Funded by
DFG Deutsche Forschungsgemeinschaft

DOC-Prozessstudien in Waldböden zeigen biogeochemische Limitierung der Kohlenstoffspeicherung von Unterböden auf

DOC process studies in forest soils reveal biogeochemical limitation of subsoil carbon storage

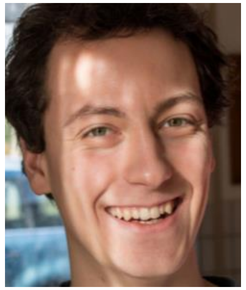
a contribution of:

SUB SOM

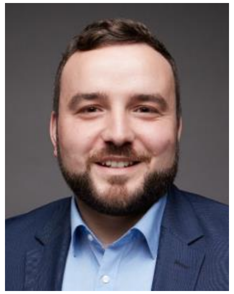
SUBSOM
The forgotten part of carbon cycling: organic matter storage and turnover in subsoils





Georg Guggenberger, Patrick Liebmann,
Robert Mikutta, Karsten Kalbitz,
Patrick Wordell-Dietrich, Timo Leinemann,
Sebastian Preusser, Jörg Bachmann,
Axel Don, Ellen Kandeler,
Bernd Marschner, Frank Scharschmidt



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Mitigation of climate change by soils

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opinion & comment

COMMENTARY:

Aligning agriculture and climate policy

A. Chabbi, J. Lehmann, P. Ciais, H. W. Loescher, M. F. Cotrufo, A. Don, M. SanClements, L. Schipper, J. Six, P. Smith and C. Rumpel

The 4‰ initiative to sequester carbon in soils has the potential to connect sustainable development goals, enhance food security and mitigate climate change by utilizing waste organic residues.

nature COMMUNICATIONS

PERSPECTIVE

https://doi.org/10.1038/s41467-020-18887-7 OPEN

Check for updates

Towards a global-scale soil climate mitigation strategy

W. Amelung[1,2,23✉], D. Bossio[3], W. de Vries[4], I. Kögel-Knabner[5], J. Lehmann[6,7], R. Amundson[8], R. Bol[2], C. Collins[9], R. Lal[10], J. Leifeld[11], B. Minasny[12], G. Pan[13], K. Paustian[14], C. Rumpel[15], J. Sanderman[16], J. W. van Groenigen[17], S. Mooney[18], B. van Wesemael[19], M. Wander[20] & A. Chabbi[21,22,23✉]

Bundesministerium für Ernährung und Landwirtschaft

Warenkorb 0 Suche Menü

Startseite › Ministerium › Presse › Pressemitteilungen › Das Kohlenstoffspeicherpotential in den Böden ausbauen: Neue Pro

25. Mär 2022 — Pressemitteilung — Nr. 37/2022

Das Kohlenstoffspeicherpotential in den Böden ausbauen: Neue Projekte zum Klimaschutz in der Landnutzung gesucht

Das Bundeslandwirtschaftsministerium veröffentlicht zwei Förderbekanntmachungen zur Kohlenstoffspeicherung in landwirtschaftlichen Böden.

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Subsoil organic carbon storage and carbon saturation of soil mineral surfaces

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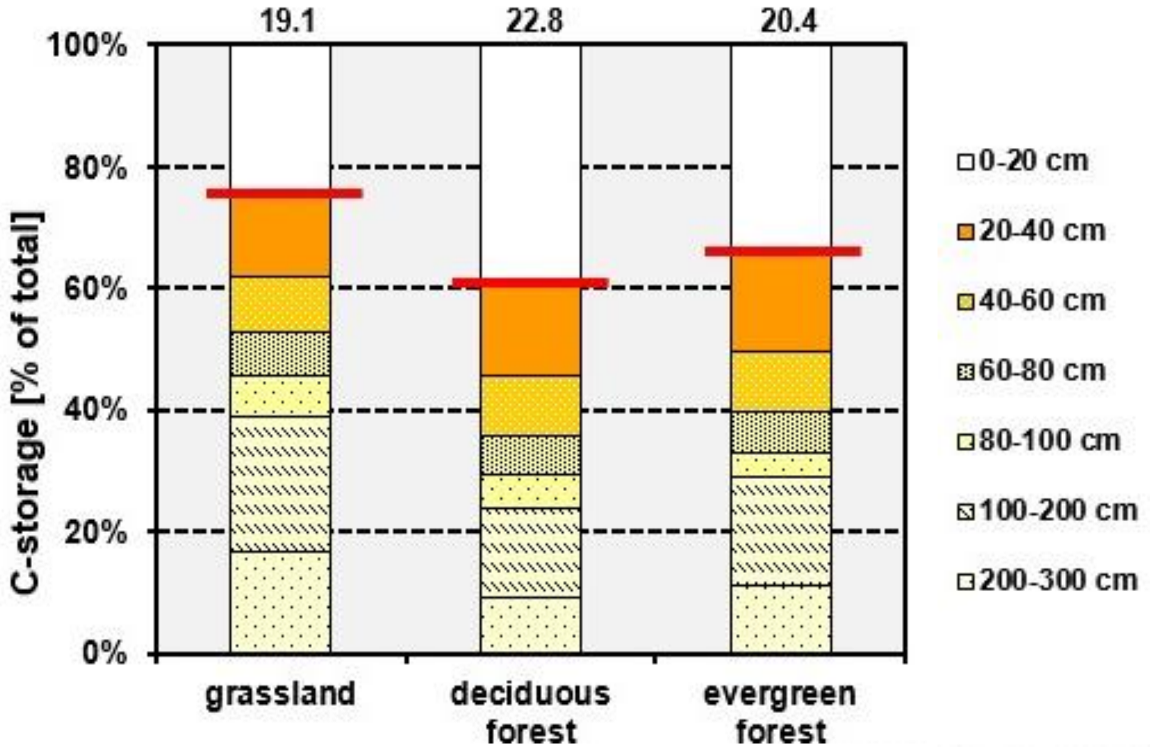
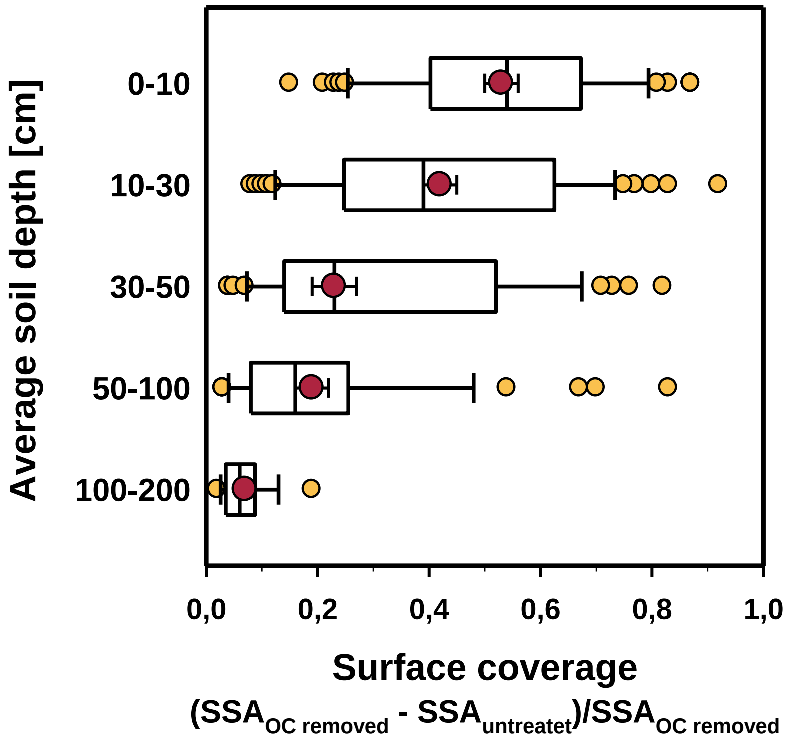


Jobbággy, Jackson (2000) Ecol. Applic.



