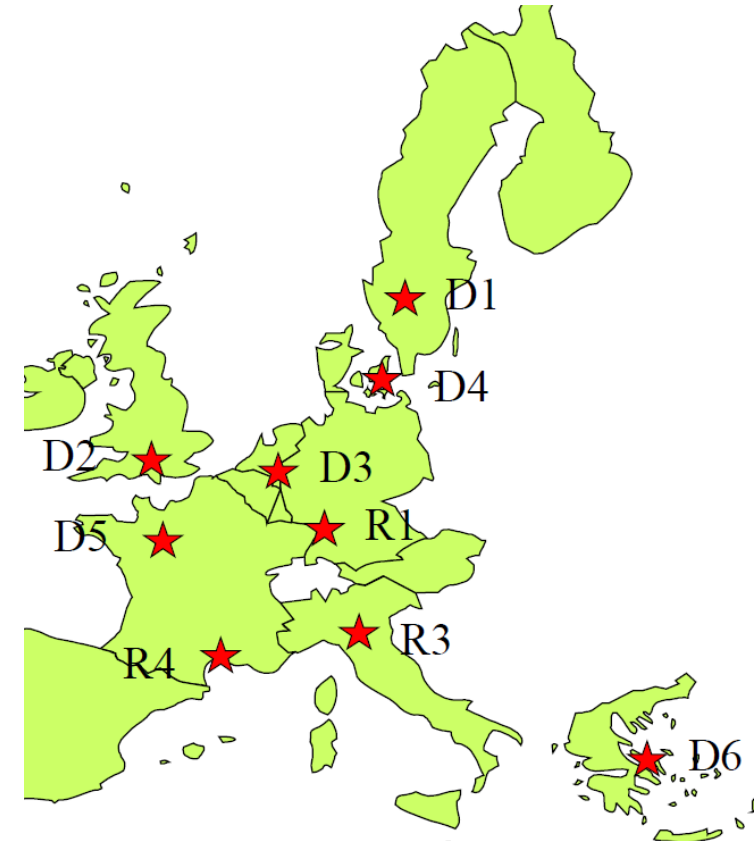


Critical review of conceptual approaches to macropore flow in leaching and drainage models

Bernhard Jene, Stefan Reichenberger & Jorge Olivares-Rivas

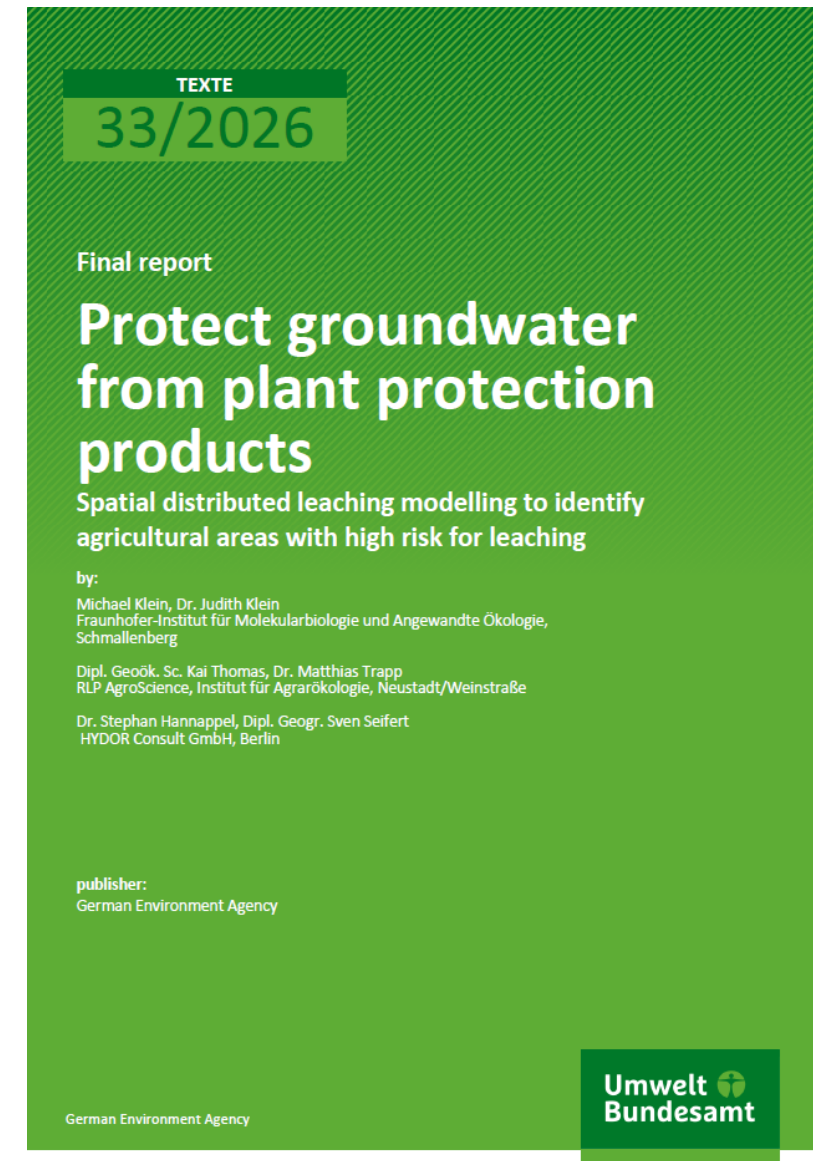
Background

- Macropores provide rapid shortcuts in structured soils through which pesticides may rapidly reach drains or deeper soil layers
- For EU registration macropore flow is explicitly taken into consideration
 - surface water: six FOCUS Drainage scenarios
 - Groundwater: one FOCUS leaching scenario (Châteaudun)
- The only regulatory model currently used for macropore flow is FOCUS-MACRO

