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Untangling the relative importance of policy, soil moisture and land use variables for stream water quality

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Context and research questions

- **EU Nitrates Directive**: improve management of animal manures and Nitrogen containing chemical fertilisers/materials spread on agricultural land

→ For **Northern Ireland**:
- from 2007: **Nitrates Action Programme** (NAP) + **Phosphorus Regulations**
- from 2019: **Nutrients Action Programme** (NAP)

→ Restrictions on fertilisation: **'Closed' period** (prohibited fertilisation), **set-back distances from watercourses**, **maximum application rate**

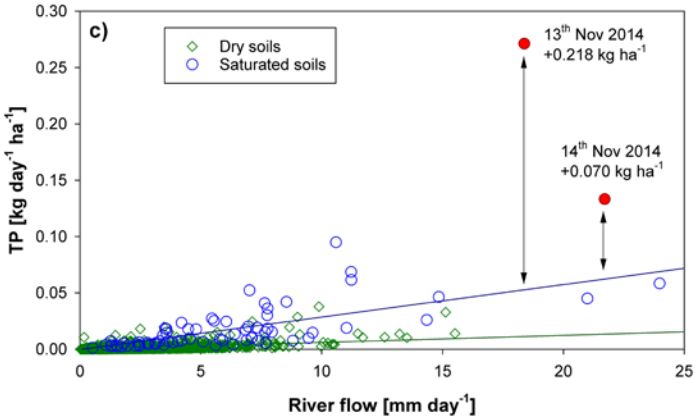
	2007-2010	2011-2014	2015-2018	2019-present
Org. manure Set-back distance (m)	10 / 10	10 / 10	10 / 15	10 or 15* / 15
Chem. fert. Set-back distance (m)	1.5 / 1.5	2 / 2	2 / 5	2 / 5
Org. manure Max application rate (m^3 ha^{-1})	50	50	50	50 or 30*

Slope < 12 or 15% / Slope = 12-15% other land, 15-20% grassland

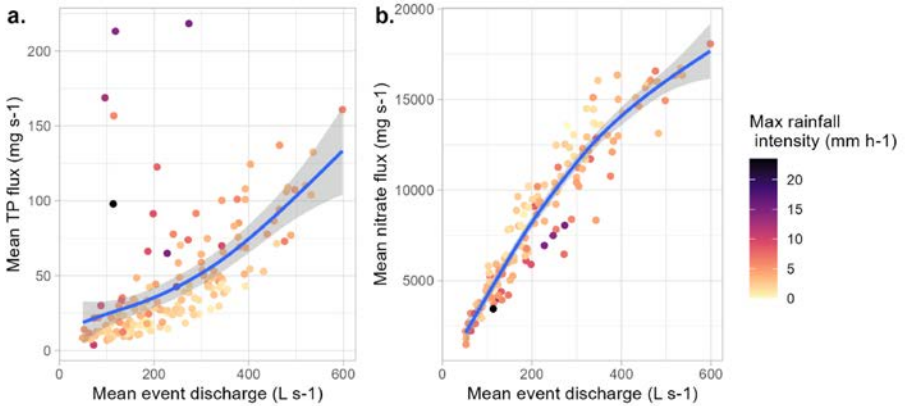
*From April 2019: for Feb. + Oct 1st-15th

Context and research questions

- Increasing **weather pressures** (rainfall) → **nutrient losses** (leaching, runoff)



Mellander & Jordan, 2021



Dupas et al., 2024

→ ***How effective are the NAP regulations under weather and land use pressures?***

→ ***What is the relative importance of soil moisture, land use intensity and fertiliser spreading regulations for stream water quality ?***