Kaiser, Guggenberger (2003) Eur. J. Soil Sci.

SSA: specific surface area as determined by N_2 adsorption

Surface coverage → 1: Mineral surface is completely covered by organic matter

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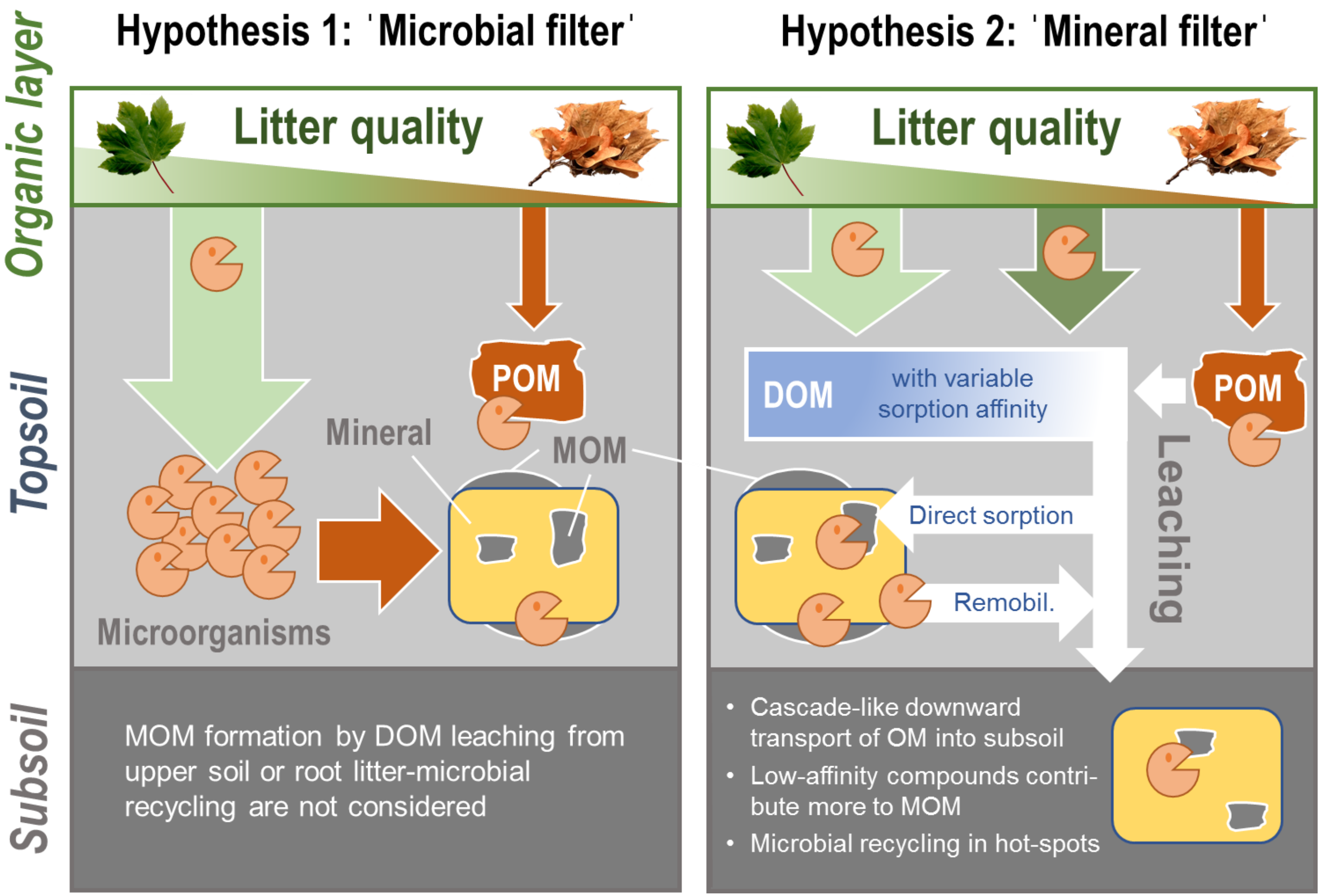
Pathways in the formation of mineral-organic associations

- **Microbial efficiency-matrix stabilization** (Cotrufo et al., 2013)
- **Microbial carbon pump** (Liang et al., 2017)
- **Cascade model of sorption, microbial processing and desorption** (Kaiser, Kalbitz, 2012)
- ***In-vivo* microbial turnover versus direct sorption** (Sokol et al., 2019)



Mikutta, Turner, Schippers, Gentsch, Meyer-Stüve, Condron, Peltzer, Richardson, Eger, Hempel, Kaiser, Klotzbücher, Guggenberger (2019) Sci. Rep.

Research questions

(1) Why is the OC loading of minerals in subsoil so low?

(2) What is the *in-situ* turnover of OC entering the mineral soil as DOC?

(3) What is the role of microbial processing for the formation and mobilization of mineral-associated organic carbon (MAOC)?

(4) Can higher OC input to subsoil increase MAOC in subsoil?

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Beech forests in northern Germany

Grinderwald	Rüdershausen	Ebergötzen
Dystric Cambisol	Haplic Luvisol	Dystric Cambisol
(Glacio-flucial sand)	(Silty loess)	(Triassic red standstone)






Photos: Patrick Liebmann

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Photos: Patrick Liebmann

Subsoil observatories with ^{13}C labeled litter as source material of DOC entering mineral soil

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3 Suboil observatories
in a Dystric Cambisol under beech

- Removal of old litter
- Replaced with **^{13}C labeled litter**
- After 22 months removal of remains of labeld letter and replacement by unlabeld litter (**switch-off**)

Photos: Patrick Wordell-Dietrich

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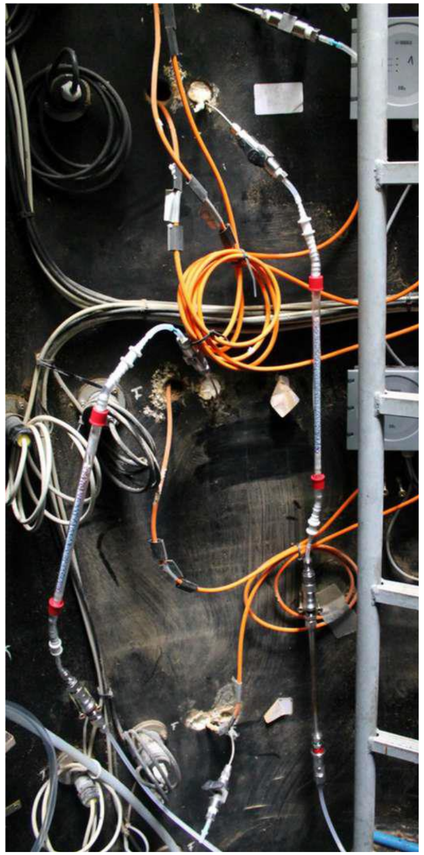
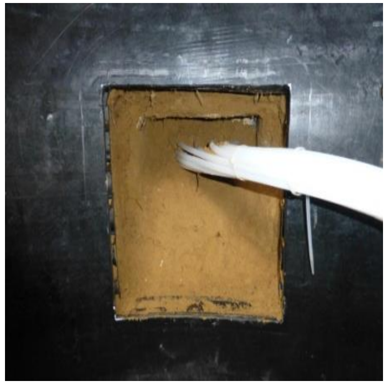
Subsoil observatories: Installations for ^{13}C monitoring










