Technische Universität Braunschweig

Institut für Geoökologie
AG Umweltgeochemie

Picture Snowscat in Unsplash

Sensitivity of river catchments to discharge–controlled dissolved carbon export

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- Dissolved Carbon: DOC and DIC.
- DOC main sources: soil organic layers and riparian zones.
- DIC

$$CO^{*}_2 + H_2CO_3 + HCO_3^- + CO_3^{2-}$$

Carbon dioxide

Carbonic acid

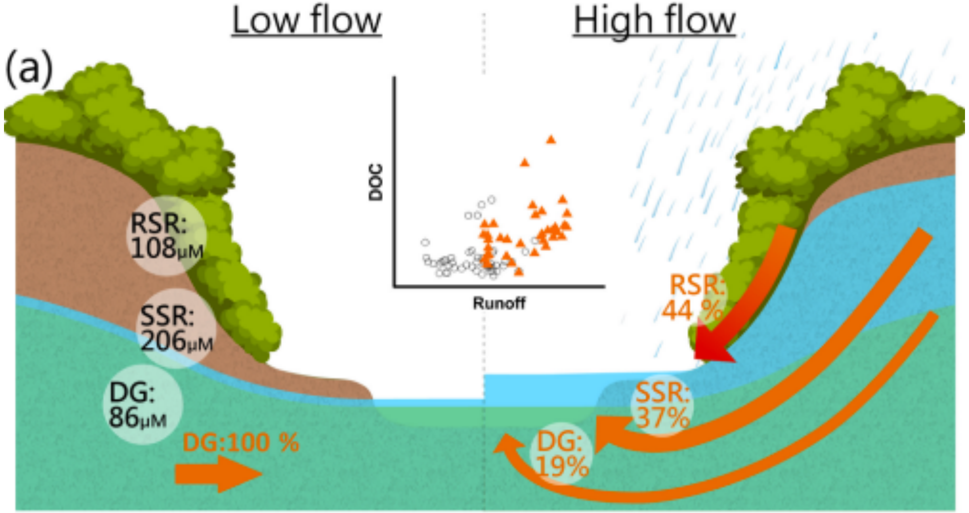
Bicarbonate ions

Carbonate ions

- DIC derived for mineral weathering and microbial degradation of organic matter.
- DIC buffers pH, sustains aquatic photosynthesis and biogenic calcification and interacts with other elemental cycles, such as P and Ca.

DOC and DIC influenced by discharge

- DOC export influenced by discharge
  - generalised response to discharge: positive relation between DOC concentrations in river and discharge. Variety ecoregion and catchments size (Zarnestle et al., 2018).
  - episodic discharges determine DOC fluxes' seasonality (e.g. Broder and Biester 2015)

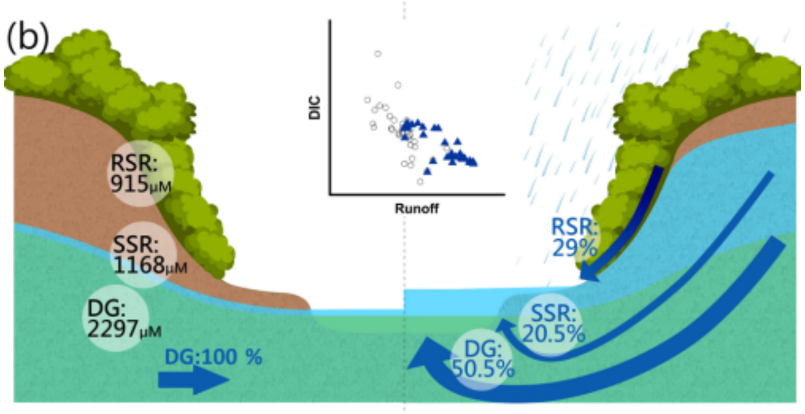


RSR, rapid surface runoff
SSR, subsurface runoff
DG, deep groundwater

Shih et al., 2018

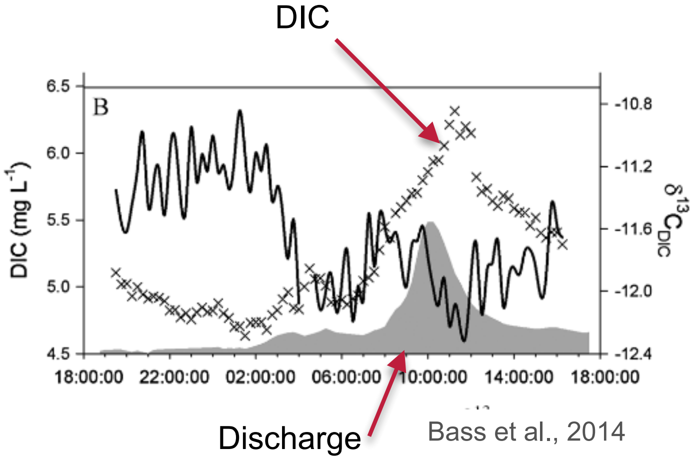
DOC and DIC influenced by discharge

- DIC export influenced by discharge
  - negative: dilution of ground water fluxes (e.g. Rosentreter and Eyre 2019, Shih et al., 2018)
  - positive: connection of soil micropores activation ground water influx (Bass et al., 2014)



RSR, rapid surface runoff; SSR, subsurface runoff; DG, deep groundwater

Shih et al., 2018



Bass et al., 2014

Motivation

- Understanding how different catchment characteristics (vegetation cover, size and slope) influence the release of DOC and DIC under varying discharge conditions.
- Catchment sensitivity: the magnitude of the response in terms of dissolved carbon concentrations in the river related to changes in discharge.

How do catchment characteristics influence dissolved carbon release under changing flow conditions in natural conditions?

- Hypothesis: morphology and vegetation cover, rather than the size of the catchment or of the carbon pools, determine the sensitivity of river catchments towards DOC and DIC release.

