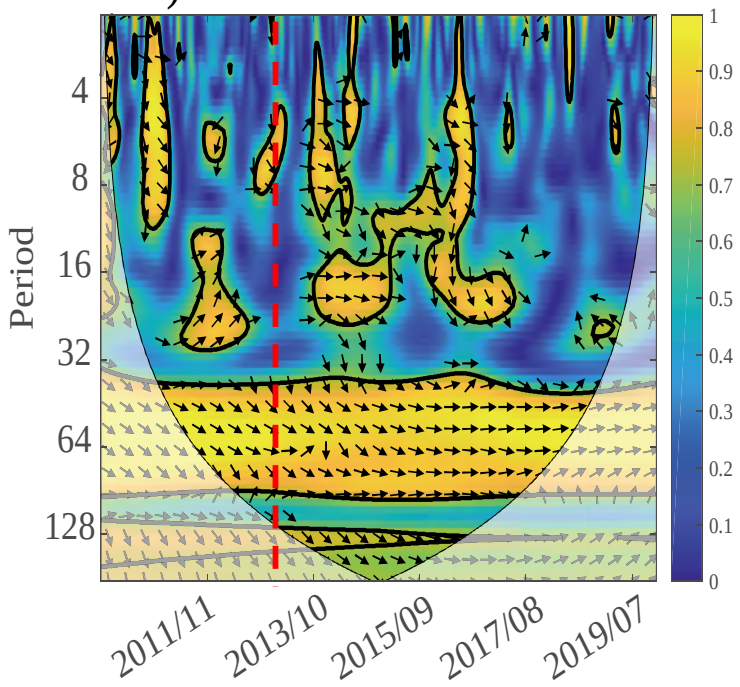
Wavelet analysis-runoff & DOC



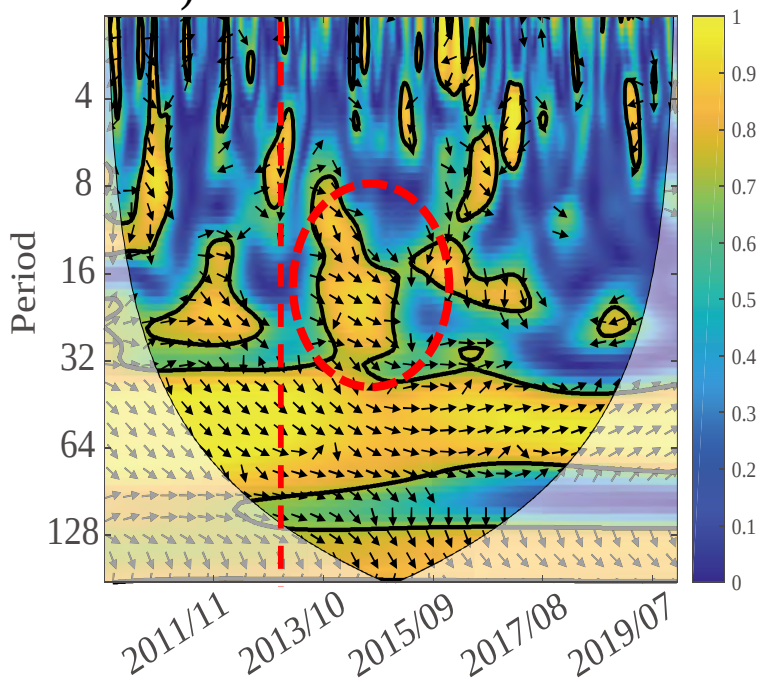
- Runoff and DOC had negative relationships at all stations in the 32-64 weeks period.
- Runoff peaked between 4 and 8 weeks before DOC.
- The dominating phase shifted to a perfect negative correlation after deforestation.