Study catchments

- **Upper Bann** – 220 km^2
- **Colebrooke** – 232 km^2

- Monitored to **provide evidence in support of the NAP for Northern Ireland**

- Dominated by **sloping grassland hills** and **poorly-drained soils**

- **Contrasting farming intensities**:
  Upper Bann >> Colebrooke

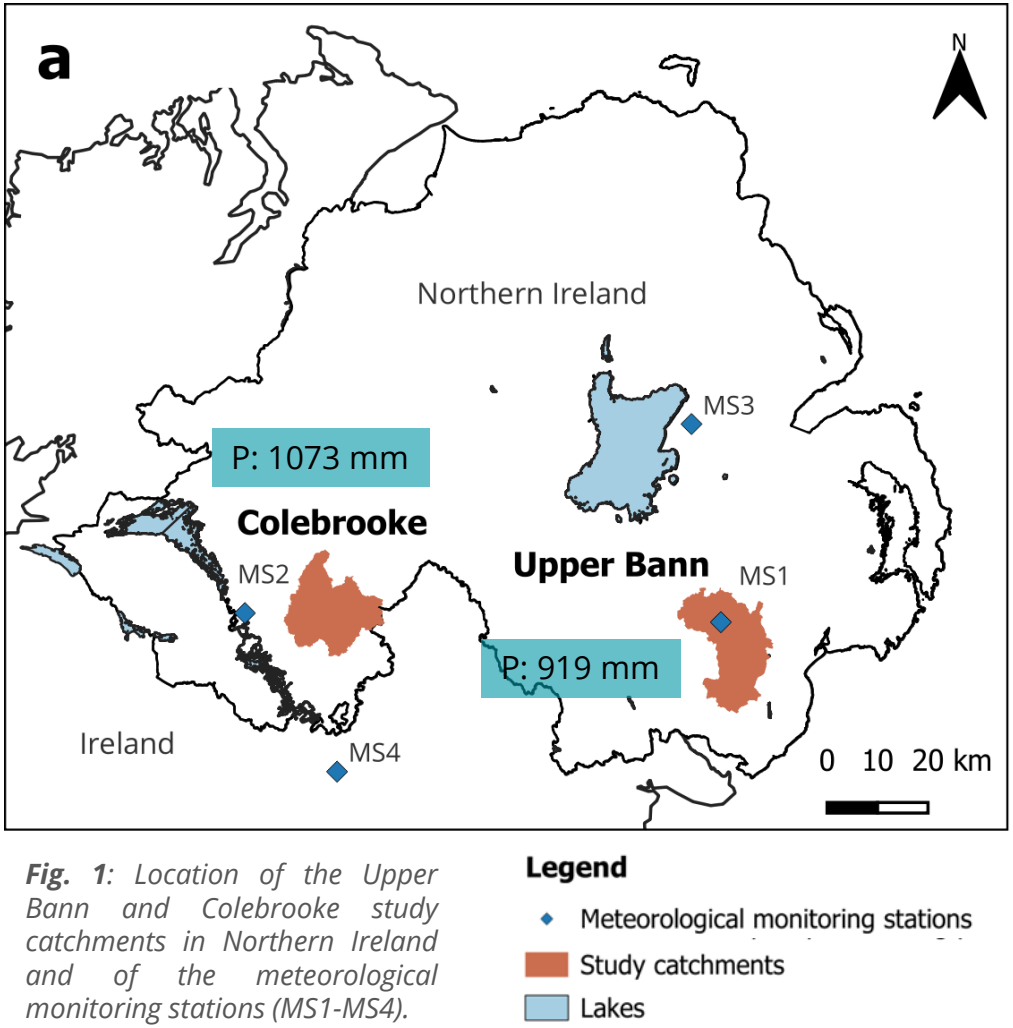


***Fig. 1**: Location of the Upper Bann and Colebrooke study catchments in Northern Ireland and of the meteorological monitoring stations (MS1-MS4).*

Stream water quality monitoring

- **2009-2023**: **Fortnightly** stream water quality monitoring: **Total Oxidised Nitrogen**, **Total Phosphorus**, **Soluble Reactive Phosphorus**

