How is microbial carbon use efficiency distributed within the soil pore network?

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Introduction

Microbial Carbon Utilization Efficiency (CUE) is an integrative measure that can capture the balance with which micro-organisms affect the accumulation and loss of OC.

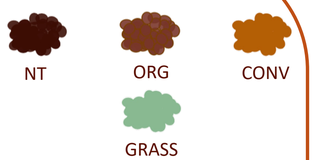
Different agricultural management methods affect soil structure, porosity, the availability of organic matter (OM) and the microbial communities that live there.

From a microbial point of view, the fate of OC in soils depends on the encounter between OM and decomposers or decomposition enzymes.

The effect of the spatial distribution of pores and their size is still poorly understood.

Experimental design

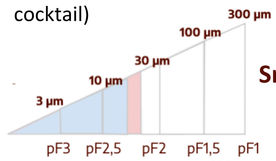
Sampling of unperturbed soil cores on the 'La cage' long-term experimental system in Versailles, 3 management methods, no-till, organic, conventional and Foljuif grassland (France).



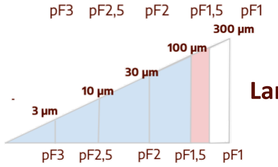
2 Soils and 4 different management methods

Two targeted pore sizes 30 µm and 300 µm using Jurin's law.

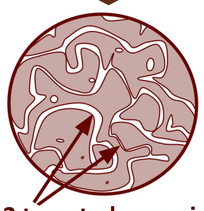
- Water used to adjust the soil's water potential
- Solution supplied at the target pore size (water or carbon cocktail)



Small pores



Large pores



2 targeted pore sizes

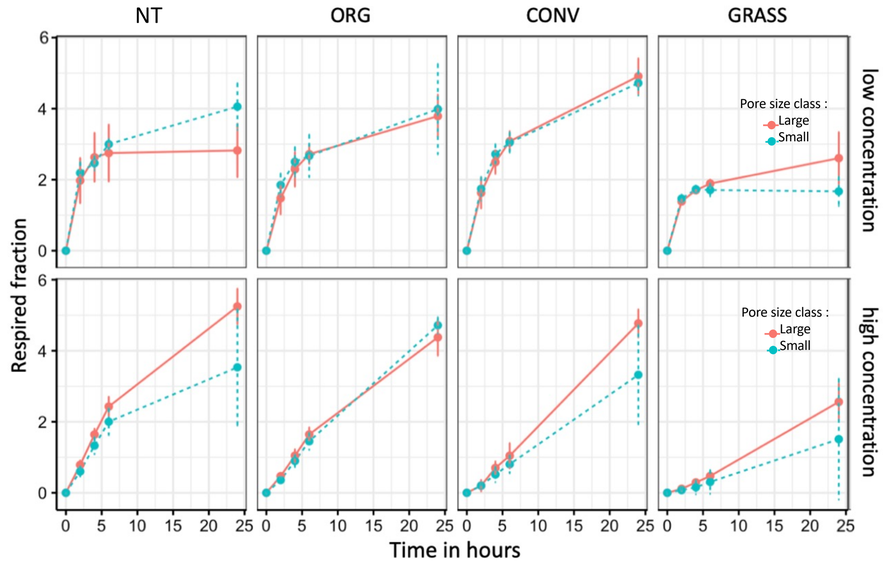
2 concentration of the C mixture

24 hour incubation and measurement of respiration and ^{13}C-CO_2

At the end of the incubations, measurement of the 13C microbial biomass.