Wavelet analysis-runoff & sulfate

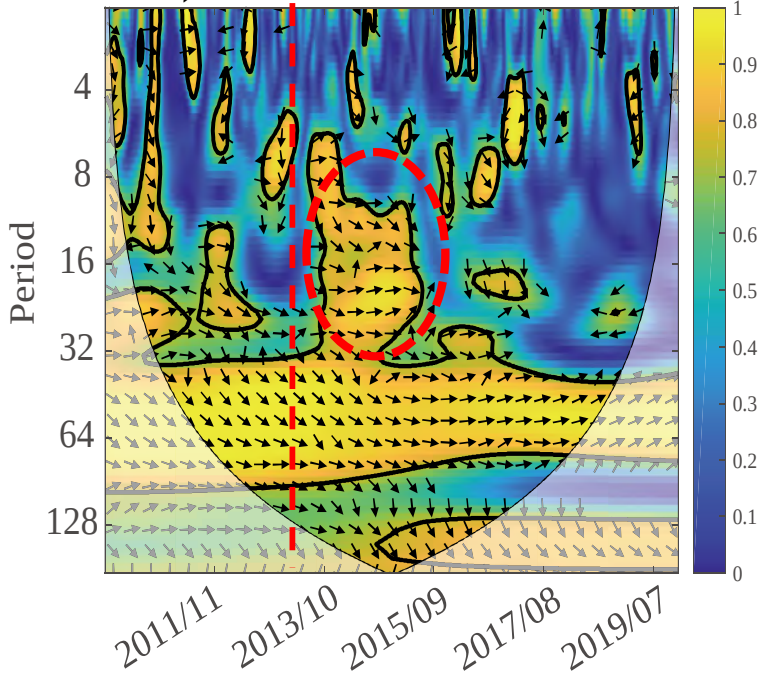
W17 ↘ ➡



W10 ↘ ➡



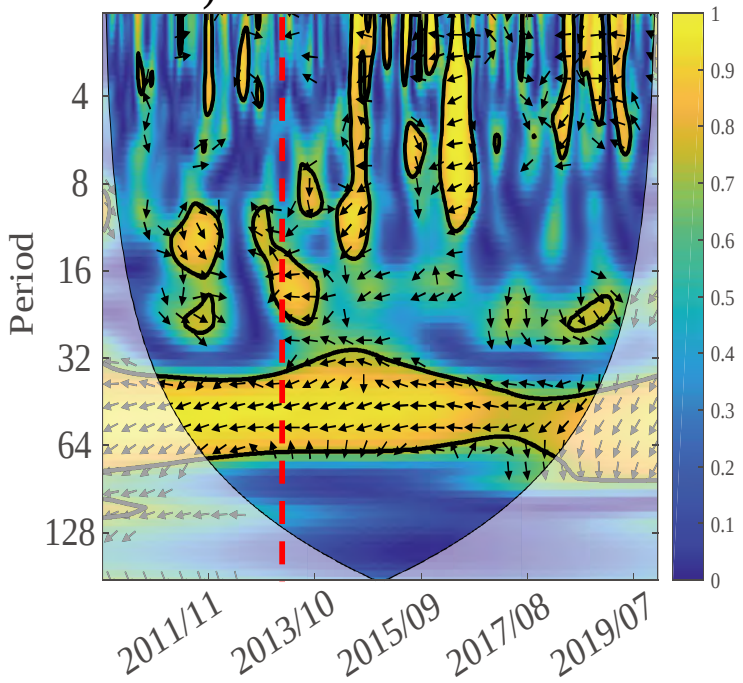
W14 ↘ ➡



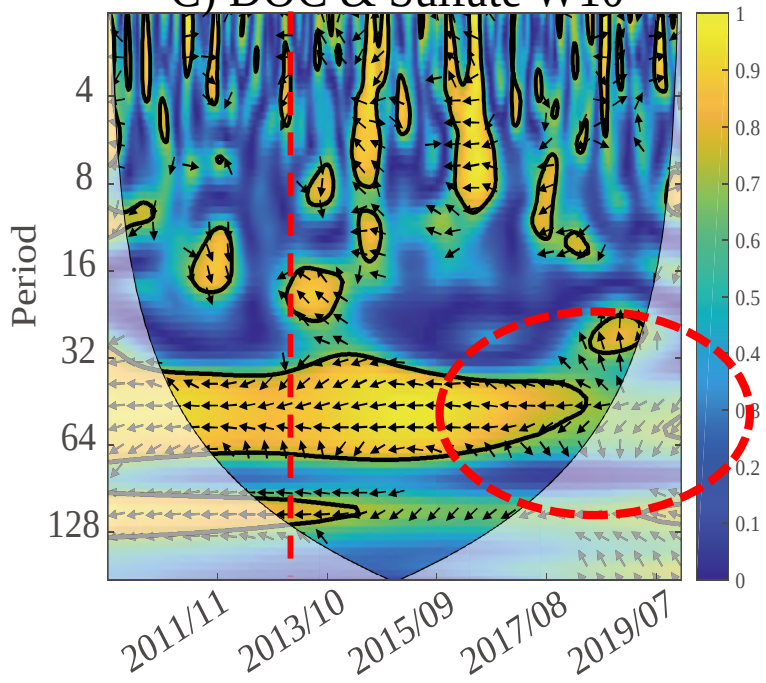
- Runoff and sulfate had positive relationships from 32 to 100 weeks period at all stations
- The dominating phase shifted to a perfect positive correlation after 2015.