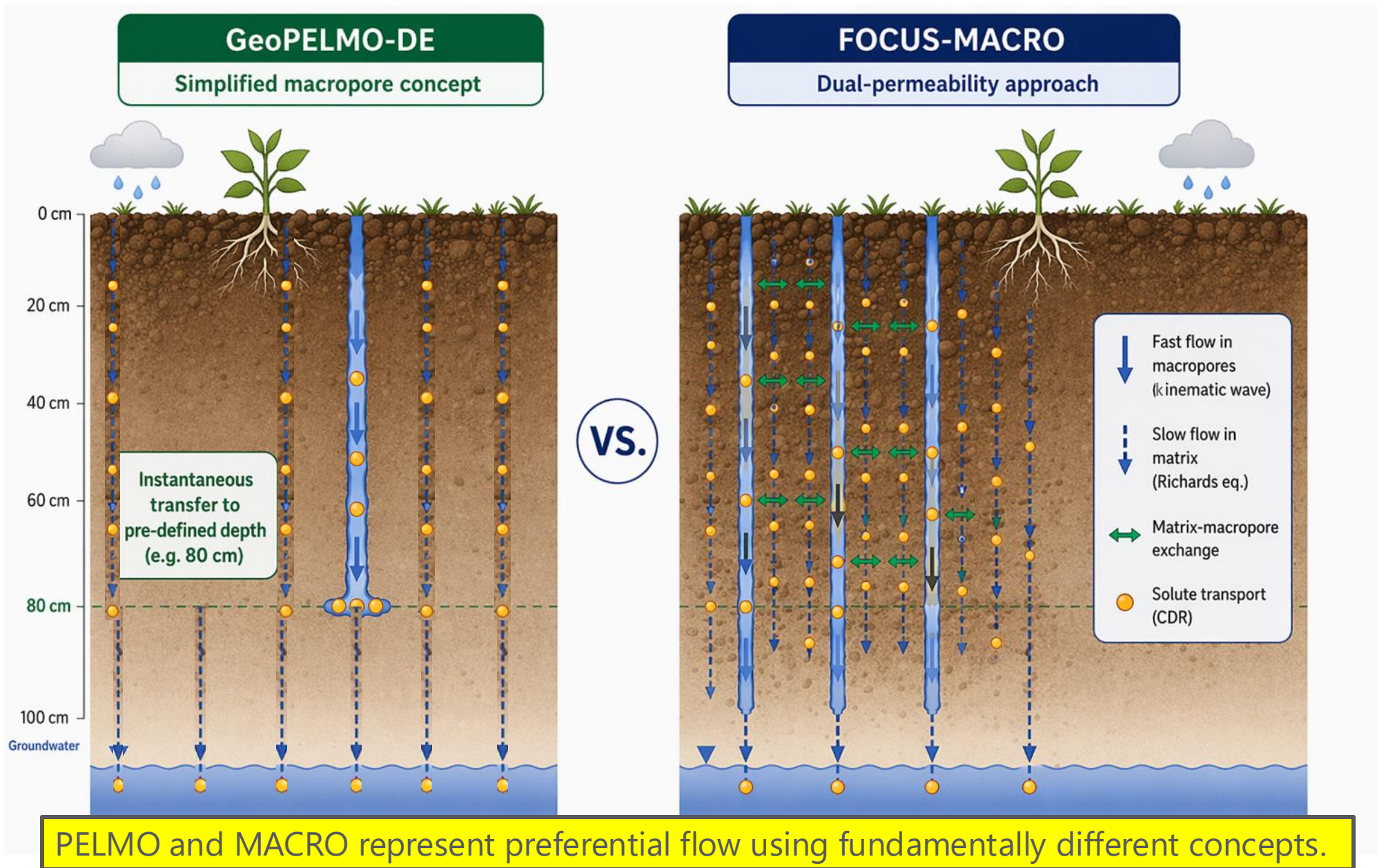


Macropore flow in GeoPELMO-DE

- Macropore flow was implemented in GeoPELMO-DE for spatially distributed leaching modelling in Germany
- The predicted groundwater concentrations were:
 - Considerably higher than without macropore flow
 - Considerably higher than the FOCUS-Hamburg scenario which is Tier-1 for German assessment
- Limited experience on how macropore flow in Pelmo compares to MACRO
- FOCUS-MACRO used as benchmark due to its validation status and its regulatory acceptance



Macropore flow in PELMO and MACRO



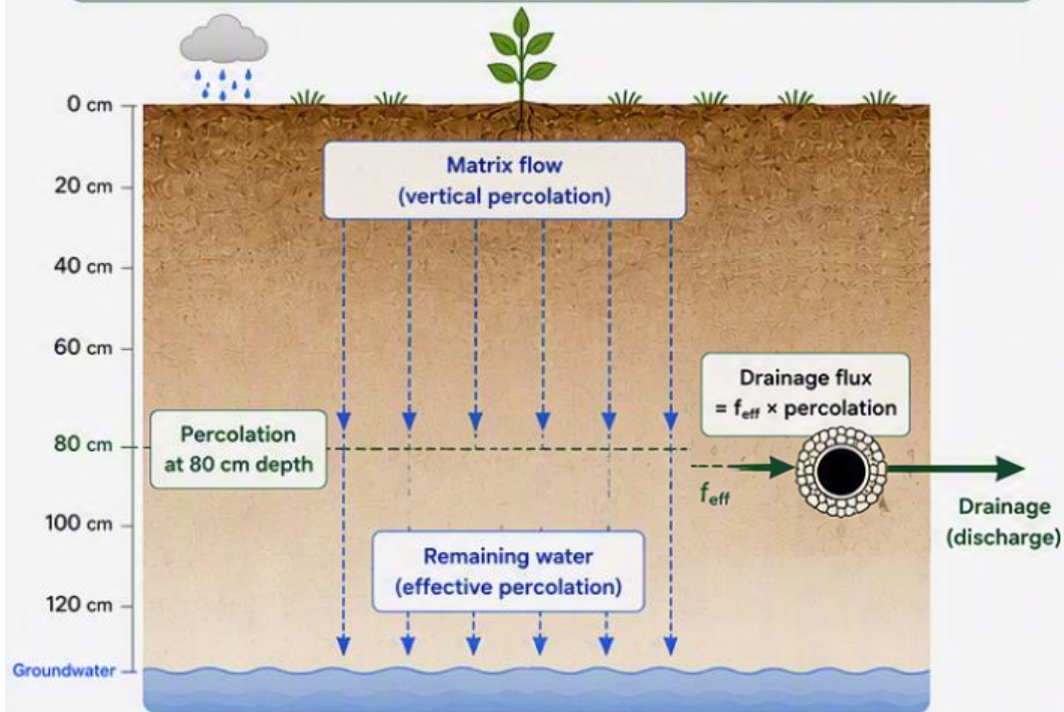
Drainage in PELMO and MACRO

VS.

GeoPELMO-DE

Simplified drainage factor concept

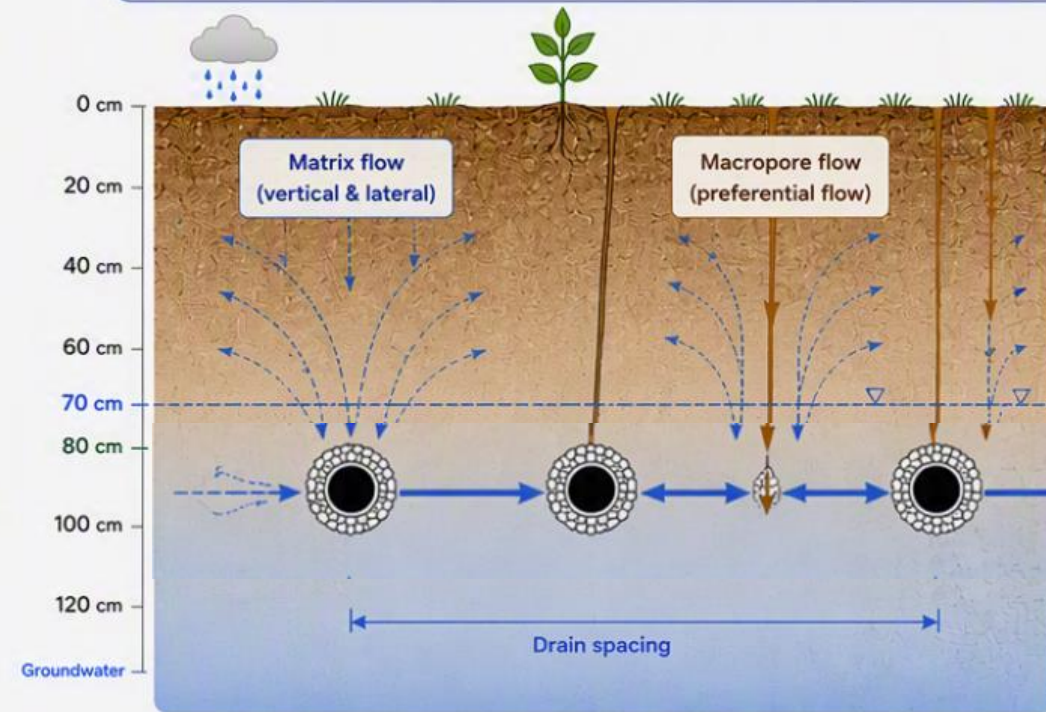
- f_x Drainage is derived from percolation at 80 cm
- % Fixed efficiency factor (f_{eff}) – soil dependent
- ⊗ No explicit lateral flow calculation
- ! Drain depth fixed (~80 cm)
- ⇄ Drain flow prescribed (post-processing split)