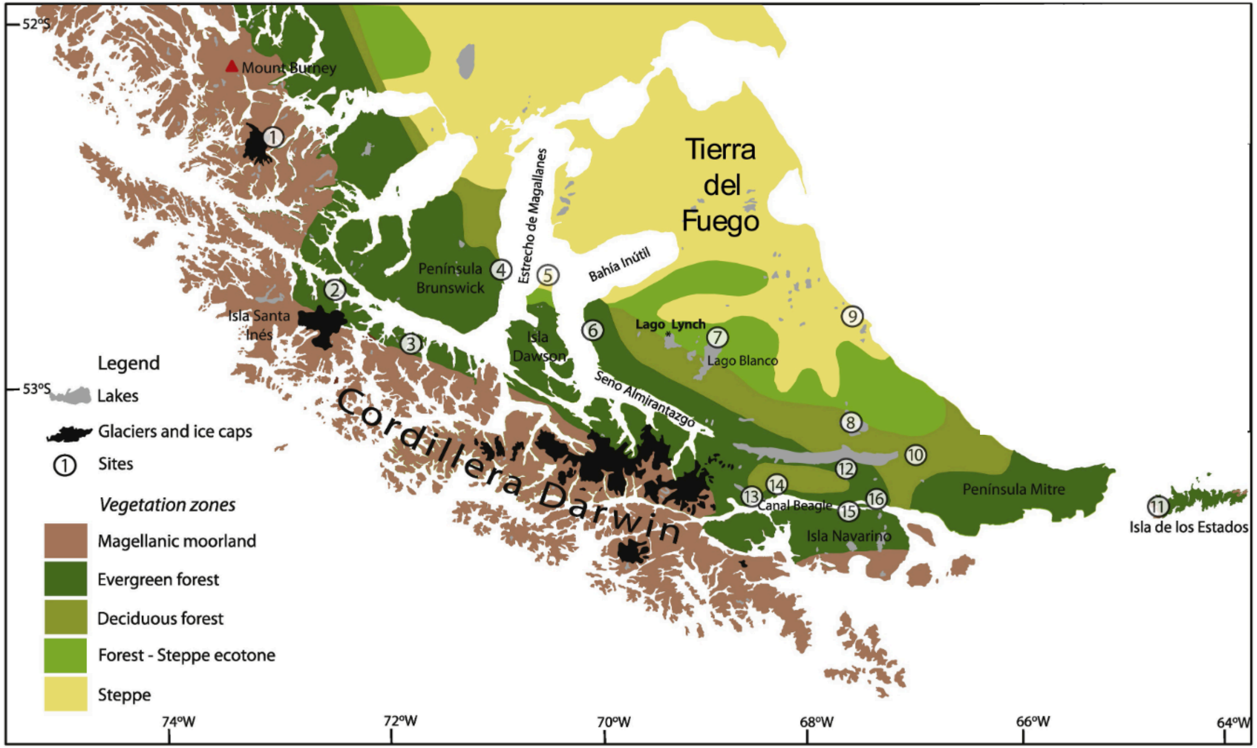
Methods

- 8 catchments
  - Different dominant vegetation
  - Different slopes
  - Different catchment sizes

- Sampling between 2010 – 2011
  - Each river was sample between 15 to 27 times along the year
    - DOC and DIC concentrations, pH, conductivity, discharge
    - 5 rivers with continuous discharge measurements over 1 year

- Linear regression f: $\ln(Q) \longrightarrow \ln(C)$, Q is the discharge rate
  - C is DOC or DIC concentrations

Tierra de Fuego – Vegetation Zones – Climate



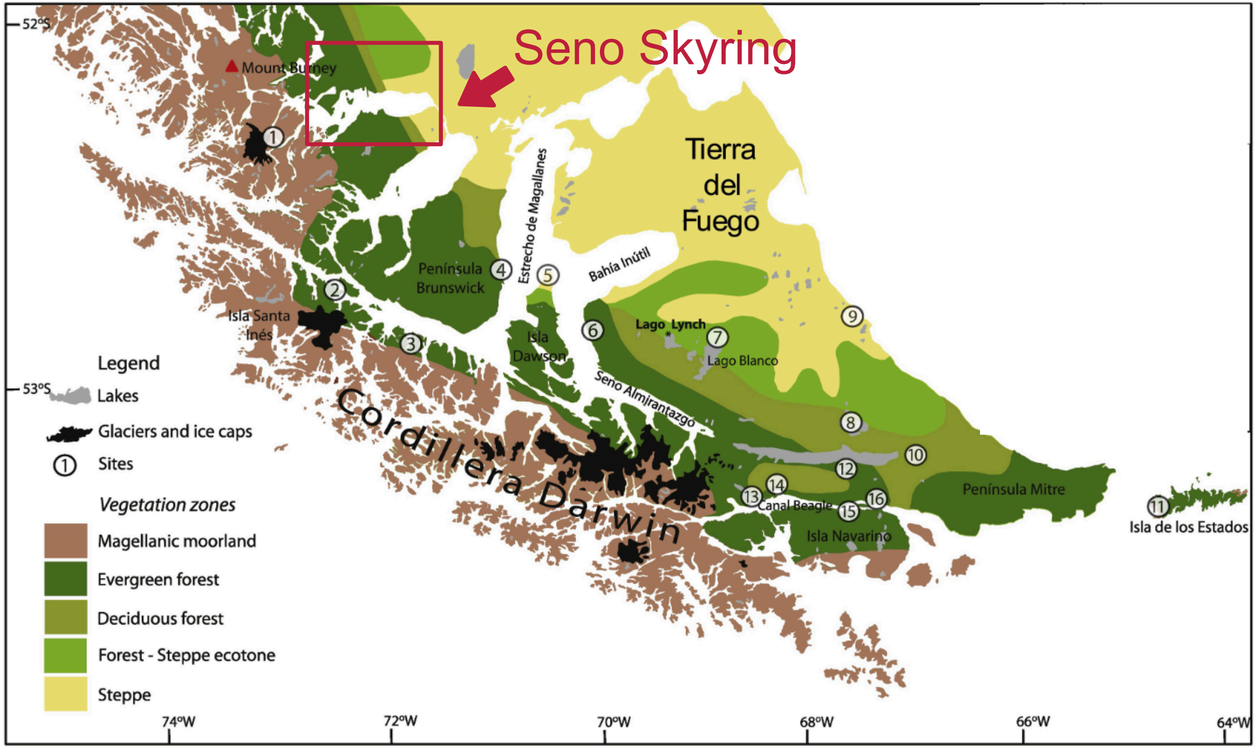
Mansilla et al., 2018

- Precipitation gradient

  ~2000 – ~300 mm (yr)