Wavelet analysis-DOC & sulfate

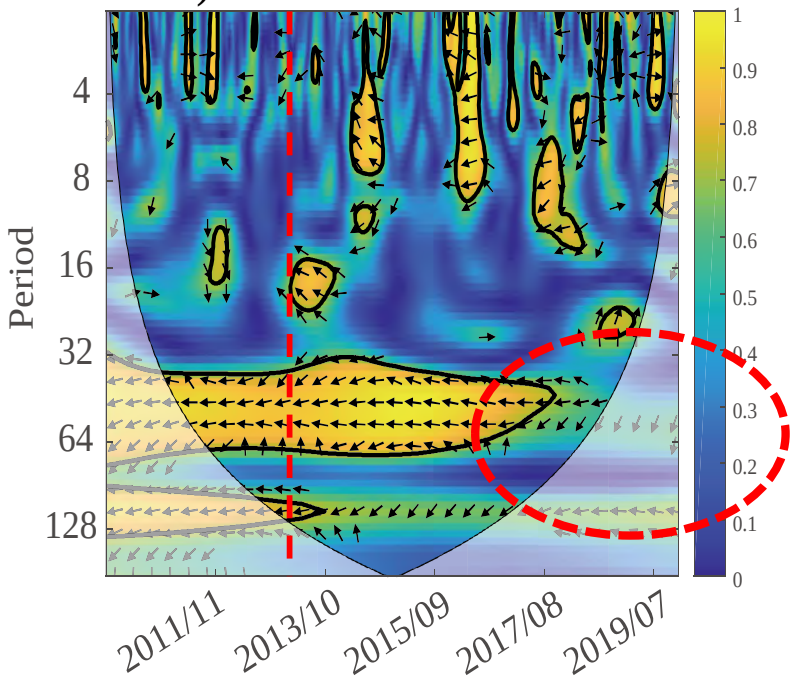
W17 ⬅



W10 ⬅



W14 ⬅



- DOC and sulfate - almost perfect negative correlation from period lengths of 32 to 64 weeks.
- The negative correlation between DOC with runoff and sulfate was apparent over the whole examined 10-year period in W17 but ended in W10 after the deforestation.

Conclusion

- Catchment deforestation levels over 25% (W10) substantially affected the S and C streamwater coupling of more than ‘natural’ environmental changes (W17).
- WTC analysis pinpointed to underlying catchment relationships between variables to anthropogenic impact.
- Continuous long-term monitoring data was the key to elucidate the underlying effect of deforestation on hydrological and biochemistry processes.

Thanks for your attention!

The paper was published on Frontiers in forests and global change
More information can be found in doi: 10.3389/frwa.2022.1003693

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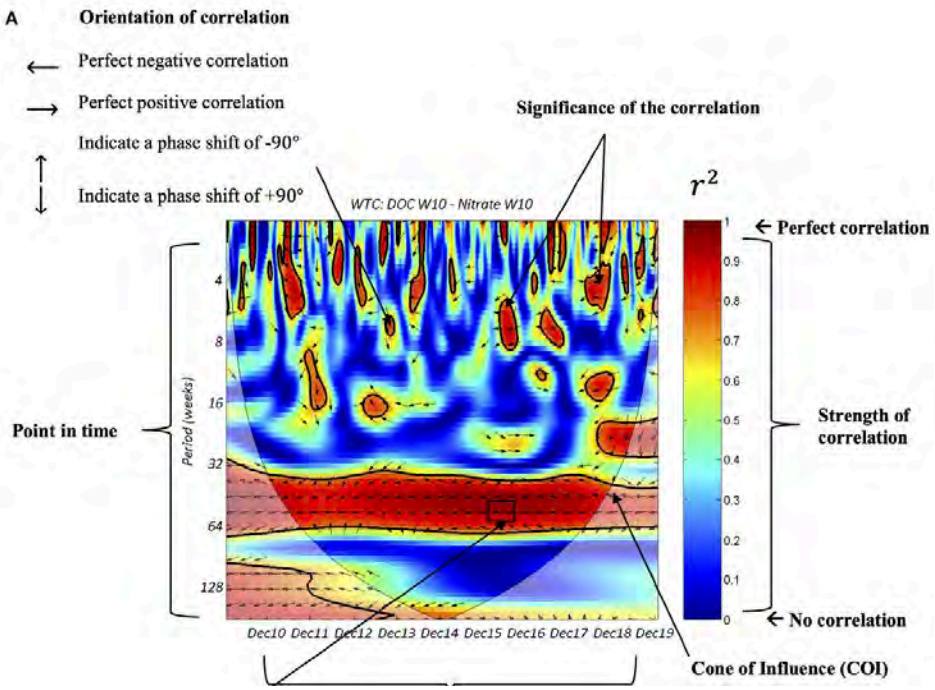
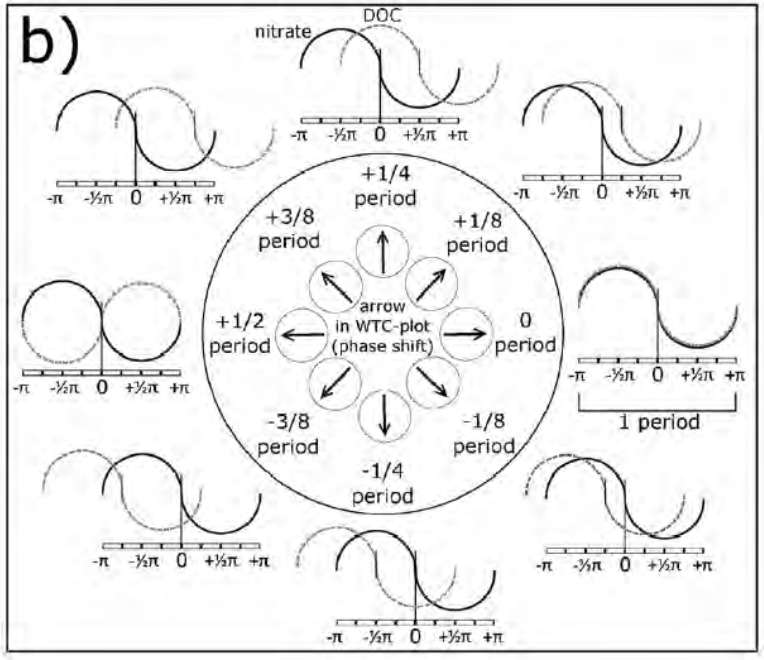
Deforestation alters dissolved organic carbon and sulfate dynamics in a mountainous headwater catchment—A wavelet analysis