→ Baseline/quiescent conditions

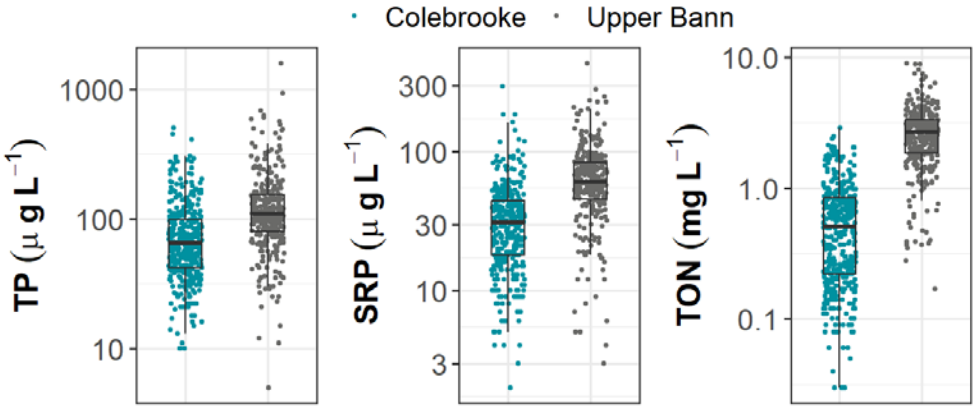


Fig. 3: Distribution of TP, SRP and TON concentrations in the Upper Bann and Colebrooke catchments over the period Feb 1st – March 15th 2009-2023.

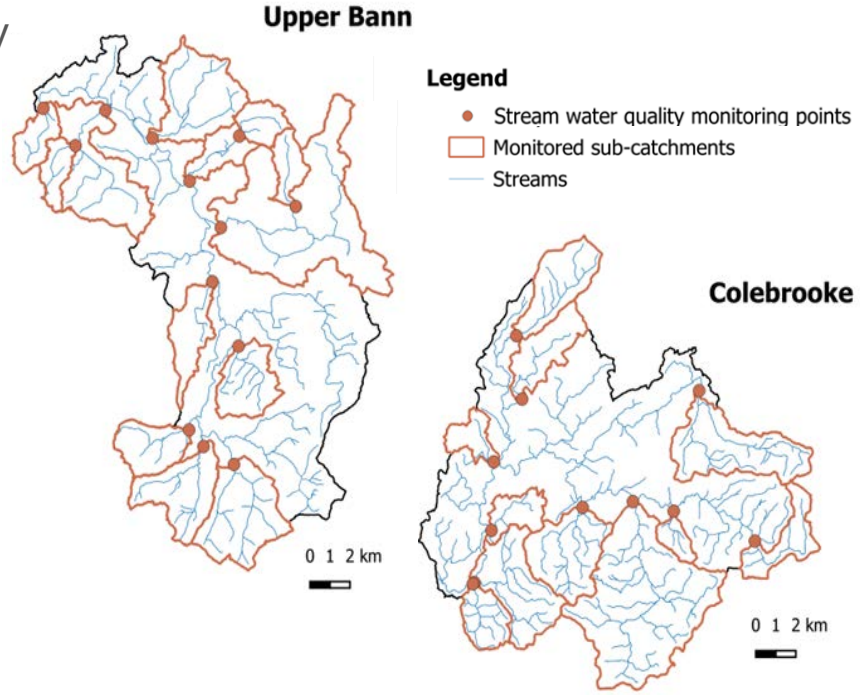


Fig. 2: Location of the monitored sub-catchments in each of the study catchments.

Soil moisture monitoring

- **Precipitation**, **air temperature**, **wind speed** and **solar/global radiation** monitoring by Met Éireann (IE)/Met Office (UK) → **Soil Moisture Deficit**