- Mean annual T ~6ºC
- Westerlies 80%

Tierra de Fuego – Vegetation Zones – Climate



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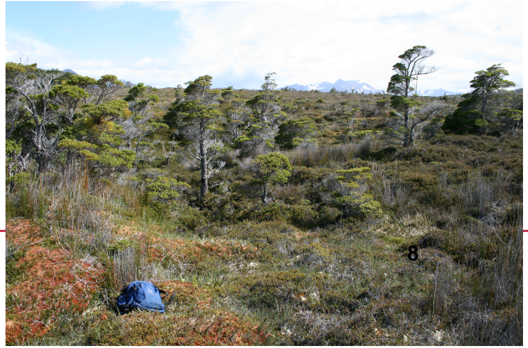
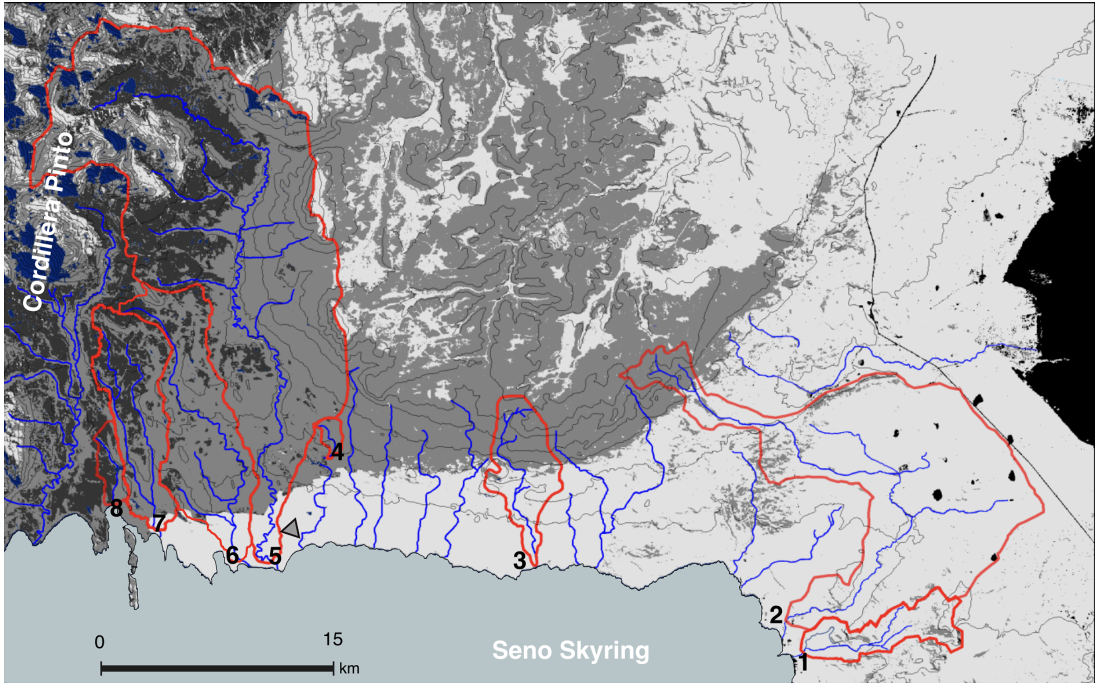


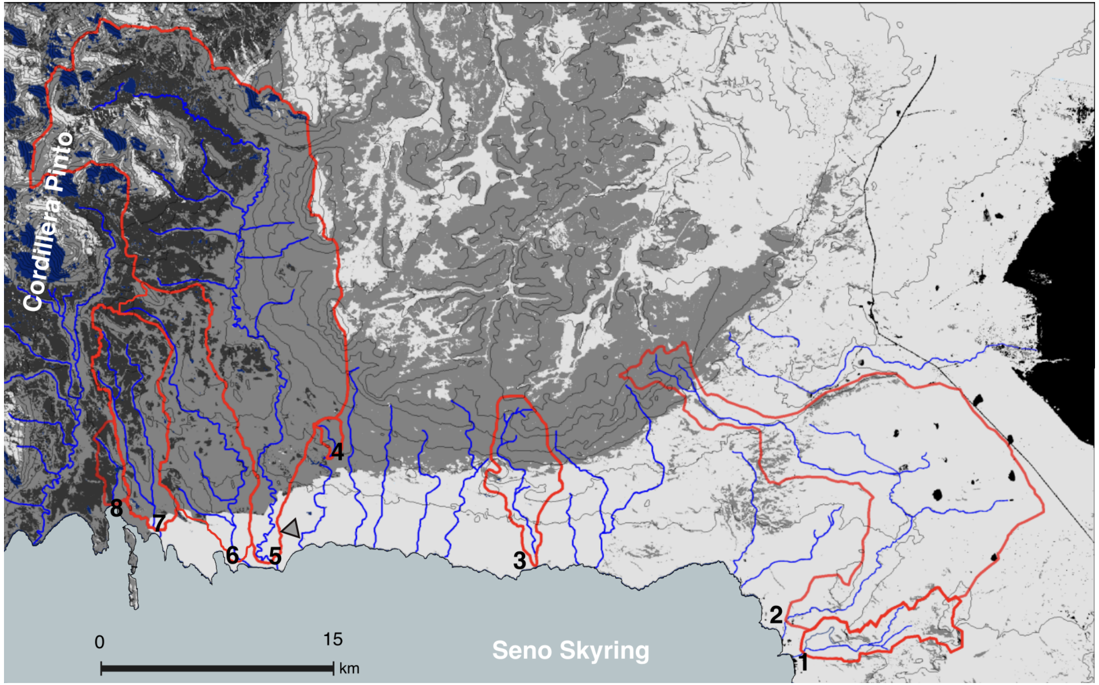
Different dominant vegetation



1. Chorrillo Laguna (CL)
2. Río Verde (RV)
3. Virgen de Montserrat (VM)
4. Río Bosquecillo (RB)
5. Río Perez (RP)
6. Río Leon (RL)
7. Río Nutria (RN)
8. Río Turba (TB)