In 10, 50, 150 cm soil depth:

CO_2 sensors and gas samplers (plus chambers on top)

Segmented plate lysimeters

TDR probes, tensiometers, thermometers

Rhizoscopes

Photos:
Patrick Wordell-Dietrich, Timo Leinemann

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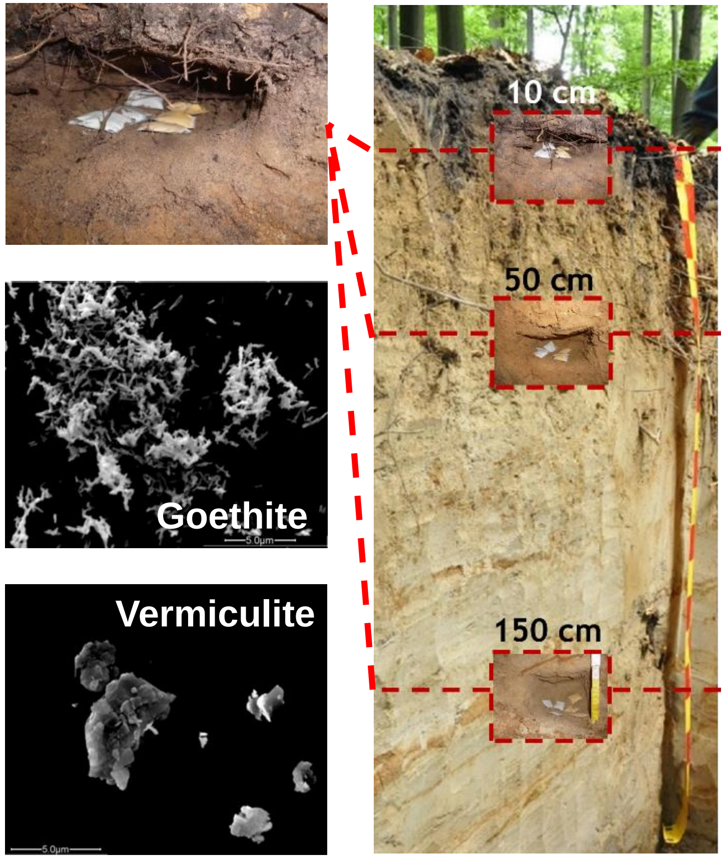
In-situ incubation of mineral-associated organic carbon (MAOC)



Goethite and vermiculite loaded with ^{13}C-labeled OM with similar concentration as clay fraction in subsoil (4-9 mg C g^{-1} mineral)

24 months field exposure

Photos:
Patrick Liebmann

Batch sorption experiments

- **Sorption isotherms** of soils from three beech sites with litter DOC extracts (up to 400 mg L^{-1})
- **Desorption experiments** with background solution


Photo: Robert Mikutta

Mean OC contents, stocks, and SOC distribution

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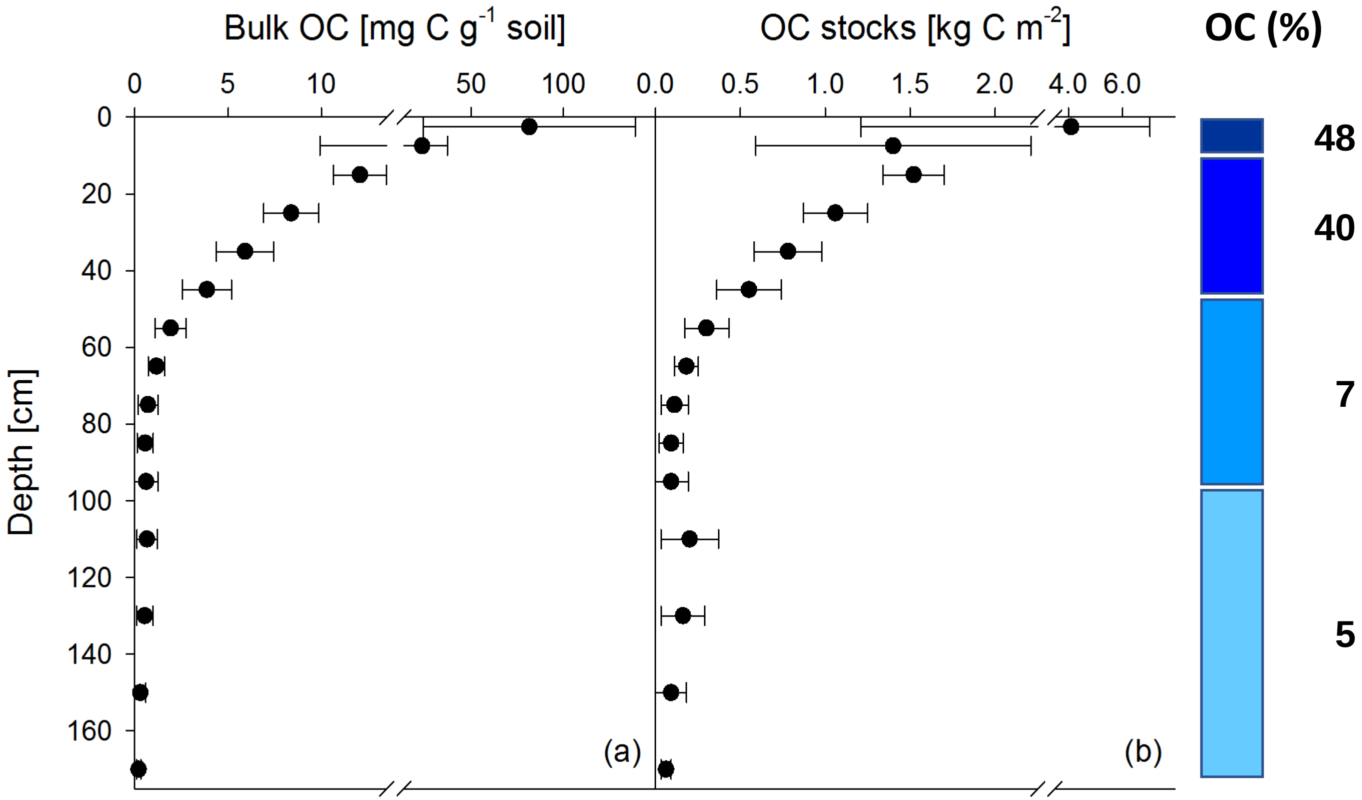
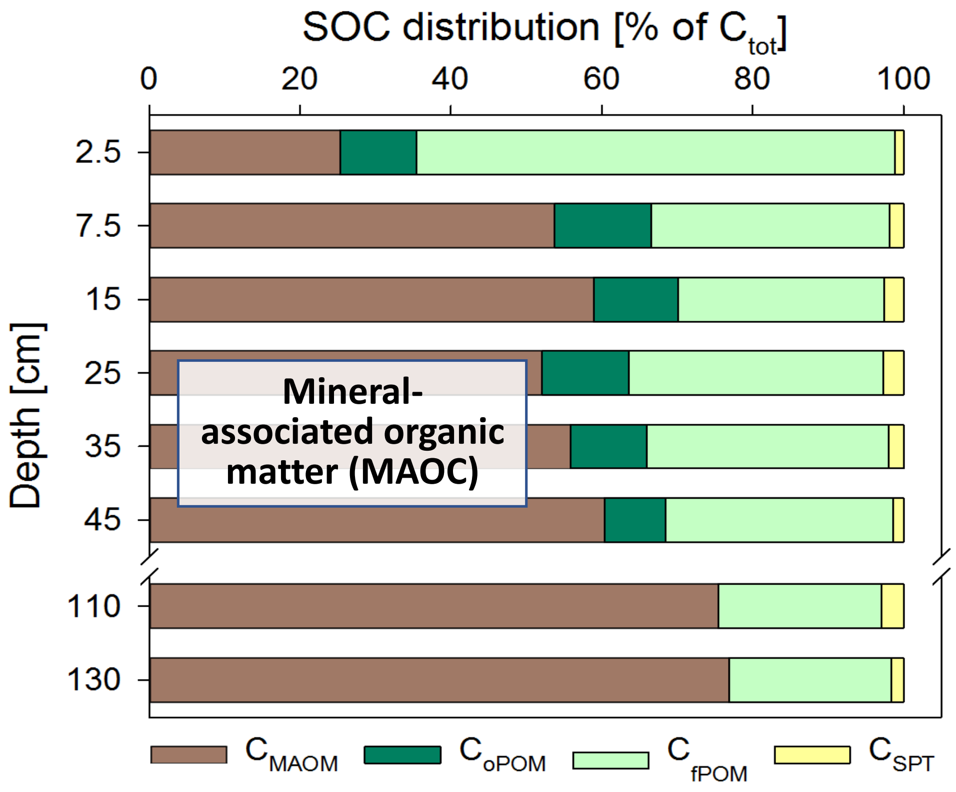