MACRO

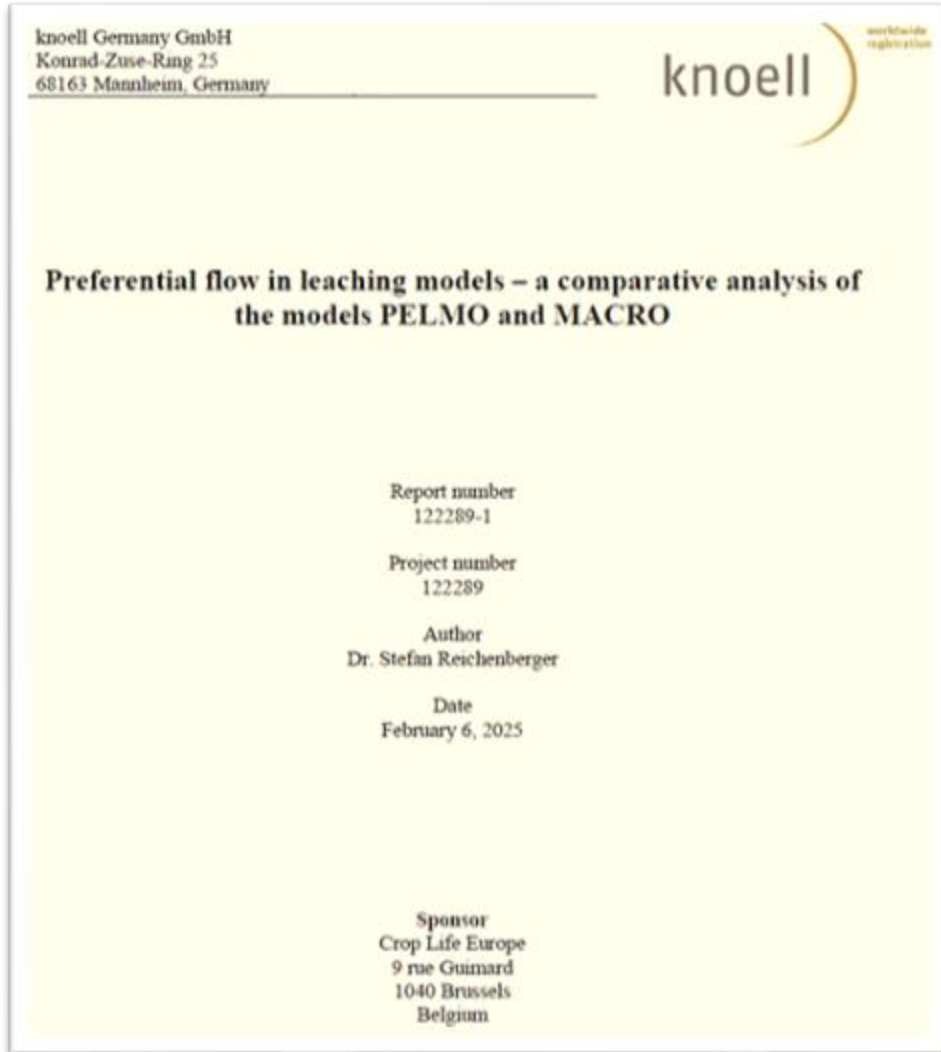
Physically based drainage concept

- 💧 Drainage is simulated hydraulically
- △ Hydraulic gradients determine drain flow
- ⇄ Explicit lateral flow to drains
- ⊙ Drain depth and spacing explicitly represented
- ≡ Drain flow emerges from the simulation



Drainage is generated and routed differently in both models

Modelling exercise to compare the concepts of PELMO and MACRO



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Report Open

Preferential flow in leaching models – a comparative analysis of the models PELMO and MACRO

Reichenberger, Stefan (Researcher)¹ Olivares-Rivas, Jorge (Project member)²

Show affiliations

Spatially Distributed Leaching Modelling (SDLM) of pesticides can be used to assess the leaching potential of plant protection products on a regional scale, such as national or even European scale. Harmonised guidance on how to perform SDLM is still lacking. For this reason, the SETAC SDLM working group is developing a harmonised framework for conducting spatially distributed leaching modelling at the European and Zonal level (Tiktak et al., 2024). This framework will include the leaching models PEARL (van den Berg et al., 2016) and PELMO (Klein, 2020). One important process in the vertical downward transport of pesticides through structured soils is preferential flow (Jarvis, 2007), which is still not considered in Tier-1 and Tier-2 groundwater leaching assessments, and neither in the upcoming first version of the harmonized SDLM framework (Tiktak et al., 2024). At the EU level, only the FOCUS scenario Châteaudun takes into account the process of macropore flow (the most important subtype of preferential flow) when simulating leaching, but only in one of the four models for which it has been parameterized.

The most widely used model to simulate preferential flow and associated pesticide transport through soils is MACRO (Larsbo and Jarvis, 2003). MACRO is physically-based and has a high validation status (e.g. Larsson and Jarvis, 1999). It can therefore be considered as a reference model for the assessment of pesticide leaching scenarios as well as the Northern 2024; 2024; es exist re flow gw leaching 2022). flow in cisions on whether O needs

Reichenberger, S. & Olivares-Rivas, J. (2026). Preferential flow in leaching models – a comparative analysis of the models PELMO and MACRO. Zenodo. <https://doi.org/10.5281/zenodo.20693360>

The objectives of this project were

- 1) To perform a comparative analysis of the process descriptions of macropore flow that are currently implemented in MACRO version 5.2 and PELMO version 5.00.
 - 2) To conduct comparative simulations with the MACRO model for already existing regulatory leaching / drainage scenarios, and to compare the results with those of the macropore version of PELMO.
- The MACRO input and output files, the processed results of MACRO and PELMO, and the results of the comparison of the output of both models were to be provided in a digital annex.

<https://zenodo.org/records/20693360>

Modelling exercise to compare the concepts of GeoPELMO-DE and FOCUS-MACRO

- 6 regulatory scenarios (FOCUS GW/SW and Northern Zone)
- 9 dummy compounds
- 54 simulations per model over 26-year
- Evaluation of magnitude and dynamics:
 - Hydrology (drainflow, percolation, water balance)
 - Pesticide transport (leaching, drainage losses, PECgw)

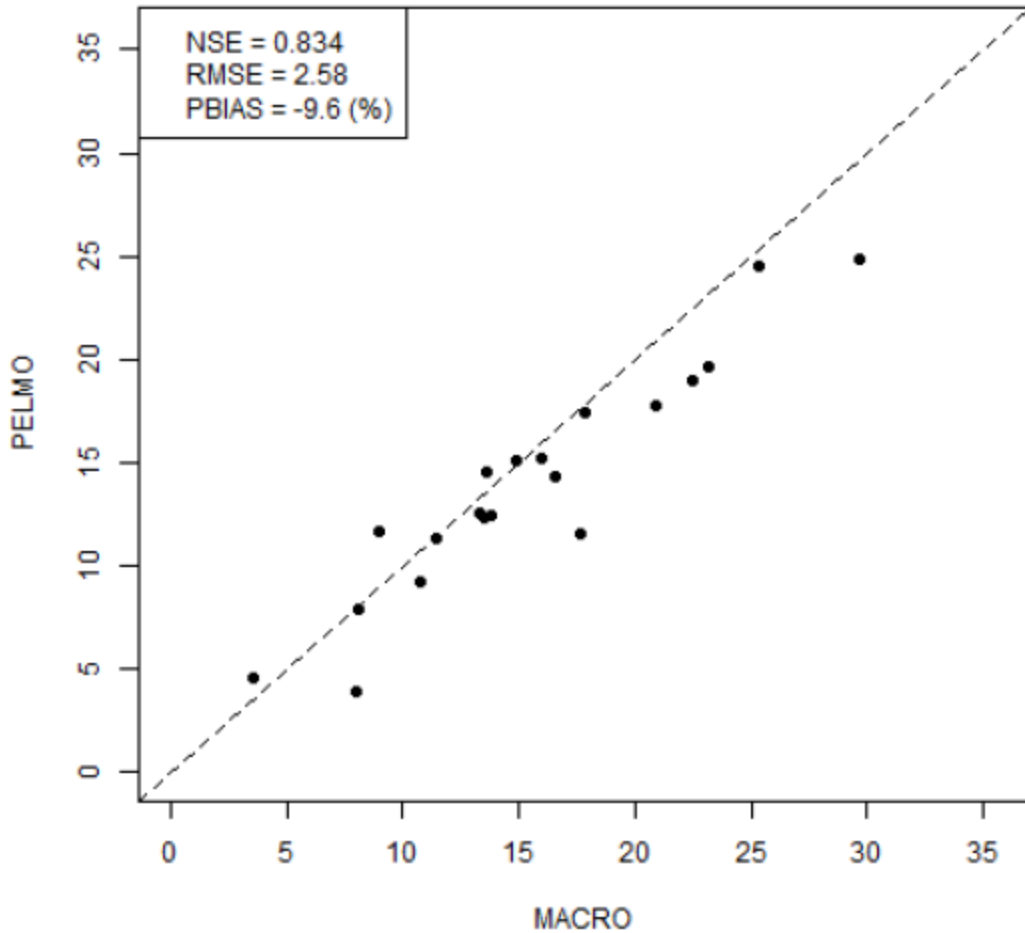
Scenario	Period
Châteaudun	1901–1926
D2 (Brimstone)	1969–1994
D3 (Vredepeel)	1969–1994
Krusenberg	1955–1980
Langvad	1968–1993
Näsbygård	1970–1995