Pérez-Rodríguez & Biester, 2022

Different dominant vegetation – Geology



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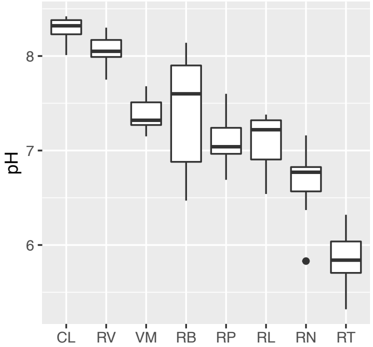
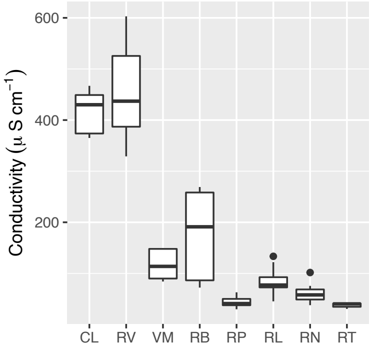
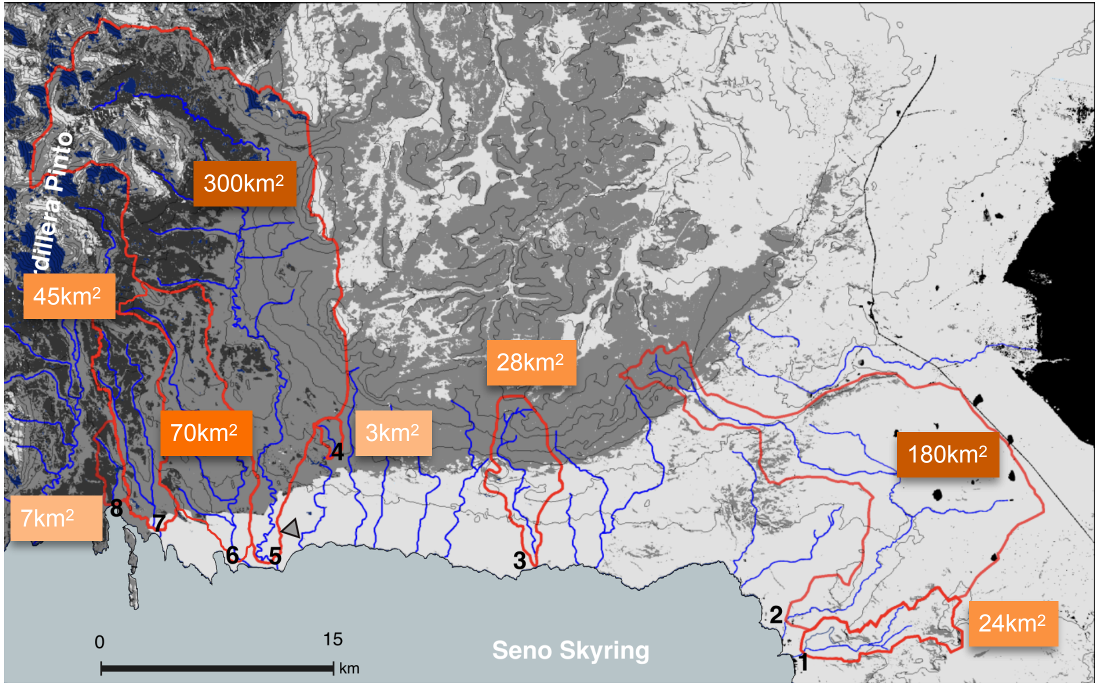




Different catchment size



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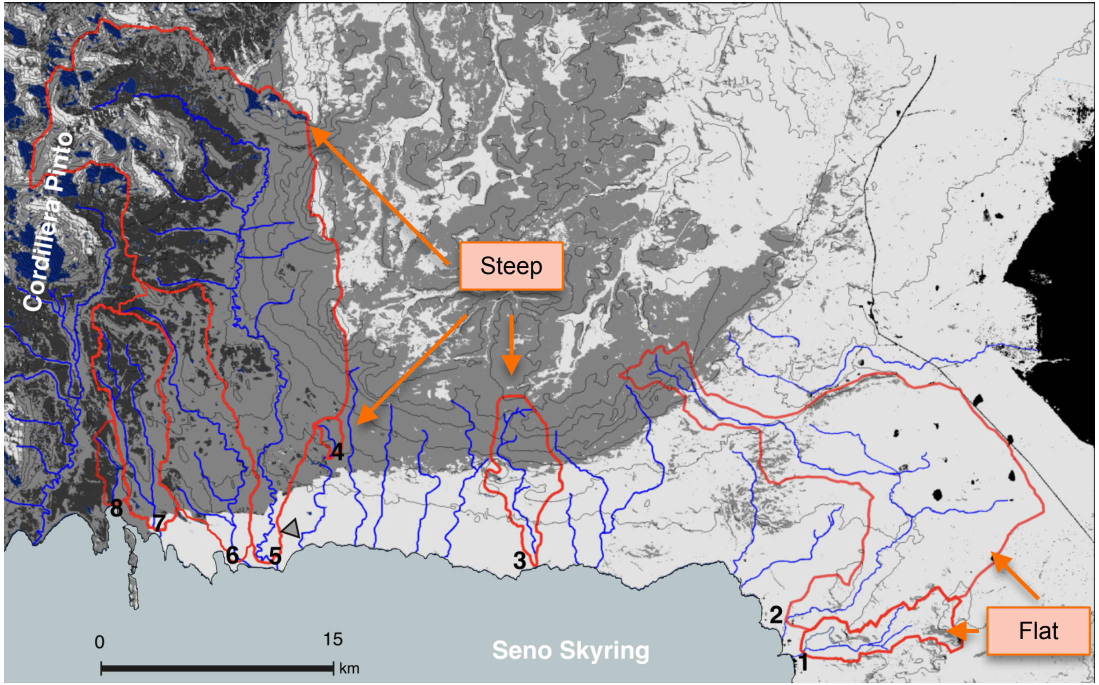
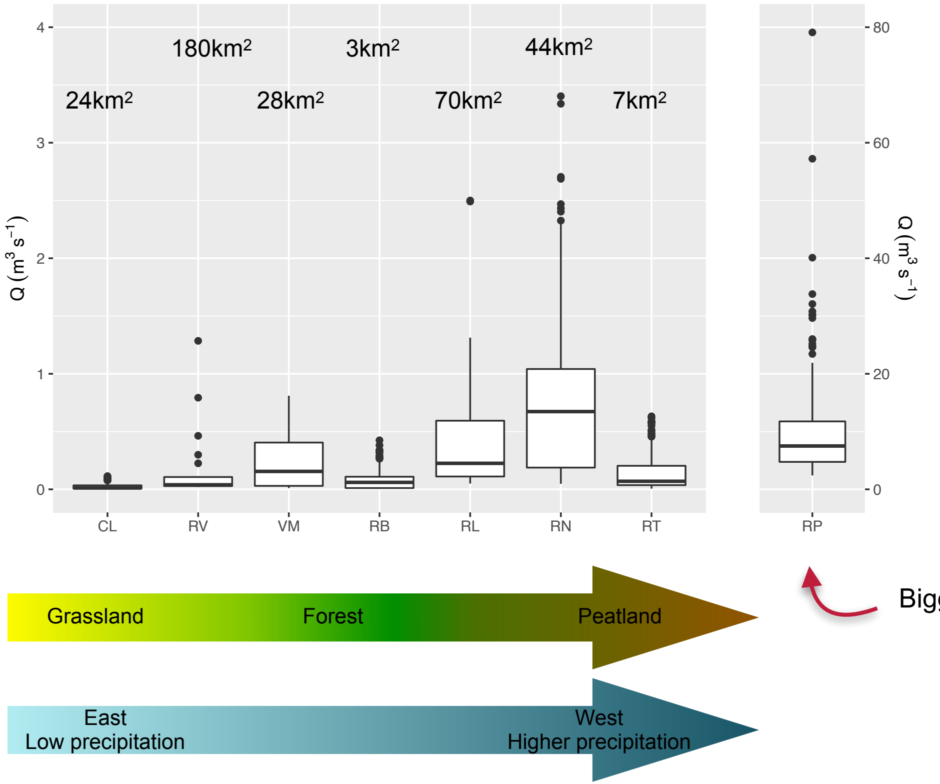
- Range: 3 – 300 km²

Different slope



- Median slope between 3 and 16%

Annual Discharge – Catchment location



Biggest catchment
300km²

Catchment sensitivity and DC releases

- Catchment sensitivity: the magnitude of the response in terms of dissolved carbon concentrations in the river related to changes in discharge.