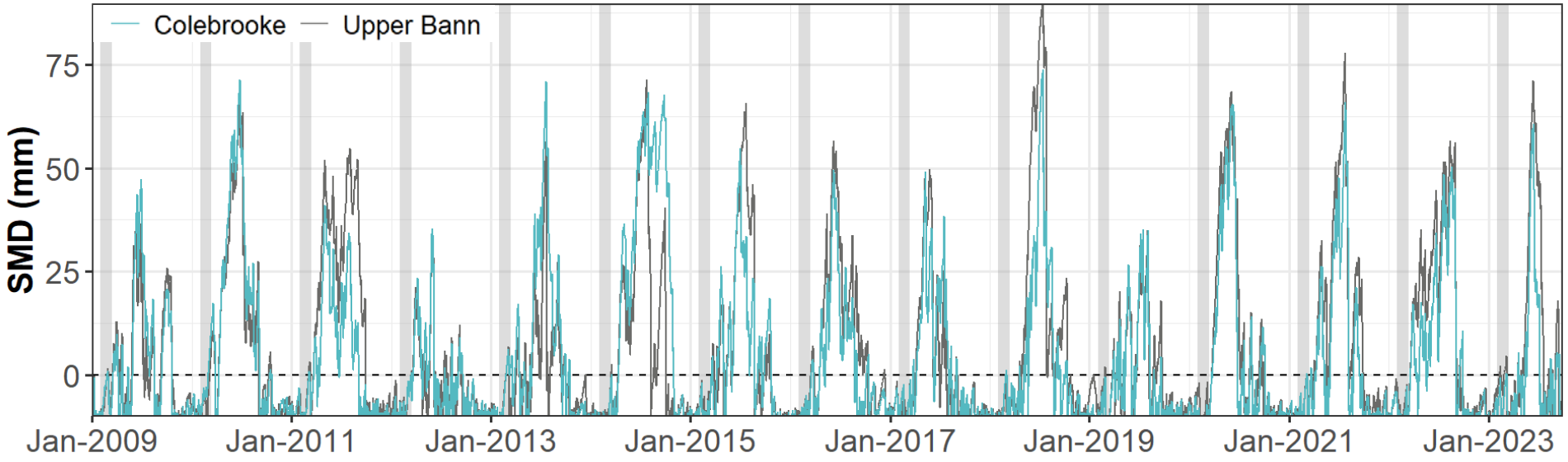


***Fig. 4**: Evolution of Soil Moisture Deficit (SMD) in the Upper Bann and Colebrooke catchments over 2009-2023 (grey bands highlight the period Feb 1st – March 15th).*

Land use monitoring

- **Land use** monitoring by UK CEH → **Fertilised land** (arable + improved grassland)