DT50 / Kfoc	10 L kg ⁻¹	100 L kg ⁻¹	1000 L kg ⁻¹
10 d	T1	T4	T7
50 d	T2	T5	T8
200 d	T3	T6	T9

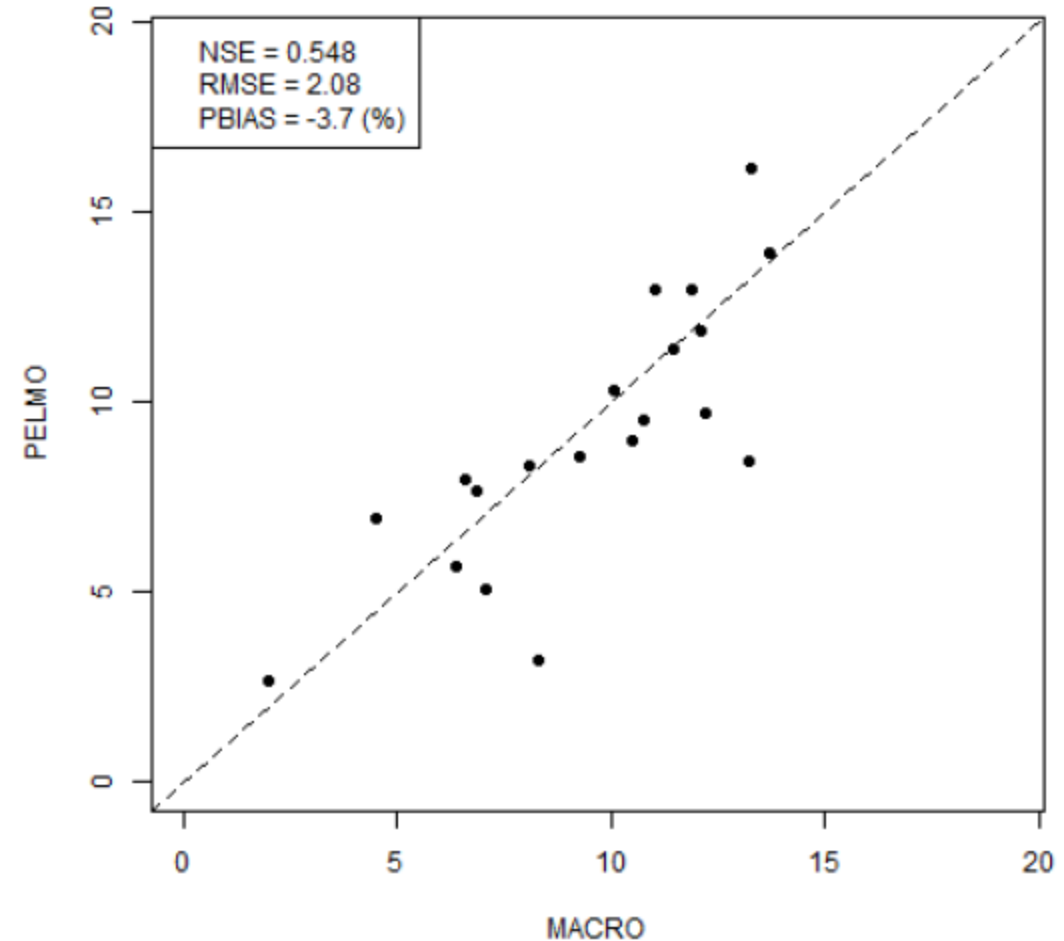
Näsbygard (loamy) - Water balance

- no trend
- moderate deviations

Drainflow in cm / a



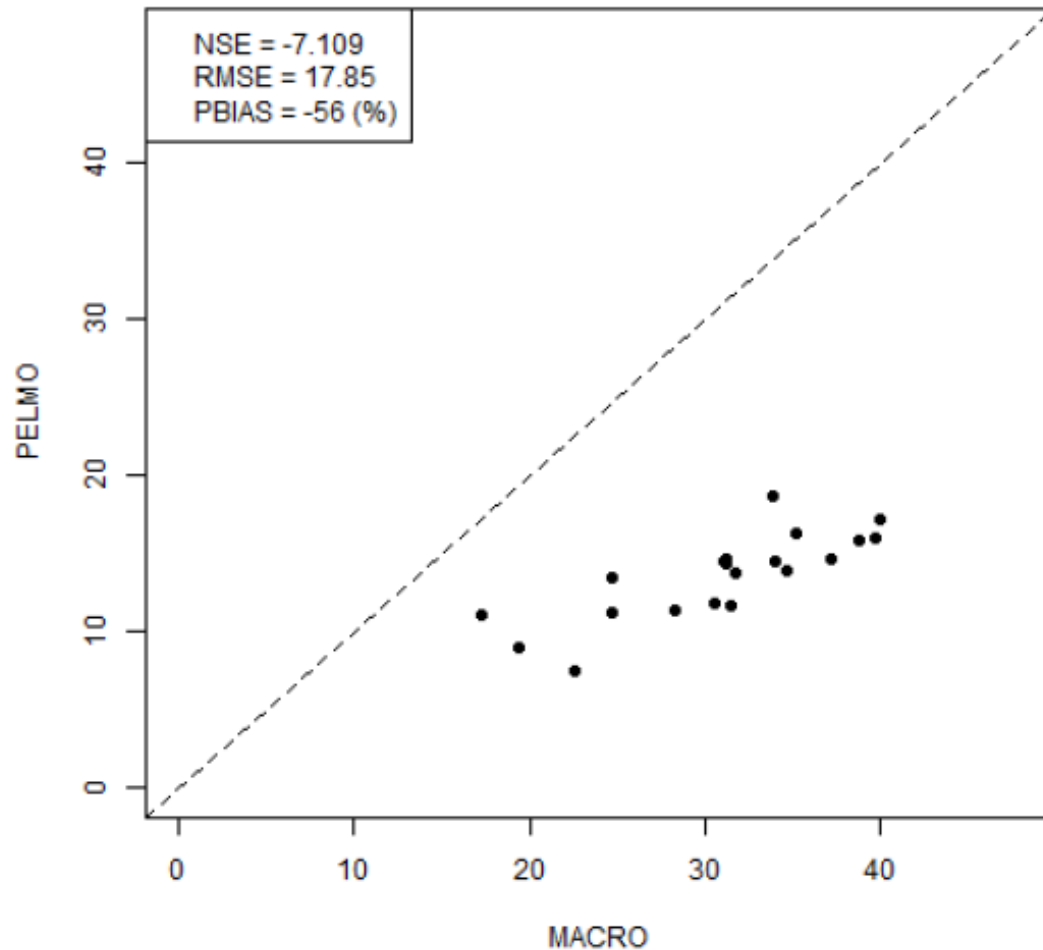
Percolation100 in cm / a