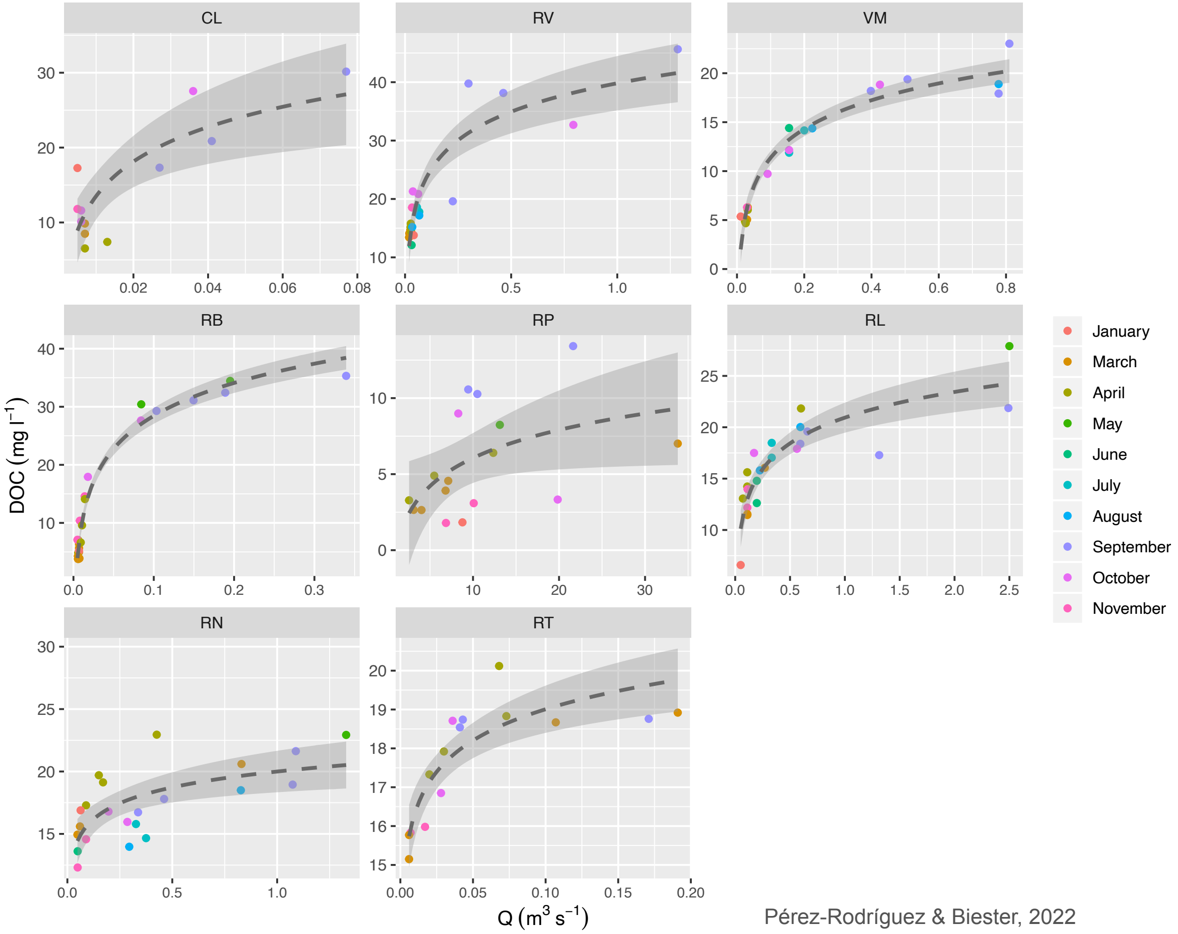
- linear regression model on the logarithmic data of DOC and DIC concentrations and discharge.
  - slope and the r^2

- Sensitivity: The extent of DOC and DIC concentration increase with increasing discharge →the steeper the slope is, the higher the sensitivity.

Discharge vs DOC

	r^2	Slope	Sig
CL	0.56	0.39	0,01
RV	0.83	0.28	***
VM	**0.95**	**0.40**	***
RB	**0.86**	**0.54**	***
RP	0.25	0.47	0,05
RL	0.71	0.23	***
RN	0.47	0.11	***
RT	0.76	0.07	***