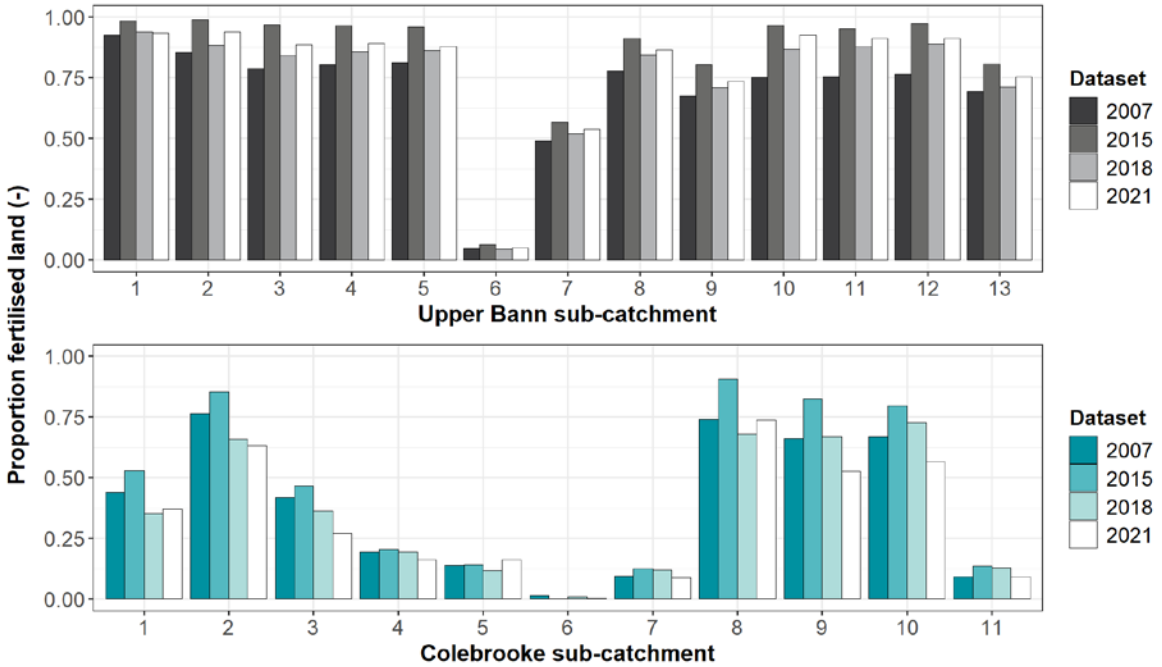
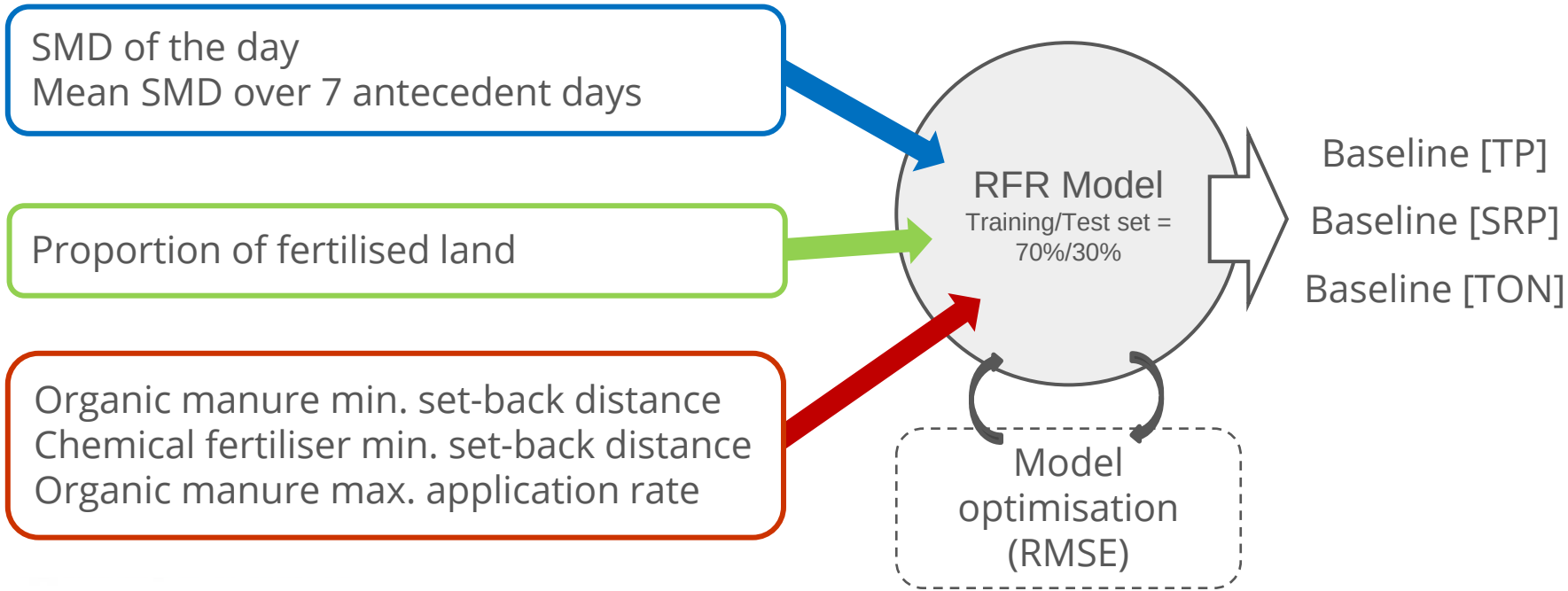


***Fig. 5**: Temporal variability in the proportion of fertilised land (arable + improved grassland) for each Upper Bann and Colebrooke sub-catchment.*

Relative importance modelling

- **Random Forest Regressions**:



Models performance

- TON models performed better than TP/SRP models
- Poorer models' performance on the test sets (higher decrease in performance for the P than TON models)