Results

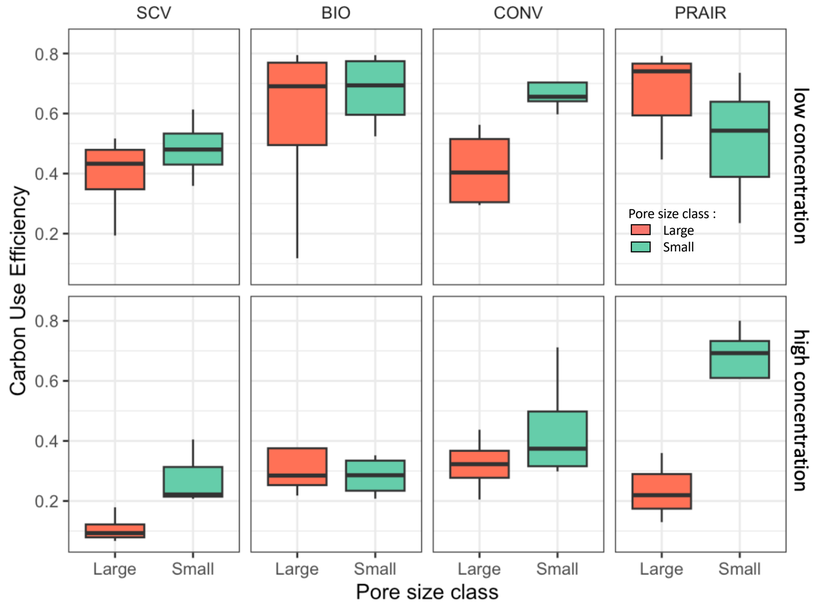
Respiration was significantly different among soils (F = 20.89; p < 0.001), differences between pore size classes was only significant at the high substrate concentration (F = 7.069, p = 0.014), with a higher fraction respired in large pores (4.24 ± 1.14) than in small pores (3.27 ± 1.71).



% of respired C from the carboned mixture in the different soils management methods

The CUE was significantly affected by the concentration of the substrate mixtures (F= 22.89; p < 0.001). The effect of soil management on CUE was significant (F = 4.10; p= 0.011).

Pore size has a significant effect on CUE (F = 8.85; p < 0.01). Small pores have a significantly higher mean CUE (0.50 ± 0.20) than large pores (0.38 ± 0.22). In all management methods, small pores seem to favor higher CUE. This trend is particularly marked with high concentration support.



CUE for all the different management methods in the two different pore size for each combination of soil and carbon input (Anova was performed using a linear model with no interaction)
lm (CUE ~ pores + concentration + soil)

Discussion and conclusion

Higher CUE in small pores may be related to:

Small pores: more stable microenvironments, poor in resources, but favourable to a more efficient use of C by slow-growing microbes (K-strategist). Large pores: greater respiration, rapid metabolism but less efficient (R-strategist), subject to more predation and frequent supplies of labile substrates.

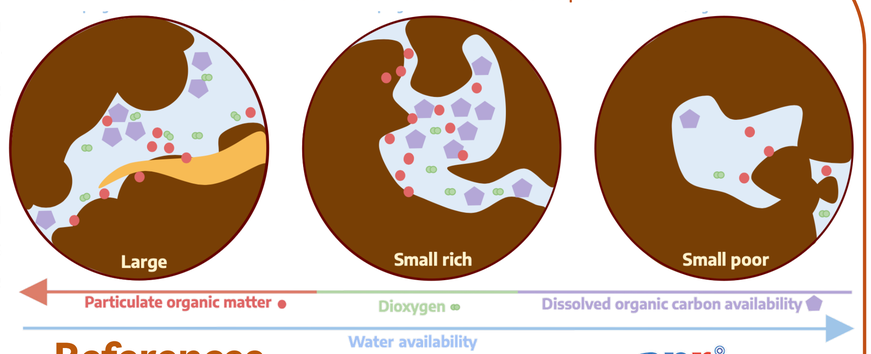
Implications for carbon storage

Because of their high CUE, small pores favor the formation of microbial biomass and stable necromass, contributing to the storage of persistent organic C. These results reinforce the idea that the physical structure of the soil strongly influences the potential for carbon sequestration via microbial traits.

Effects of soil use and pore structure

The management method had a strong influence on porosity and, indirectly, on CUE. Grassland soils had a higher CUE, probably linked to a more efficient microbial community (dominated by fungi in acid soils). The main difference between farming systems lies in tillage: no-till increases pore size, which can reduce overall CUE. pH is also a determining factor: the lowest values (grassland, pH 5.2) are associated with a higher CUE than agricultural soils (pH 7.1).

Microscale environment in different pore sizes



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