Master 2's internship opportunity (master 2 thesis) – from January/February 2025 (6-month duration)

Vulnerability of mineral-organic associations in wheat rhizosphere under climate stress

Background and objectives

Soils are the largest reservoir of organic carbon on Earth, storing more than both the atmosphere and terrestrial vegetation combined. This large storage capacity makes them a key player in addressing two major global challenges: maintaining agricultural productivity and mitigating climate change (see 4 per 1000 Initiative). In some soils, up to 90% of organic carbon is bound to minerals, forming **mineral-organic associations** (Lugato et al., 2021). These associations are far from passive repertories: some have been shown to supply up to one-third of the nitrogen absorbed by grassland species (Jilling et al., 2025). These associations play a central role in **soil fertility and climate regulation**. Yet, the mechanisms underlying their formation, stability, and bioavailability remain poorly understood.

The rhizosphere (the zone of soil directly influenced by plant root) is a hotspot for the destabilization of these associations. Through the release of root exudates and stimulation of microbial activity, mineral-organic associations can be disrupted via desorption, depolymerization of organic matter, and partial dissolution of mineral phases (Bölscher et al., 2025). This process releases organic compounds that become accessible to soil microbes and plant roots. However, the nature of these associations varies: organic matter may be adsorbed onto crystalline minerals, co-precipitated with poorly crystalline phases, or bound to amorphous mineral structures (Basile-Doelsch et al., 2020; Kleber et al., 2021; Jamoteau et al., 2025). These structural differences likely influence their vulnerability and their capacity to serve as nutrient reservoirs.

In addition, environmental factors such as shifting precipitation patterns, marked by more frequent droughts and extreme rainfall events (IPCC, 2023), may further affect the stability of these associations. Changes in soil moisture, redox conditions, pore connectivity, microbial communities, and the quantity and composition of root exudates could disproportionately impact associations, notably the ones involving poorly crystalline mineral phases.

This internship/master 2 thesis aims to identify which types of mineral-organic associations are most susceptible to destabilization in the rhizosphere, and therefore most bioavailable, under changing precipitation regimes.

Internship description

The selected candidate will contribute to a laboratory experiment designed to compare two types of mineral-organic associations: one formed by adsorption of organic matter onto mineral surfaces, and another formed by co-precipitation with amorphous mineral phases. These associations will be synthesized in the lab using ^{13}C-labeled organic matter, allowing for precise tracking of carbon dynamics in the soil and in CO_2 emissions.

The labelled associations will be incorporated into soil microcosms planted with wheat and maintained under controlled conditions for two months. During this period, the intern will monitor $^{13}CO_2$ emissions to assess carbon mineralization and the extent of association destabilization. Soil samples, both bulk and rhizosphere, will be collected and analyzed using isotope ratio mass spectrometry (IRMS) to quantify remaining ^{13}C and determine how much carbon was mobilized in the rhizosphere.

This internship offers hands-on training in soil biogeochemistry, isotope tracing, and plant-soil interactions. The candidate will work within a collaborative and interdisciplinary research team, with opportunities to contribute to scientific publications and explore future doctoral (PhD thesis) research related to soil carbon stabilization and fertility.

Practical information

The internship will take place at CEREGE (Aix-en-Provence, France), starting in February 2025 for a duration of six months (flexible start date). It will be hosted within the Sustainable Environment and Climate research team at CEREGE. The intern will be supervised by Floriane Jamoteau (Research Scientist, INRAE) and Isabelle Basile-Doelsch (Senior Research Scientist, INRAE). Guillaume Leduc (Research Scientist, CNRS) and Anne-Lise Jourdan (IR, CNRS) will provide support and expertise for isotopes measurements.

The internship includes a monthly salary of €660.

Application and Contact

To apply or request further information, please contact Floriane Jamoteau (jamoteau@cerege.fr). The applications should include: a CV, cover letter, Master 1 academic transcripts and your Master 1 internship report (if available).

Cited literature:

Basile-Doelsch, I., Balesdent, J., Pellerin, S., 2020. Reviews and syntheses: The mechanisms underlying carbon storage in soil. Biogeosciences Discussions 1–33. https://doi.org/10.5194/bg-2020-49

Bölscher, T., Cardon, Z.G., Garcia Arredondo, M., Grand, S., Griffen, G., Hestrin, R., Imboden, J., Jamoteau, F., Lacroix, E.M., Pérez Castro, S., Persson, P., Riley, W.J., Keiluweit, M., 2025. Vulnerability of mineral-organic associations in the rhizosphere. Nat Commun 16, 5527. https://doi.org/10.1038/s41467-025-61273-4

IPCC, 2023. Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, pp. 35–115.

Jamoteau, F., Doelsch, E., Cam, N., Levard, C., Woignier, T., Boulineau, A., Saint-Antonin, F., Swaraj, S., Gassier, G., Duvivier, A., Borschneck, D., Pons, M.-L., Chaurand, P., Vidal, V., Brouilly, N., Basile-Doelsch, I., 2025. Interplay of coprecipitation and adsorption processes: deciphering amorphous mineral–organic associations under both forest and cropland conditions. SOIL 11, 535–552. https://doi.org/10.5194/soil-11-535-2025

Jilling, A., Grandy, A.S., Daly, A.B., Hestrin, R., Possinger, A., Abramoff, R., Annis, M., Cates, A.M., Dynarski, K., Georgiou, K., Heckman, K., Keiluweit, M., Lang, A.K., Phillips, R.P., Rocci, K., Shabtai, I.A., Sokol, N.W., Whalen, E.D., 2025. Evidence for the existence and ecological relevance of fast-cycling mineral-associated organic matter. Commun Earth Environ 6, 690. https://doi.org/10.1038/s43247-025-02681-8

Kleber, M., Bourg, I.C., Coward, E.K., Hansel, C.M., Myneni, S.C.B., Nunan, N., 2021. Dynamic interactions at the mineral–organic matter interface. Nat Rev Earth Environ 2, 402–421. https://doi.org/10.1038/s43017-021-00162-y

Lugato, E., Lavallee, J.M., Haddix, M.L., Panagos, P., Cotrufo, M.F., 2021. Different climate sensitivity of particulate and mineral-associated soil organic matter. Nat. Geosci. 14, 295–300. https://doi.org/10.1038/s41561-021-00744-x