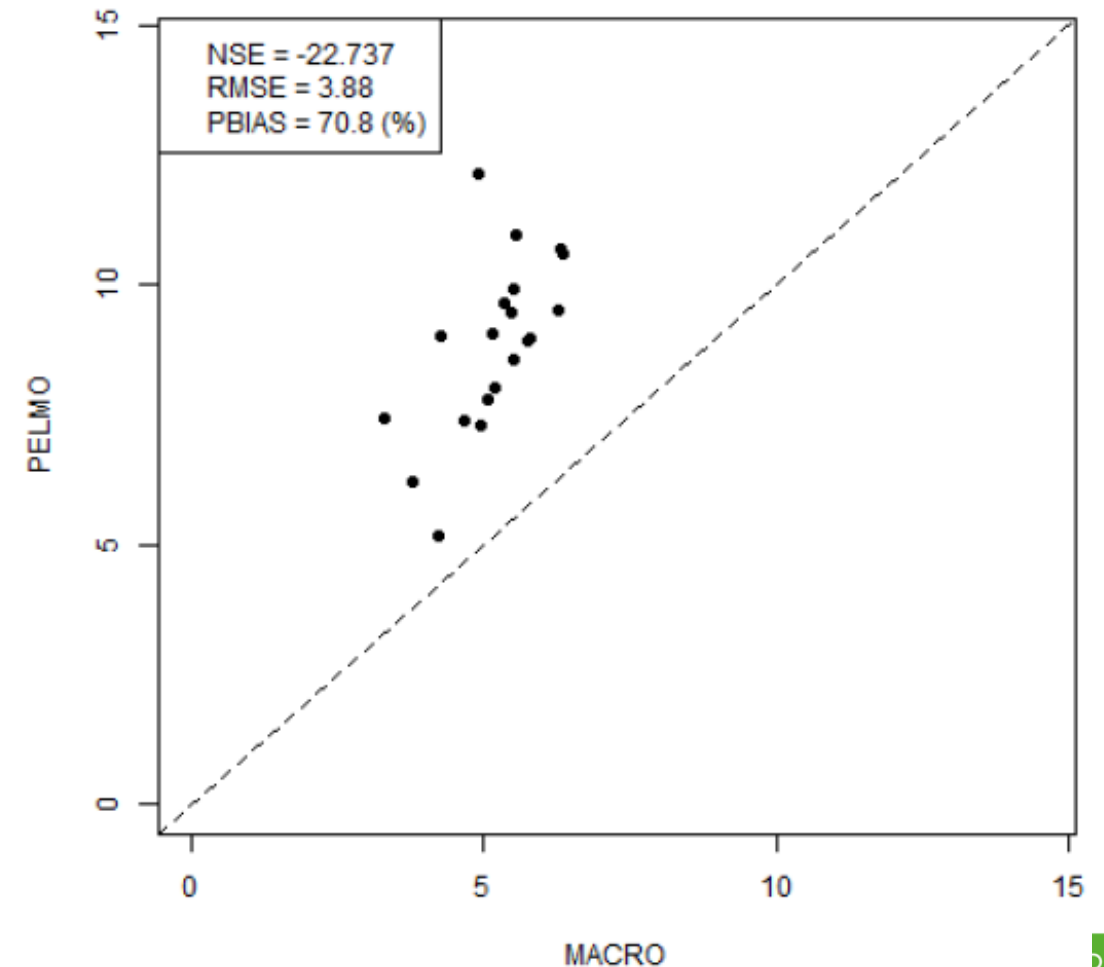
FOCUSsw-D2 (clayey) - Water balance

- clear trend
- MACRO: higher drainflow
- PELMO: higher percolation

Drainflow in cm / a



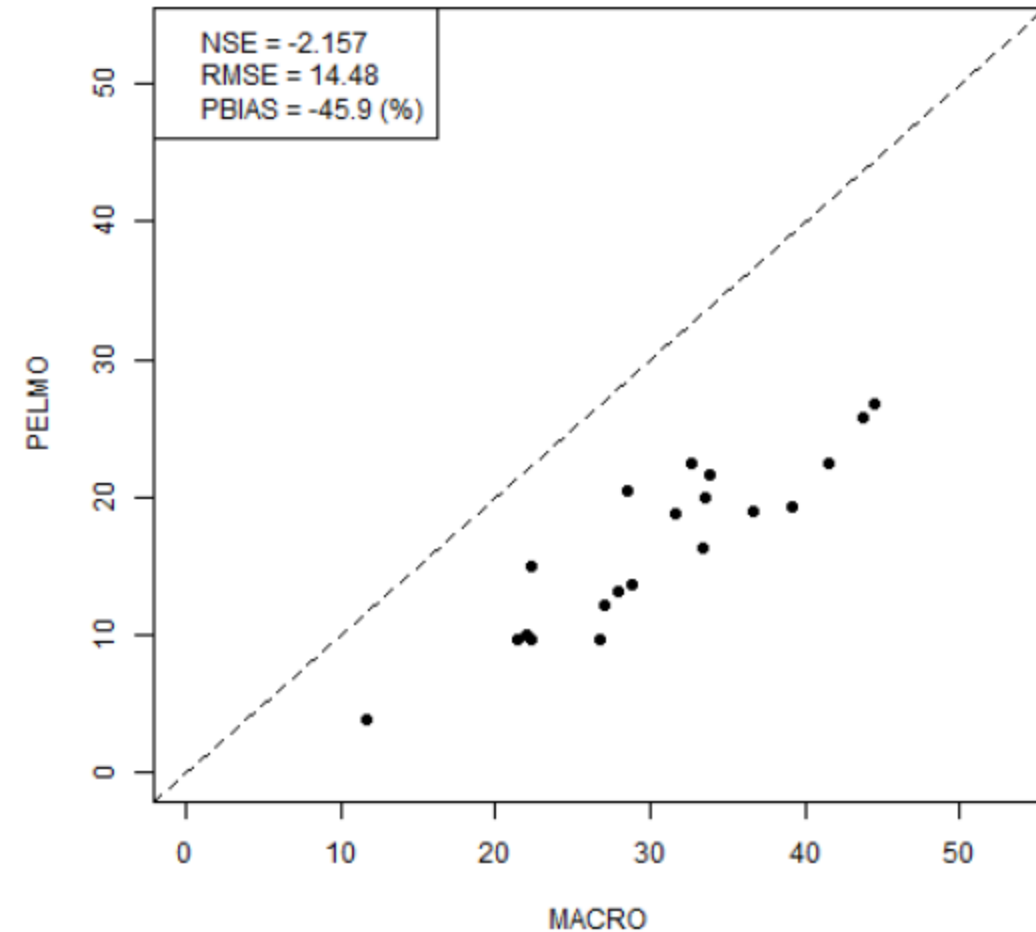
Percolation100 in cm / a



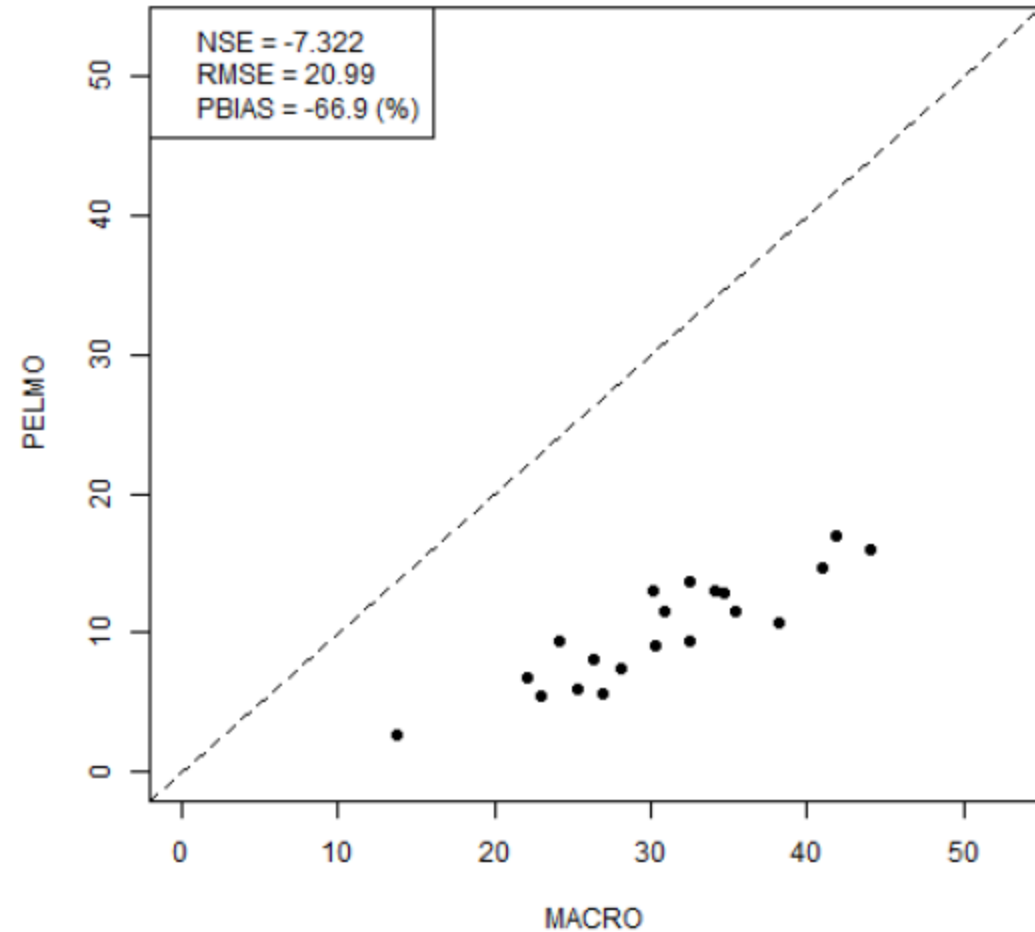
FOCUSsw-D3 (sandy) - Water balance