Liebmann, Wordell-Dietrich, Kalbitz, Mikutta, Kalks, Don, Woche, Dsilva, Guggenberger (2020) Biogeosci.



C_{MAOM} = C mineral-associated organic matter fraction
C_{oPOM} = C in occluded particulate organic matter fraction
C_{fPOM} = C in free particulate organic matter fraction
C_{SPT} = C in sodium polytungstate density solution

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Mean concentrations of DOC and UV absorption

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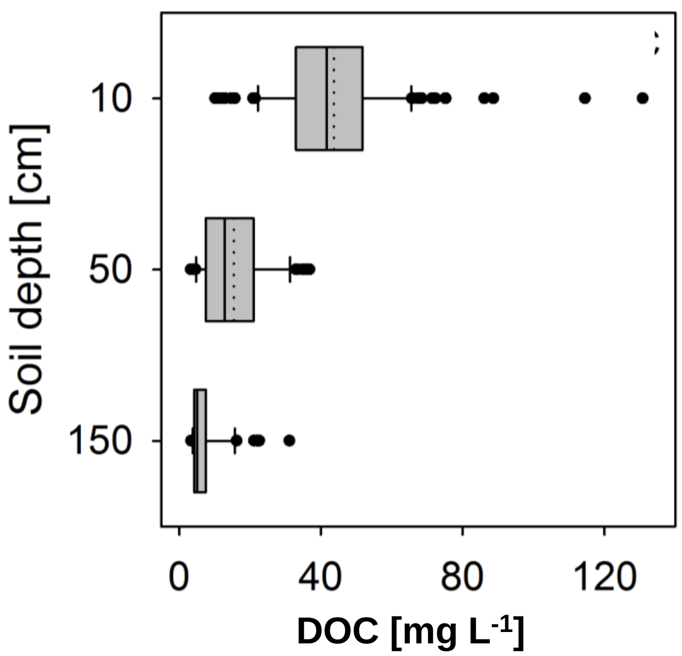

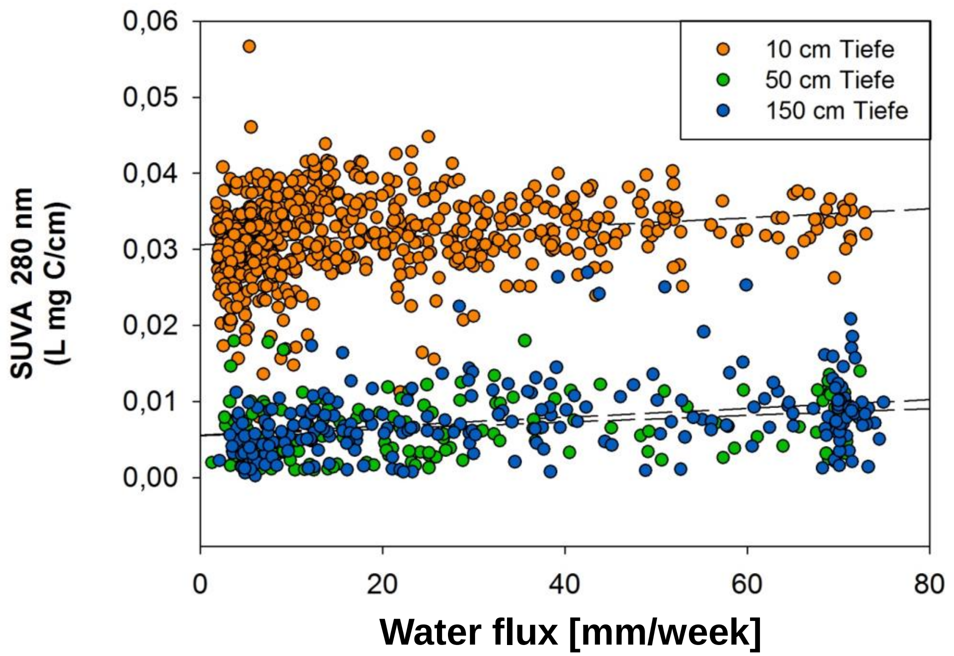

Leinemann, Mikutta, Kalbitz, Schaarschmidt, Guggenberger (2016) Biogeochem.