Catchment	Response variable	Optimised parameters		
		R^2	RMSE	MAE
Upper Bann	TP	0.681	66	36
	SRP	0.502	30	20
	TON	0.849	0.52	0.36
Colebrooke	TP	0.418	49	32
	SRP	0.507	20	12
	TON	0.931	0.14	0.09

***Table 1**: Performance of the RFR models.*

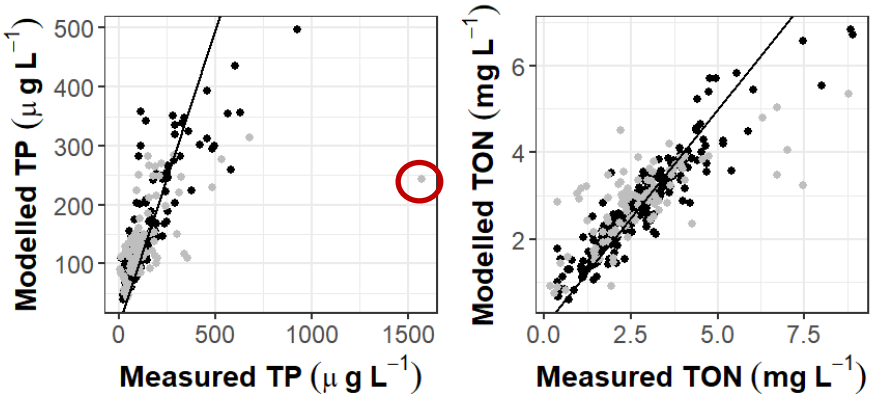


***Fig. 6**: Exemple of measured vs modelled TP and TON concentrations with highlight of a low flow high P concentration point not well reproduced by the model.*

Drivers of stream water quality in Upper Bann

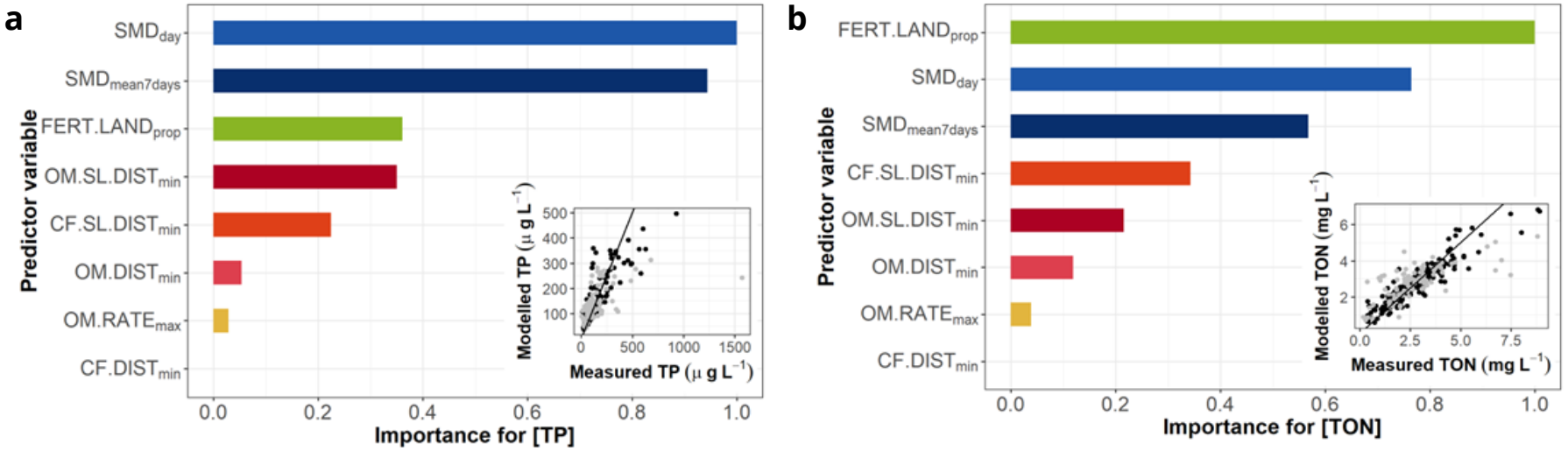


***Fig. 7**: Relative importance of each predictor variable for TP (a) and TON (b) concentration in the Upper Bann catchment. For each panel, the predictor variables are ranked by decreasing importance, with the importance ranging from 0 (lowest importance) to 1 (highest importance).*