- clear trend
- MACRO: higher drain-flow and percolation

Drainflow in cm / a

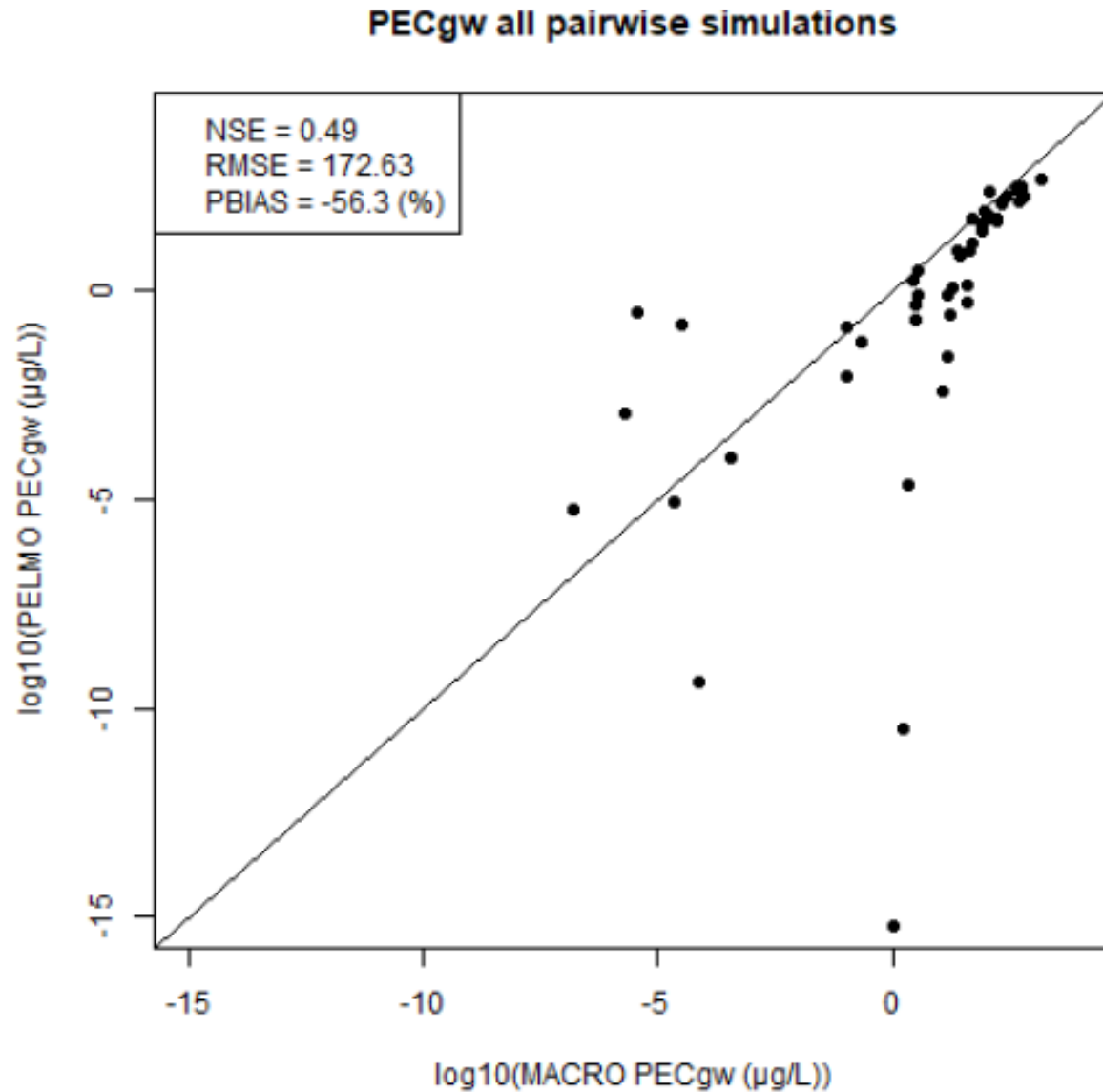


Percolation100 in cm / a



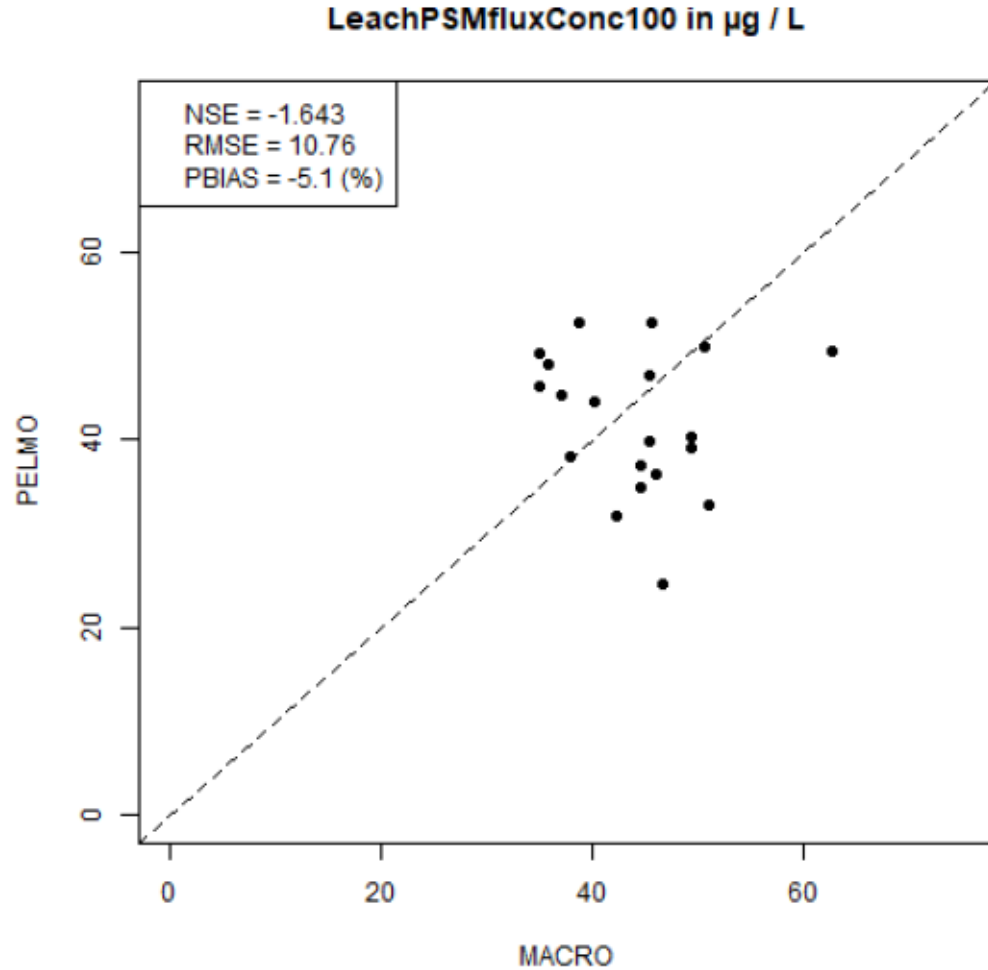
Solute transport: PECgw

- no clear trend
- high differences

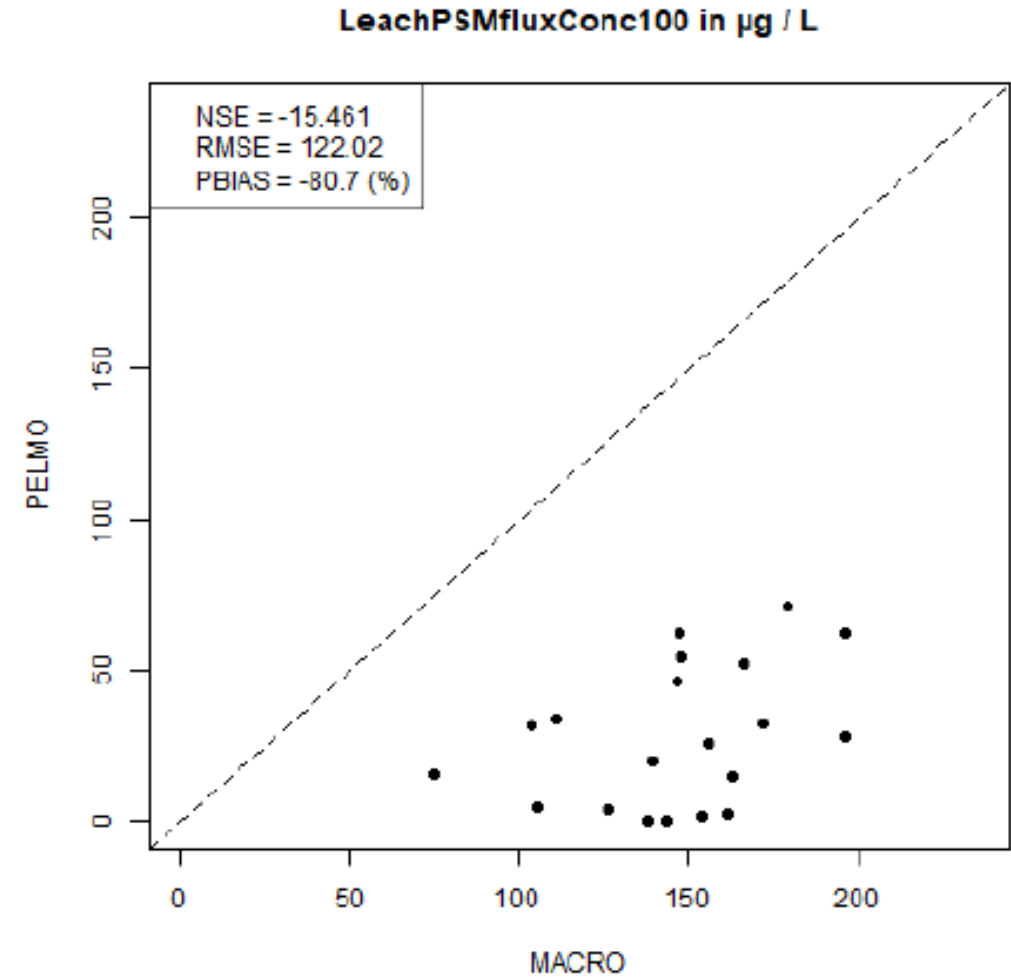