Small DOC concentrations and low aromaticity of DOM in subsoil

DOC sorption capacity: Sorption isotherms

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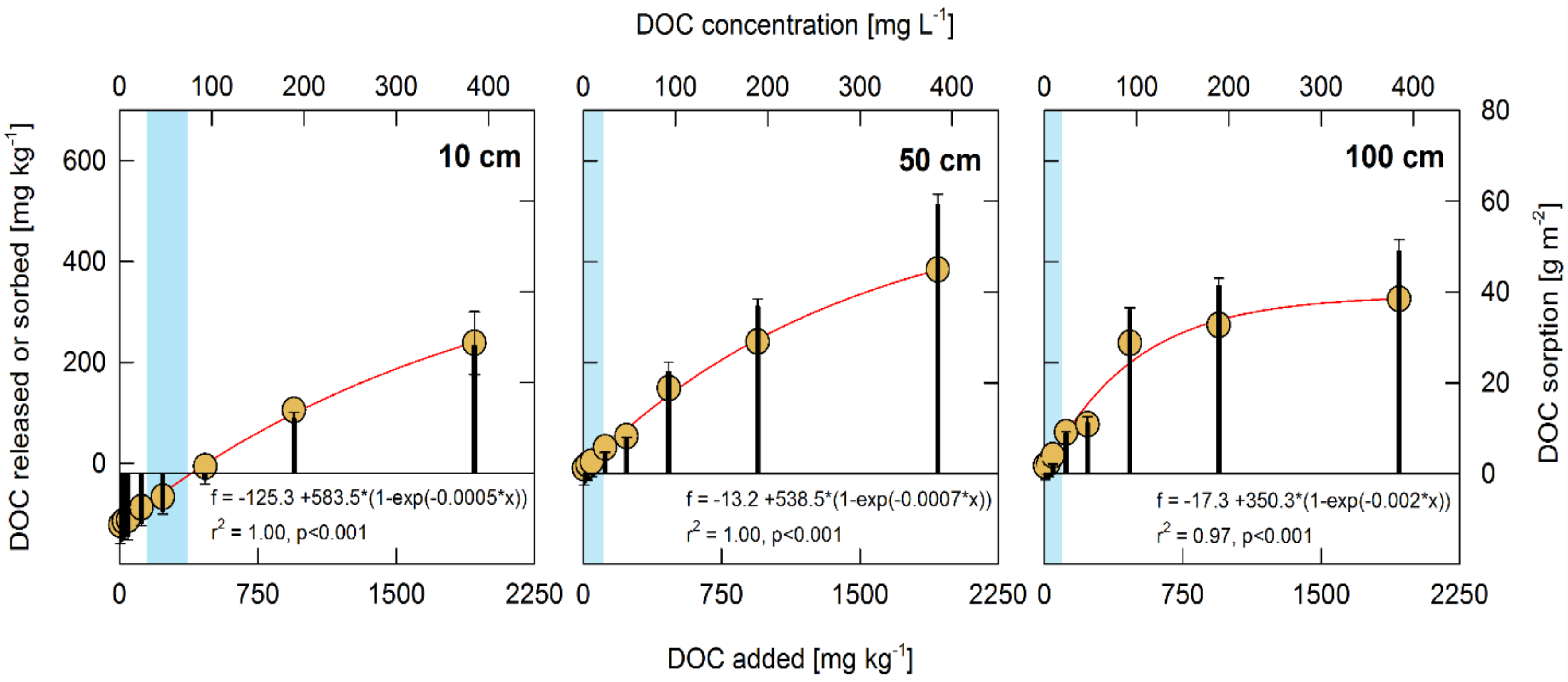

Black bars show quantified DOC sorption in g per m^2 and 10 cm soil thickness

Blue-marked areas represent typical **DOC concentrations** in the field

Liebmann, Mikutta, Kalbitz, Wordell-Dietrich, Leinemann, Preusser, Mewes, Perrin, Bachmann, Don, Kandeler, Marschner, Schaarschmidt, Guggenberger (2022) J. Plant Sci. Soil Nutr.

Sorption-desorption processes are governed by *in-situ* solution equlibrium

Sorption isotherms proof high sorption capacity, but suggest desorption at typical field DOC concentrations

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Cumulative new litter-derived (^{13}C-labeled) DOC flux in the soil

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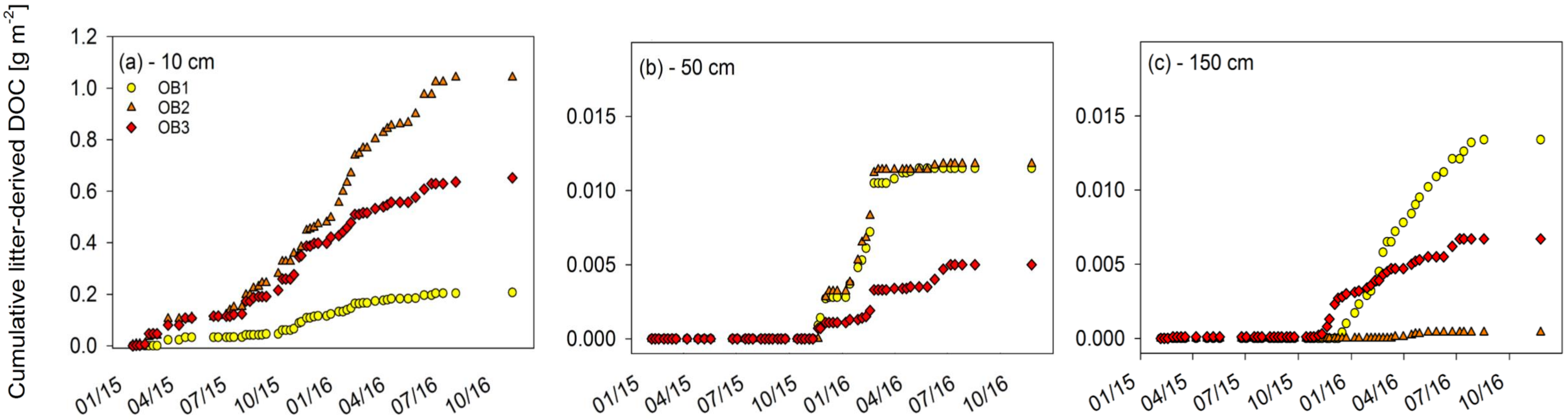

Liebmann, Mikutta, Kalbitz, Wordell-Dietrich, Leinemann, Preusser, Mewes, Perrin, Bachmann, Don, Kandeler, Marschner, Schaarschmidt, Guggenberger (2022) J. Plant Sci. Soil Nutr.

Only little transport of litter-derived DOC to deeper subsoil

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Cumulative of new litter-derived CO_2 flux in the soil

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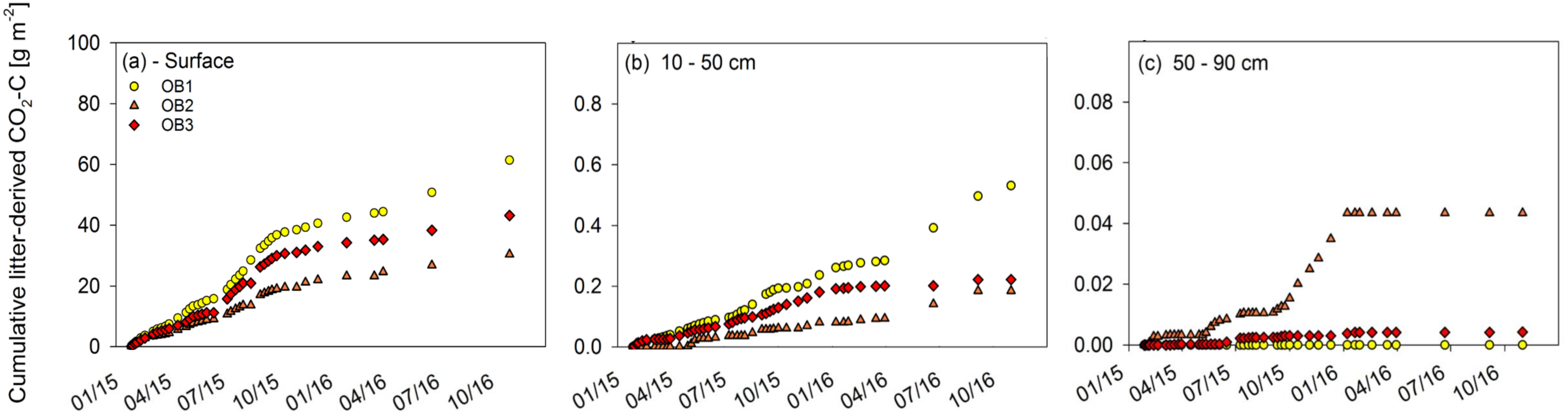


Wordell-Dietrich, Wotte, Rethemeyer, Bachmann, Helfrich, Kirfel, Leuschner, Don (2020) Biogeosci.