The **most important predictors** were:

- **SMD** for **TP**
- **Land use intensity** and **SMD** for **SRP**
- **Land use intensity** for **TON**

Driver of stream water quality in Colebrooke

Land use intensity was the **most important predictor** of **TP**, **SRP** and especially **TON** concentrations

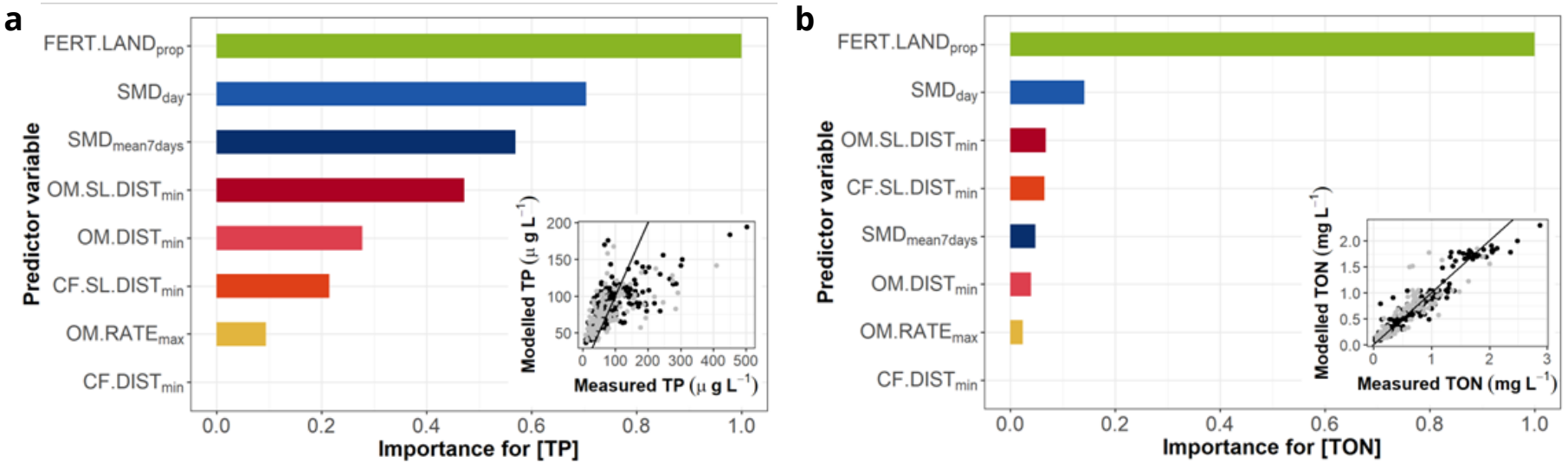


***Fig. 8**: Relative importance of each predictor variable for TP (a) and TON (b) concentration in the Colebrooke catchment. For each panel, the predictor variables are ranked by decreasing importance, with the importance ranging from 0 (lowest importance) to 1 (highest importance).*

Take home messages

- **Effect of fertiliser spreading regulations** on baseline stream water quality **overridden** by **impacts of soil moisture and land use** intensity during the first weeks of the fertilisation period

- **TP/SRP concentrations** mostly driven by **weather and land use** intensity
- **TON concentrations** mostly driven by **land use** intensity

- **Weather impact** on stream water quality **more important in catchment with higher nutrient source pressure**

→ **Reduction of excess soil nutrients** and **fertiliser spreading during more appropriate soil moisture conditions** are more effective and sustainable measures to improve stream water quality than small changes in fertiliser spreading regulations

Thank you for listening!

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The full **study** is **published and available online (Open Access)**

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