Solute transport: Drainage flux

- Different trends -
high differences

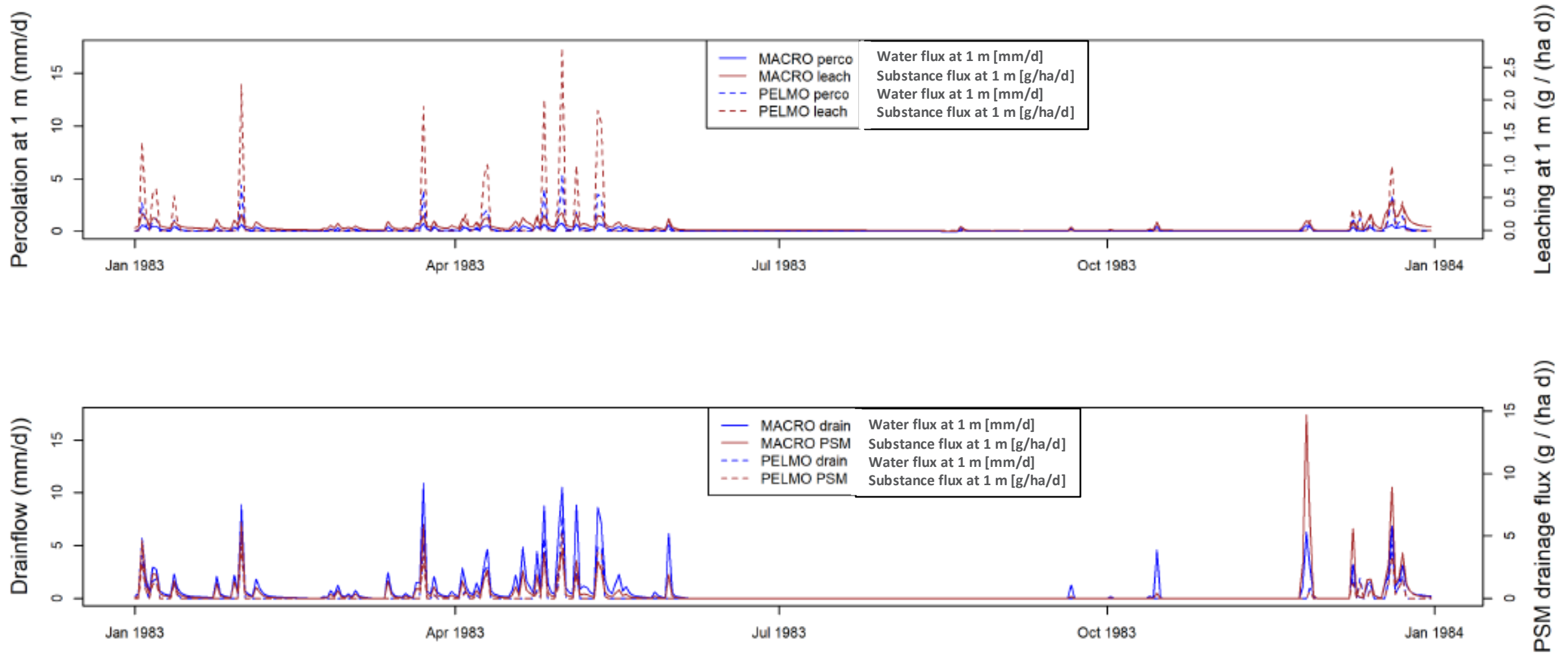


D2 and compound T2 ($K_{\text{foc}} = 10 \text{ L kg}^{-1}$, DT50 = 50 d).



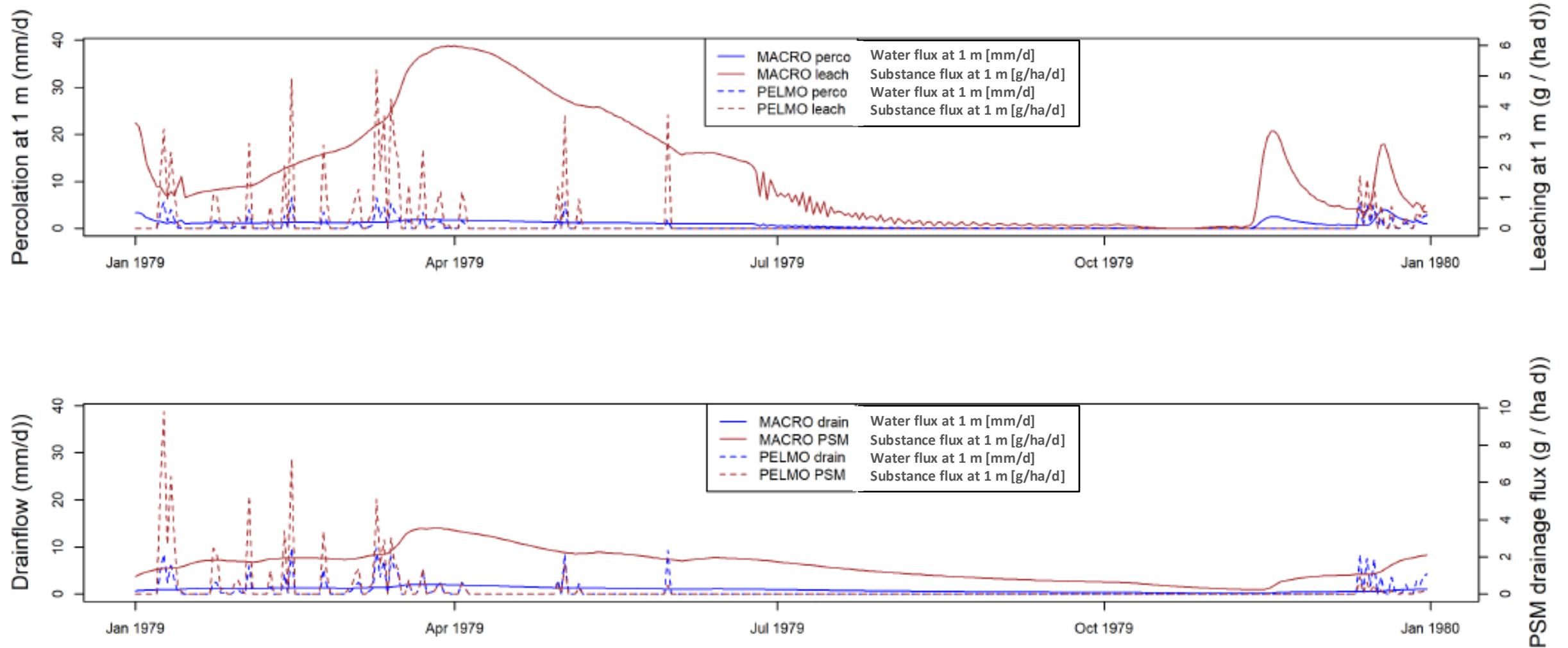
D3 and compound T2 ($K_{\text{foc}} = 10 \text{ L kg}^{-1}$, DT50 = 50 d).