0,001 ***



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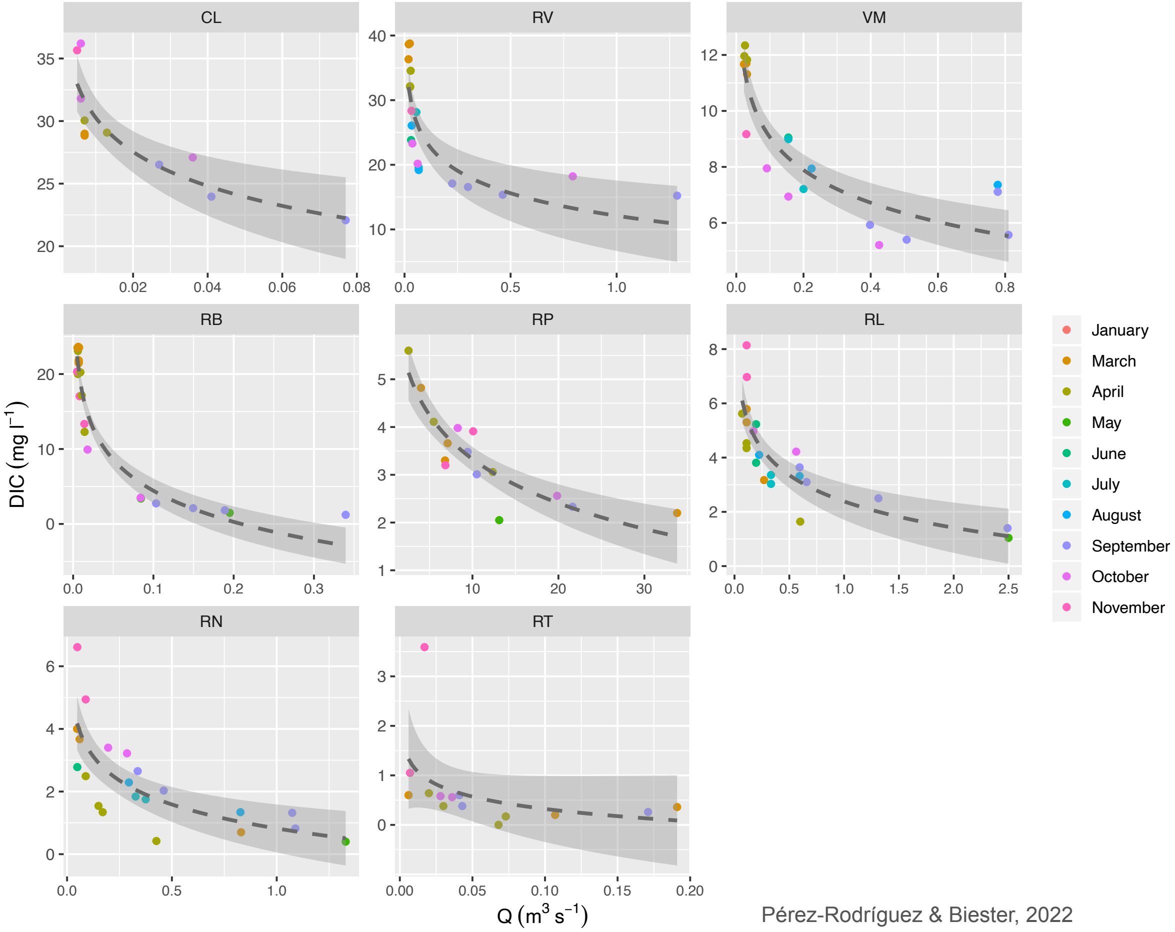
Discharge vs DIC

	r²	Slope	Sig
CL	0.80	-0.14	***
RV	0.73	-0.20	***
VM	0.80	-0.21	***
RB	**0.99**	**-0.74**	***
RP	0.79	-0.39	***
RL	0.77	-0.43	***
RN	0.59	-0.53	***
RT	0.42	-0.47	0,05

0,001 ***



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Conclusions

- Steep catchments hosting organic rich forest soils are most sensitive and have the highest and fastest increases in DOC release due to changes in discharge. Hydrology exerts a first-order control on DC releases.
- Catchments dominated by peatlands, despite the high carbon pool, are not sensitive to discharge changes. Natural peatlands buffer DOC releases.
- *Hypothesis: morphology and vegetation cover, rather than the size of the catchment or of the carbon pools, determine the sensitivity of river catchments towards DOC and DIC release.*

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Thank you for your attention!

Data published in: Pérez-Rodríguez & Biester, 2022. Biogeochemistry. 160:177–197

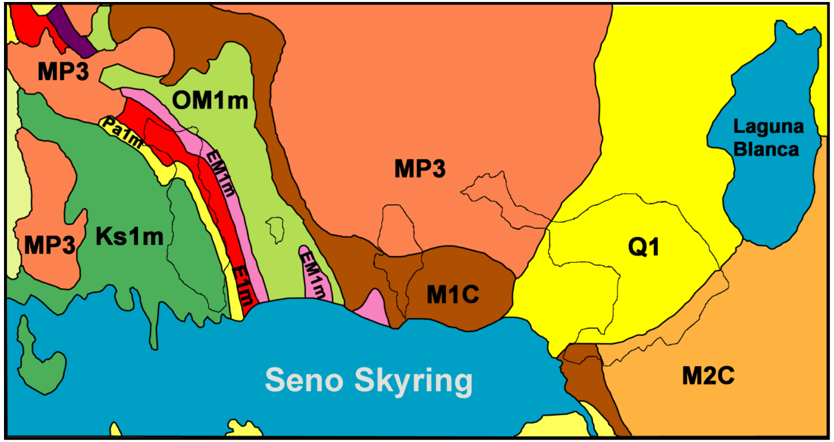
Sampling Locations – Slope variations

Table 1 Basic information on the studied catchments

Rivers	Sampling site	Catchment area (km^2)	Slope (%)	Dominant vegetation (%)		
			Median	Peatland	Forest	Grassland
Chorrillo Laguna (CL)	52° 36.986′ S 71° 29.253′ W	23.7	6.7	0	13	87
Río Verde (RV)	52° 35.820′ S 71° 30.106′ W	180.5	3.8	0	11	89
Virgen de Montserrat (VM)	52° 33.663′ S 71° 43.984′ W	27.6	14.8	0	50	50
Río Bosquecillo (RB)	52° 29.740′ S 71° 55.438′ W	2.7	11.00	8	92	0
Río Perez (RP)	52° 33.114′ S 71° 58.781′ W	300.8	15.9	29	68	3
Río Leon (RL)	52° 33.210′ S 71° 59.996′ W	69.5	9.8	13	76	12
Rio Nutria (RN)	52° 31.948′ S 72° 4.865′ W	44.7	10.1	36	61	3
Rio Turba (RT)	52° 31.005′ S 72° 7.314′ W	6.9	10.3	83	17	0

Catchment areas were extracted from pre-processed SRTM 90 m data (Jarvis et al. 2008), while a Landsat data set (NASA Landsat Program, 2011, Landsat ETM + scene L71229097_09720030328, L1T, USGS, Sioux Falls, 2003/03/28, available at: http://glovis.usgs.gov), offered by the USGS (2011) was further processed with a Hybrid classification as described by Reisen (2006) to gain information about the distribution of the main surface types (mires, forest, (sub-) alpine emerge vegetation and (sub-) alpine grassland, (anthropogenic grassland), Fuego-Patagonian steppe, free vegetation, water/no information). Slope estimates were extracted from a digital elevation map created using data provided by NASA Earth Data server