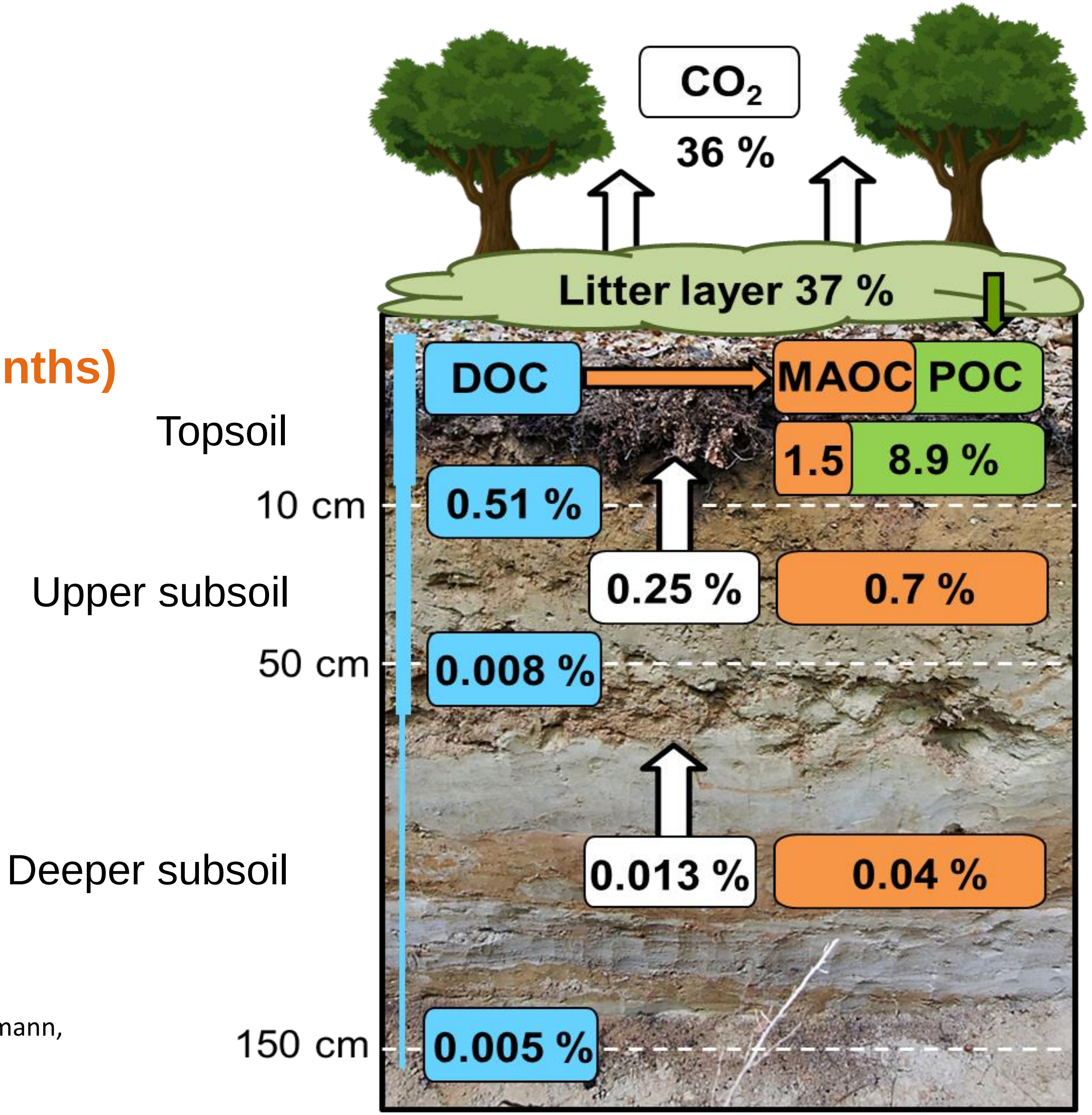
Litter-derived OC transported to subsoil is partly readily available (confirmed by ^{14}C analysis)

Recovery of litter-derived C into different C pools

(% of initially applied labeled litter after 22 months)

Pools (total recovery about 85%):

- **CO_2 soil efflux**
- **Residual litter**
- **Dissolved organic carbon**
- **Mineral-associated organic carbon**
- **Particulate organic carbon**



Only 2% of litter-derived OC formed MAOC

Predominantly MAOC formation in topsoil

Liebmann, Mikutta, Kalbitz, Wordell-Dietrich, Leinemann, Preusser, Mewes, Perrin, Bachmann, Don, Kandeler, Marschner, Schaarschmidt, Guggenberger (2022) J. Plant Sci. Soil Nutr.

Switch off: Litter-derived OC in the soil after 22 and 40 months of labeling

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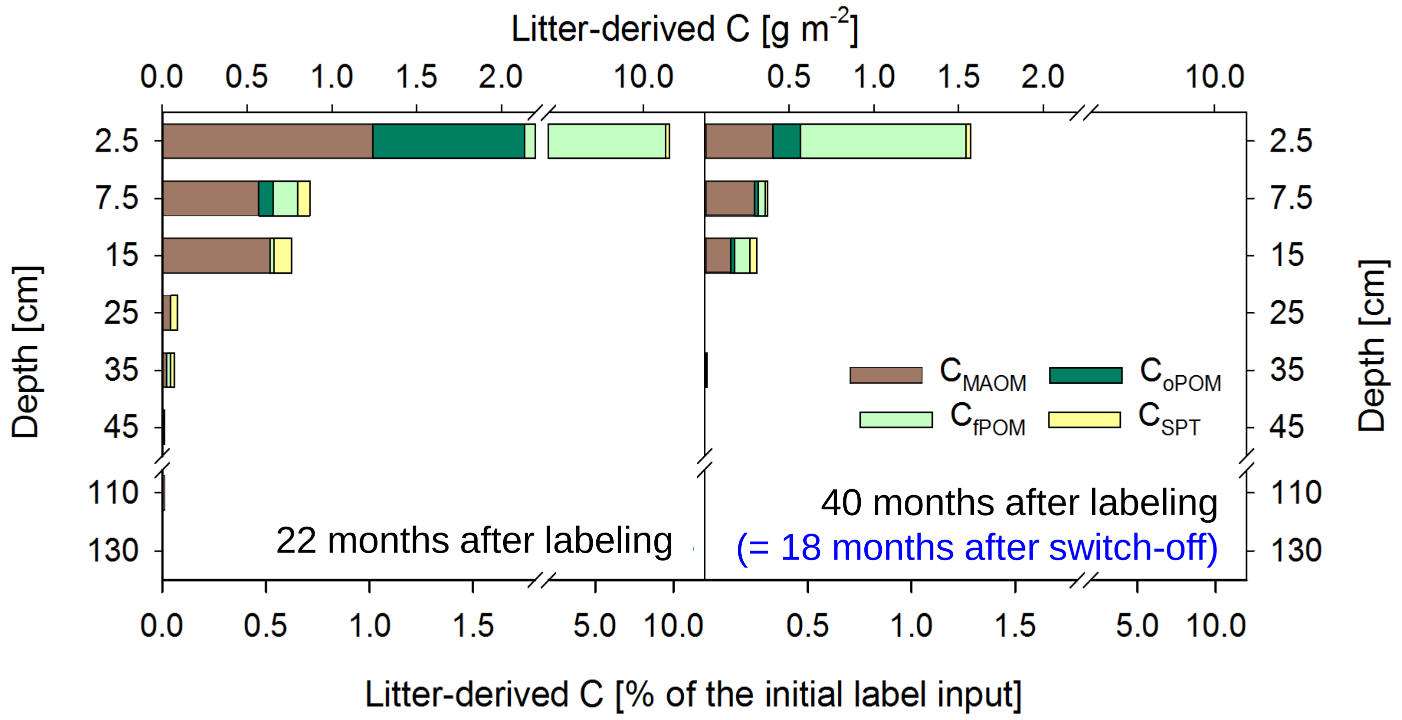