Example: Similar temporal behaviour



Time series for Scenario D2, substance T2 ($K_{f,oc} = 10 \text{ L kg}^{-1}$, $DT50 = 50 \text{ d}$) in year 1983

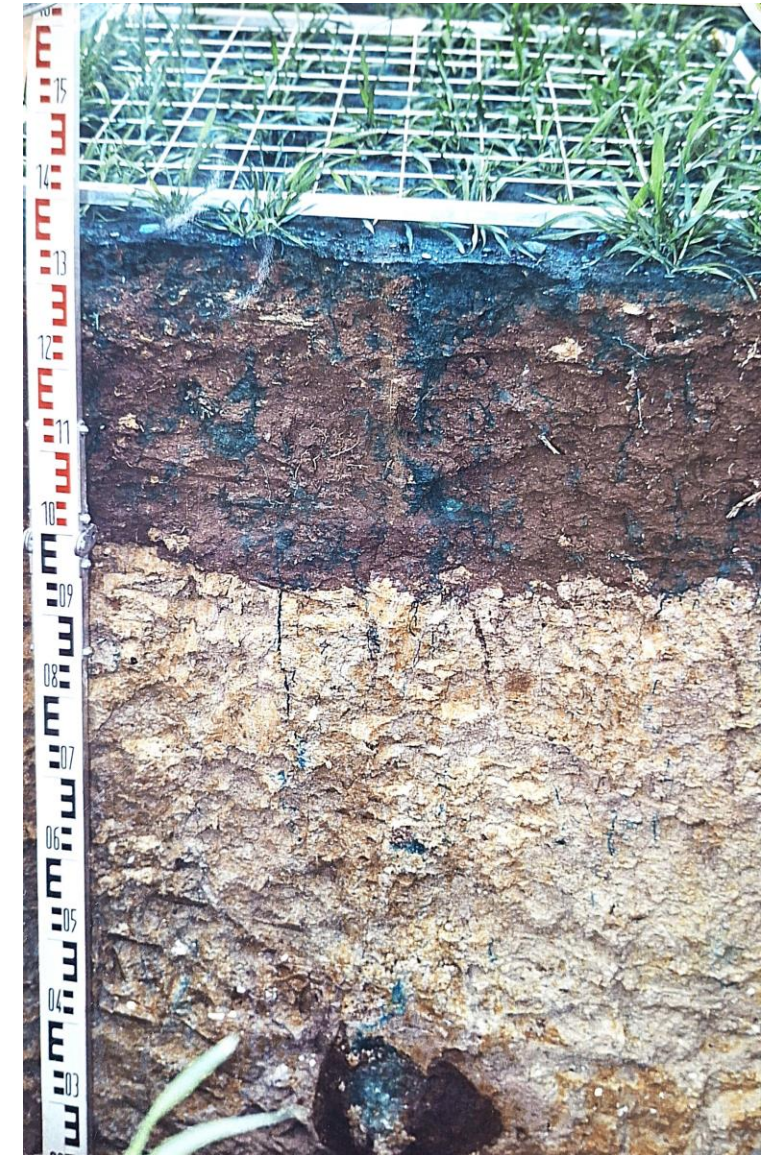
Example: Strongly different temporal behaviour



Time series for Scenario D3, substance T2 ($K_{foc} = 10 \text{ L kg}^{-1}$, $DT50 = 50 \text{ d}$) in year 1979

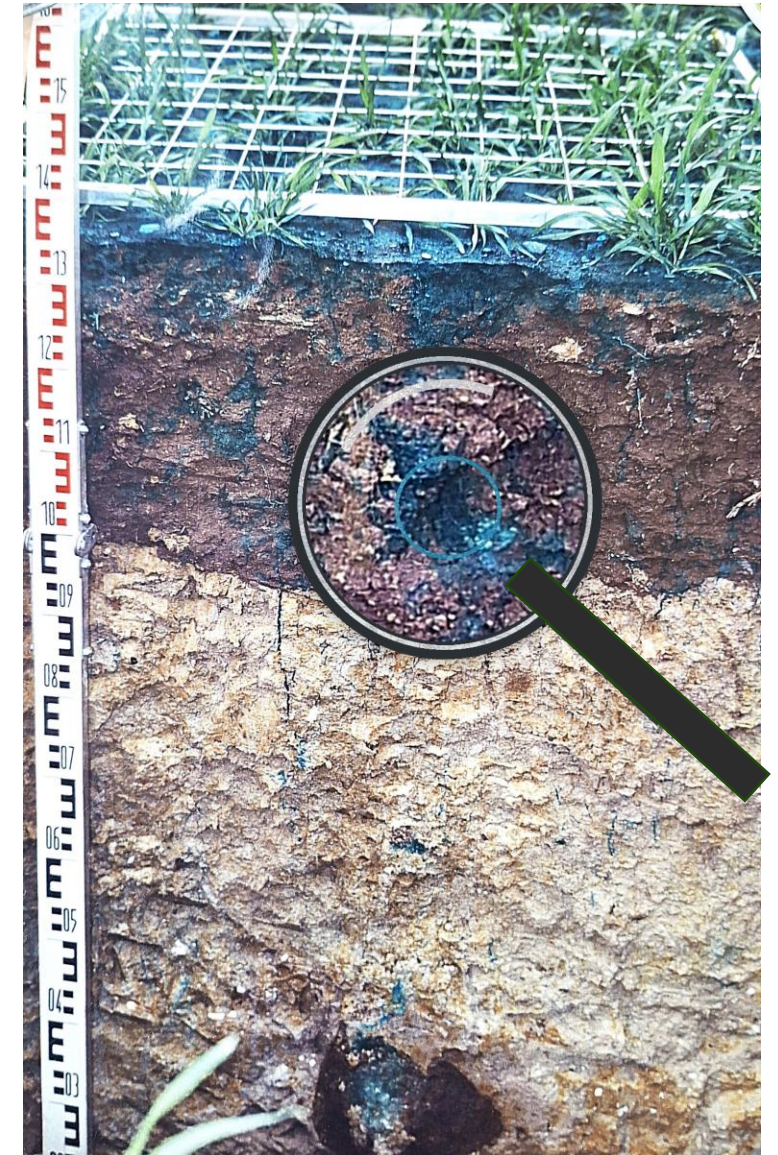
Summary

- GeoPELMO-DE and FOCUS-MACRO rely on fundamentally different macropore concepts.
- Similar results are obtained in a few scenarios
- Large deviations occur in most scenarios, particularly for drainage-driven transport.
- Differences affect hydrology, solute transport and flow dynamics



Conclusion

- Despite several calibration work (PLAP, lysimeters, MACRO) no fully independent validation of the PELMO macropore concept is available
- Large differences between GeoPELMO-DE and FOCUS-MACRO occur for water fluxes and pesticide transport
- Further testing and experience is required before regulatory application of GeoPELMO-DE with macropores
- Open access to the GeoPELMO model important for transparency and independent evaluation



Outlook

- FARM results did not identify macropore flow as a dominant predictor of groundwater concentrations.
- The role of macropore flow in groundwater assessment requires further discussion.
- Improved and transparent macropore parameterisation remains a key challenge (e.g. for use in SDLM)



Thank you very much
for your attention