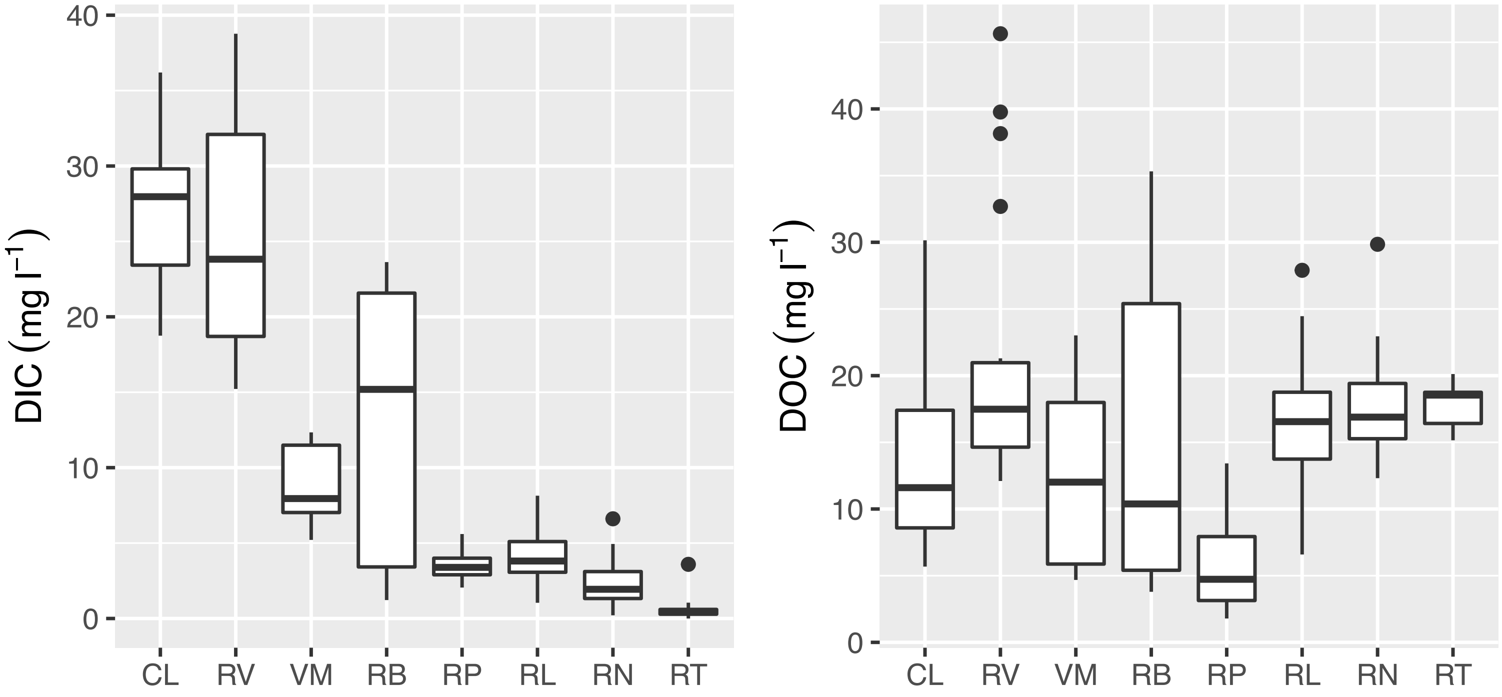
Geology



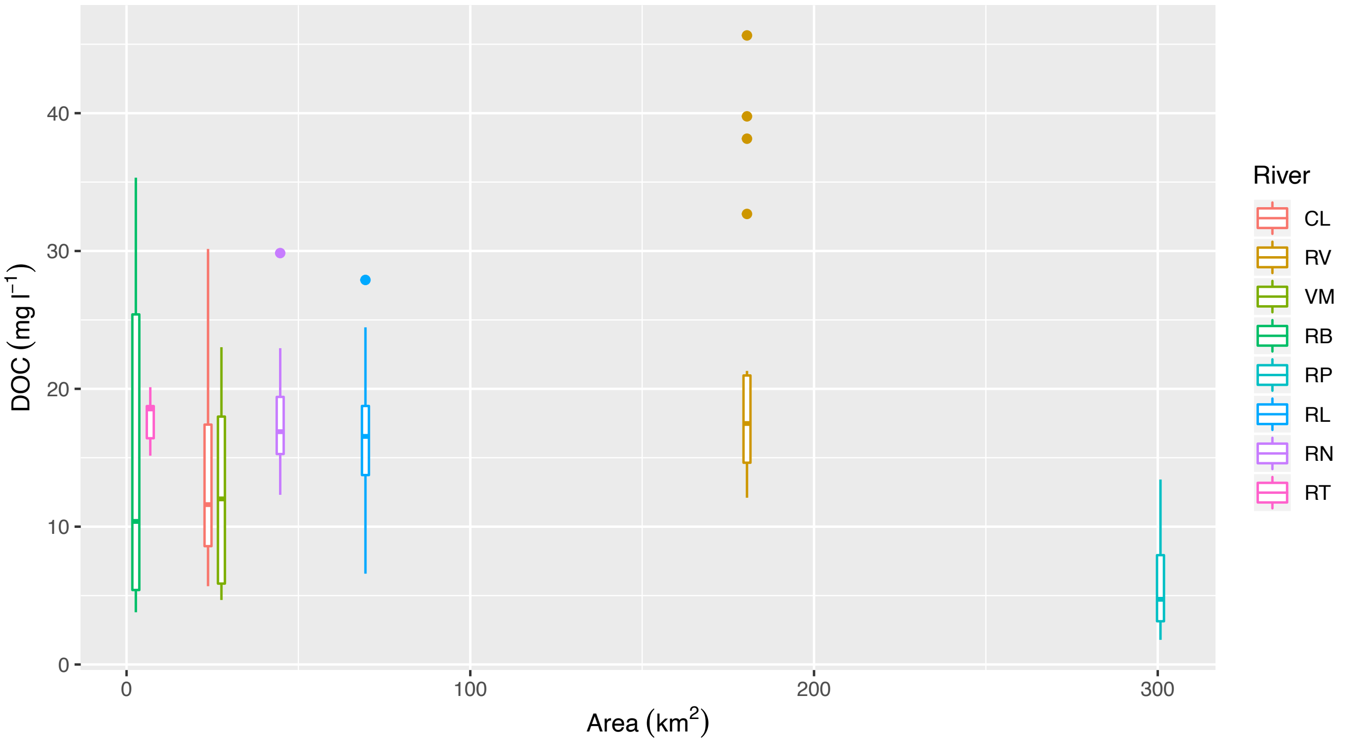
Tab.: Geological and lithological information about Seno Skyring area (from MapaGeológico de Chile 1:1000000, SERNAGEOMIN, 2003).