Fraction	Loss in 18 months [%]
C_{MAOM}	66
C_{fPOM}	89
C_{oPOM}	77
C_{SPT}	84
C_{WEOM}	80

Liebmann, Wordell-Dietrich, Kalbitz, Mikutta, Kalks, Don, Woche, Dsilva, Guggenberger (2020) Biogeosci..

New litter-derived OC is turning over fast, even after formation of MAOC

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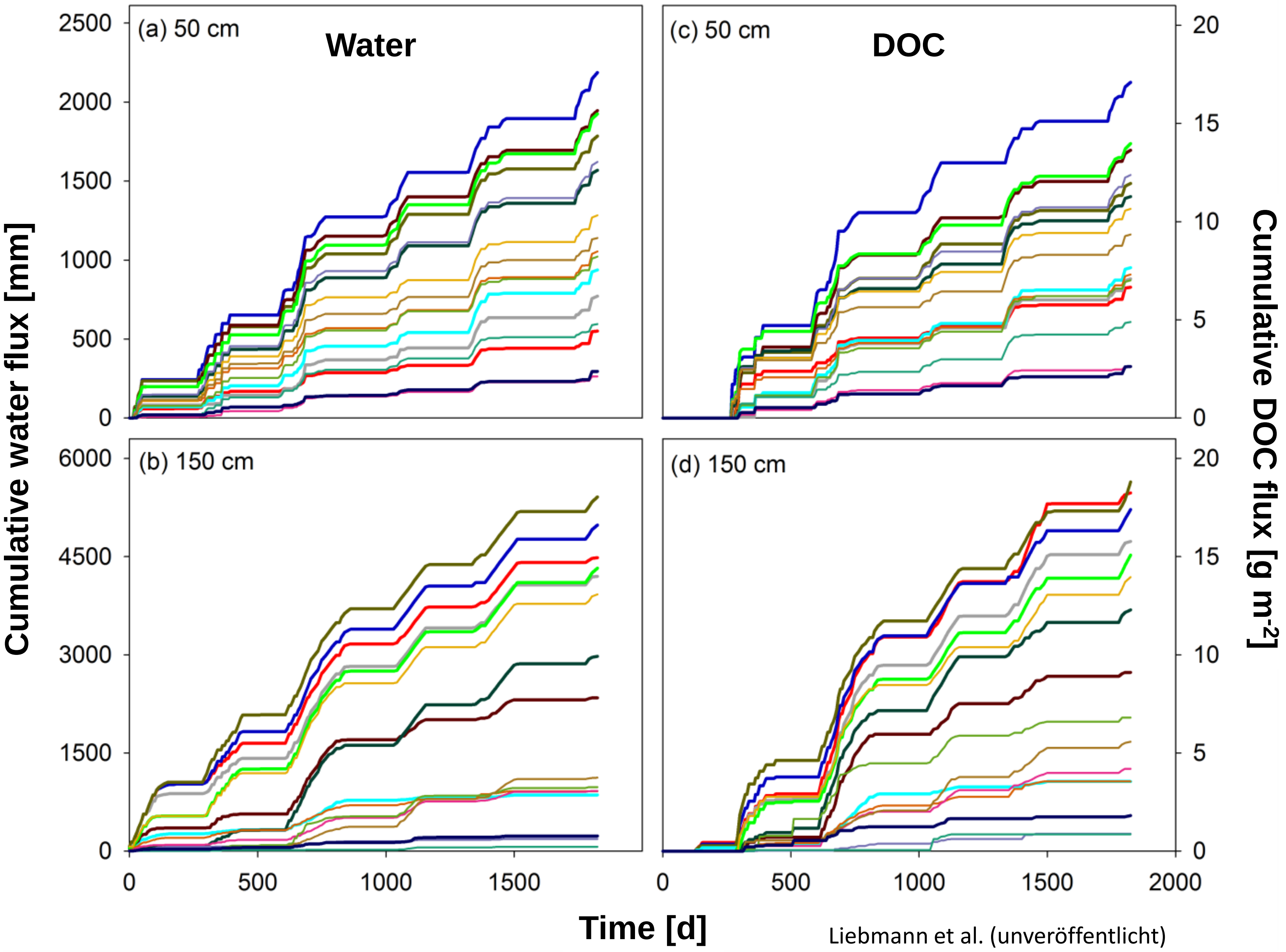
Cumulative water and DOC fluxes in 50 cm and 150 cm soil depth in individual segments



Liebmann et al. (unveröffentlicht)

Flowpaths are stable over time

Channeling along preferential flow paths reduces C retention and likely forms hot spots

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Gross C exchange of ^{13}C-labeled MAOC after 2 yrs (*in-situ* incubation of ^{13}C-loaded minerals)

ΔC (+), ΔC (-): Net difference in C content after incubation in % of Initial MAOC