Methods-wavelet analysis

Wavelet transform coherence (WTC) analysis





- The direction of the arrows indicates both the orientation of the correlation and the time delay between the two variables.
- An upward-pointed arrow means the second variable lags behind the first by 90° (one-fourth period, at a period of 64 weeks this equals 16 weeks).

Wavelet analysis has been applied to large river runoffs and global climatic indexes (Labat, 2005). Wavelet Transform Coherence (WTC) used to quantify the degree of lineal relationship between two nonstationary series in the **time and frequency** domains (Cazelles et al., 2008).

Results-strength of the correlation

Observation stations	Variables	Correlation coefficient (r)							
		DOC	Sulfate	DOC/sulfate ratio	Runoff	Temperature	Fe_{tot}	pH	Ca^{2+}
W10	DOC	1	-0.53**	0.928**	-0.162**	0.654**	0.874**	0.121**	-0.003
	Sulfate		1	-0.704**	0.425**	-0.680**	-0.587**	-0.359**	-0.265**
	DOC/sulfate ratio			1	-0.245**	0.667**	0.859**	0.200**	0.094*
	Runoff				1	-0.380**	-0.261**	-0.502**	-0.388**
	Temperature					1	0.623**	0.289**	0.318**
	Fe_{tot}						1	0.160**	0.053
	pH							1	0.255**
	Ca^{2+}								1
W14	DOC	1	-0.426**	0.882**	-0.128**	0.581**	0.741**	0.032	-0.114*
	Sulfate		1	-0.641**	0.441**	-0.620**	-0.446**	-0.159**	-0.246**
	DOC/sulfate ratio			1	-0.207**	0.583**	0.681**	0.073	-0.039
	Runoff				1	-0.384**	-0.226**	-0.383**	-0.399**
	Temperature					1	0.516**	0.233**	0.238**
	Fe_{tot}						1	0.135**	-0.057
	pH							1	0.128**
	Ca^{2+}								1
W17	DOC	1	-0.302**	0.951**	-0.203**	0.525**	0.575**	0.257**	0.065
	Sulfate		1	-0.546**	0.419**	-0.549**	-0.274**	-0.385**	0.155**
	DOC/sulfate ratio			1	-0.259**	0.586**	0.565**	0.304**	-0.005
	Runoff				1	-0.338**	-0.198**	-0.498**	-0.046
	Temperature					1	0.424	0.433**	-0.093*
	Fe_{tot}						1	0.291	0.105*
	pH							1	-0.016
	Ca^{2+}								1

- Iron (Fe_{tot}) play a more important role in regulating DOC in the mainstream. indicating DOC transport via organic-mineral complexes in this catchment.
- Sulfate is primarily regulated by temperature, secondly by Iron (e_{tot}).