Denotation	Geological age	Lithology
Ks1mp	UpperCretaceous	littoral and transitional marine sedimentary sequences
		(sandstones, conglomerates, lutites, oolitic and extraclastic limestone and turbiditic successions)
Pa1m	Paleocene	paralic deltaic marine sediments (sand- and siltstones)
EM1m	Eocene–Miocene	sublittoral marine sedimentary deposits (siltstones and mudstones)
E1m	Eocene	marine sediments (areniscas and lutites)
OM1m	Oligocene–Miocene	marine sedimentary sequences (sandstones and coquinas)
MP3	Miocene-Pleistocene	acidic to intermediate pyroclastic rocks
M1C	LowerMiocene	sedimentary sequences of alluvial and fluvial fans (graves, sands and slimes with intercalated ignimbrites)
M2C	MiddleMiocene	continental volcanic– sedimentary sequences (tuffs, sandstones and tuffites)
Q1	Pleistocene–Oligocene	alluvial, colluvial and mass removal (fluvioglacial, deltaic, littoral or undifferentiated deposits)

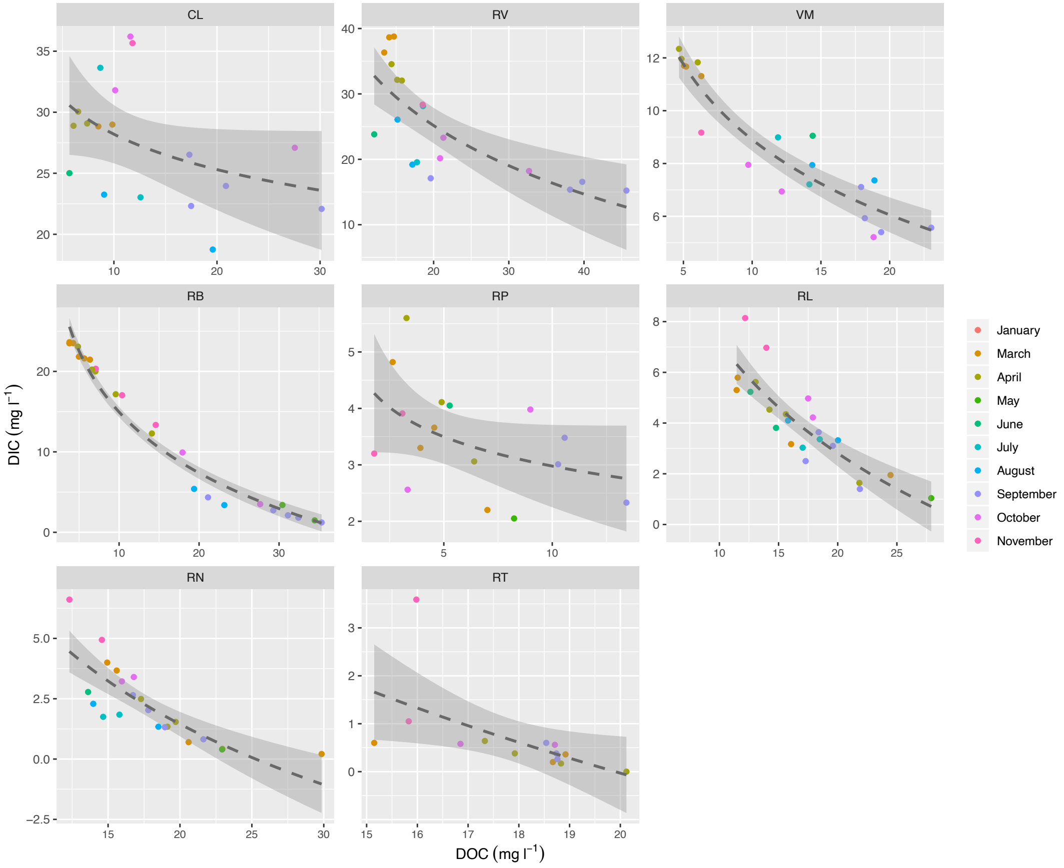
DOC and DIC average concentrations



DOC and catchment size



DOC vs DIC



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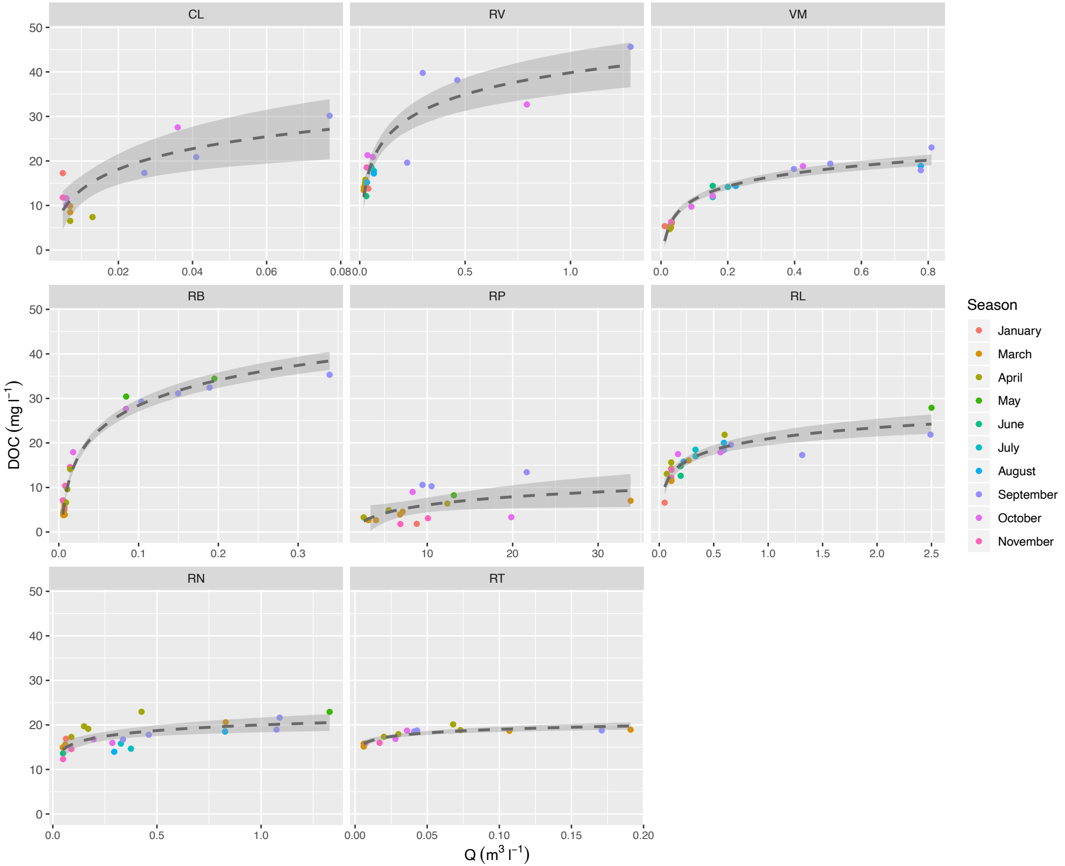
DOC same scale



DIC same scale