MC: Amount of mobilizable C during field exposure in % of **intial MAOC**

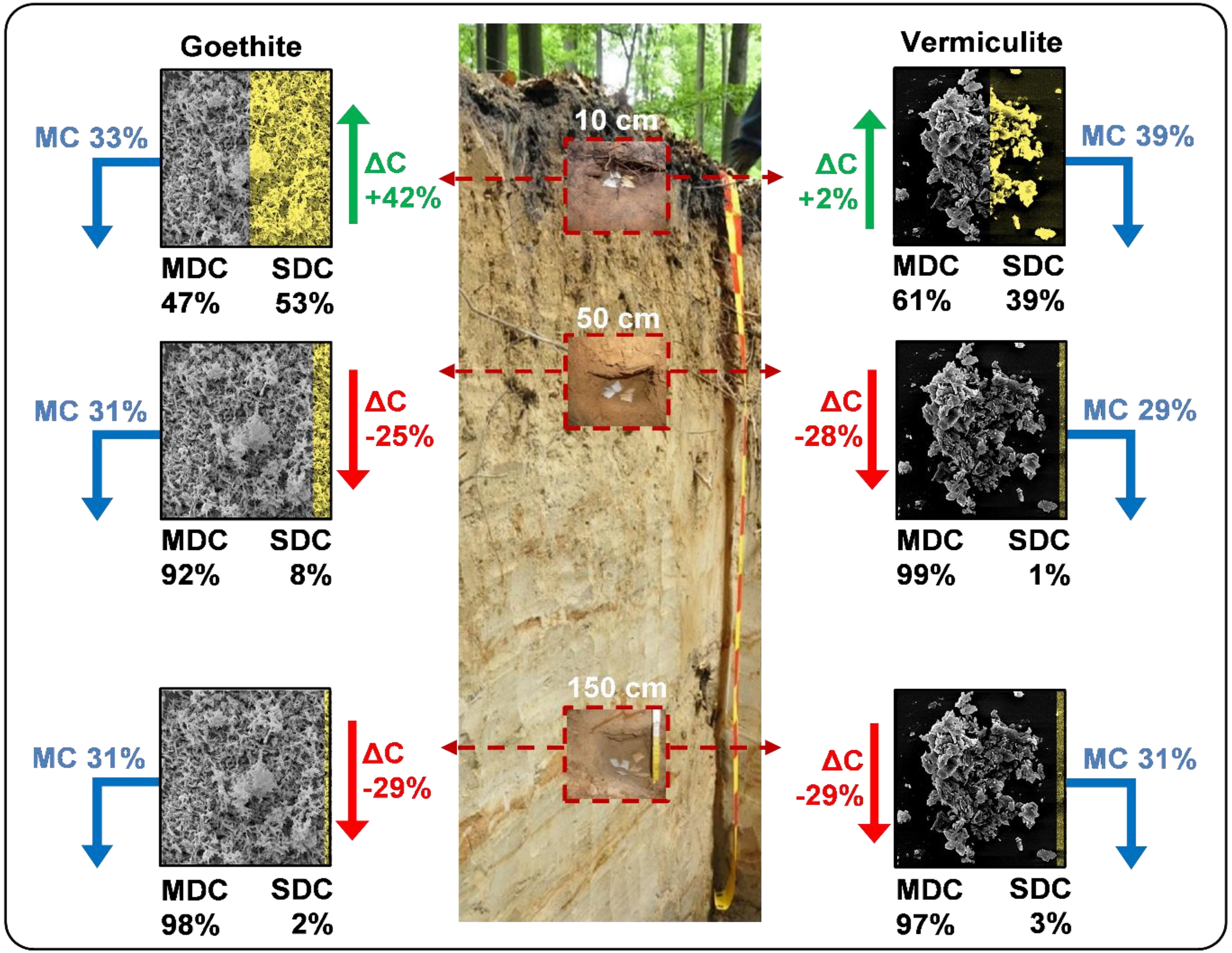
MDC: Proportion of final content of pre-existent **mineral derived C**

SDC: Proportion of final content of fresh soil **solution derived C** (yellow)

High exchange rate of C

MOAC is C source in subsoil

Considerable mobilization of native C



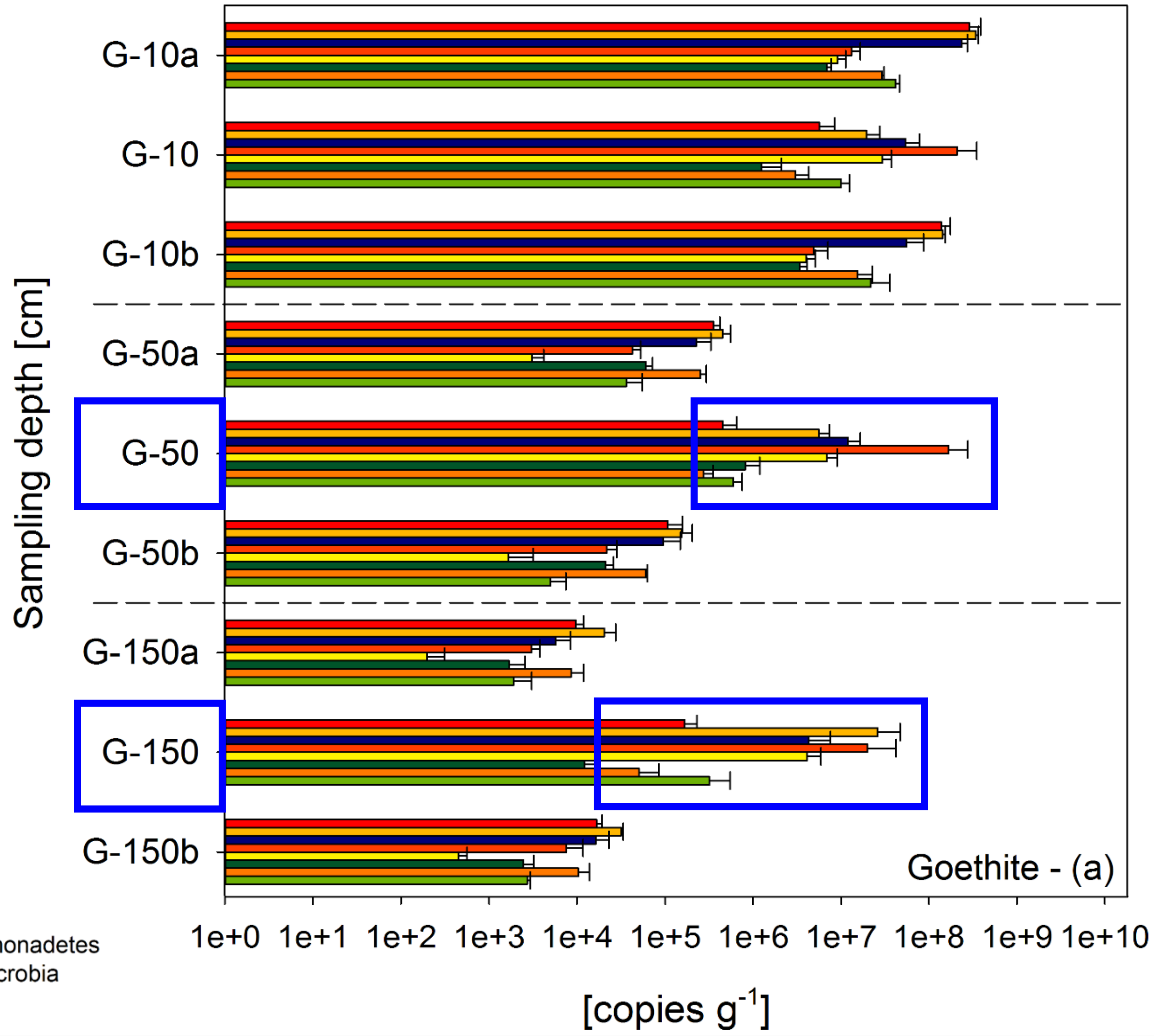
Liebmann et al. (2022) J. Plant Sci. Soil Nutr.

Bacterial community composition (goethite)

G: Goethite

10, 50 150 cm: Soil depth

a, b: above and below the buried mineral meshbags



Liebmann et al. (2022) J. Plant Sci. Soil Nutr.

Hot spots (copriotrophic *Betaproteobacteria*) on mineral surfaces in subsoil (high proportion of dissolved carbohydrates, high exchange rates of OC)

Microorganisms involved in MAOC mobilization

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Conclusions

(1) Forest subsoils are in a steady-state equilibrium between C inputs to a horizon and C outputs

(2) C input to the subsoil with DOC, potentially forming MAOC, is limited (and dominated by less sorptive and bioavailable carbohydrates)

(3) Channeling along preferential flowpaths further impedes MAOC formation

(4) Organic matter loaded minerals are microbial hotspots in the subsoil, with utilization of freshly sorbed C and mobilization of native C (priming)

(5) Increased C input into subsoils potentially promotes mobilization and mineralisation of older native organic matter (DOC priming)

Under current conditions, subsoils in temperate forests likely cannot be considered as additional C sinks.