Microbial carbon accumulation efficiency: Assessing microbial carbon pump efficiency based on ^{13}C-glucose amendment experiment

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Introduction

The process by which soil microbes transform labile organic matter into microbial residues that are stably preserved in the soil is known as the "Microbial Carbon Pump" (MCP). Accurately assessing MCP efficiency is crucial for understanding microbially mediated soil carbon sequestration. Previous assessments based on microbial carbon use efficiency (CUE) have primarily focused on living microbial biomass, while overlooking microbial residues, thereby failing to accurately reflect MCP efficiency. To address this limitation, we propose a novel approach to evaluate MCP efficiency by **calculating microbial carbon accumulation efficiency (CAE) using a ^{13}C-labeled glucose addition experiment**. This approach assumes that glucose is rapidly consumed by microbes without interacting with soil minerals and estimates CAE based on the amount of glucose-derived carbon retained in the soil at the end of the incubation. However, the sorption of glucose to soil may lead to an overestimation of CAE. Additionally, the variations in CAE and CUE across different ecosystems and the underlying controlling factors remain unclear.

Materials and Methods

- Conducting a ^{13}C-labeled glucose addition experiment using 16 soil samples collected from different ecosystems (Table 1) to investigate the sorption of glucose to soil.
- Using published data from ^{13}C-labeled glucose addition experiments, we calculated both CAE and CUE (Eq. 1–3) to explore their variations across ecosystems and identify the potential controlling factors.

$$\mathrm{CAE} = 1 - \frac{\mathrm{CO_2\_C_G}}{\mathrm{C_{added\ G}}} \quad (1)$$

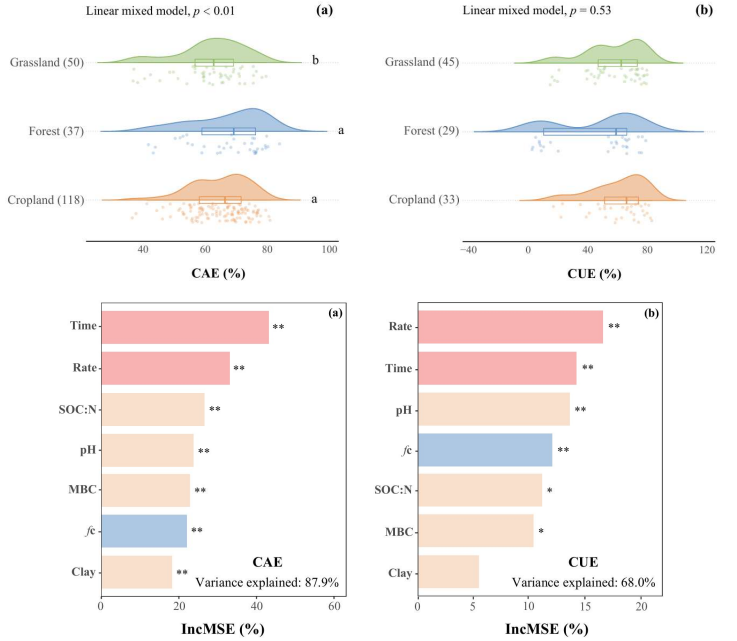
$$\mathrm{CAE} = \frac{\mathrm{Residual\ C_G}}{\mathrm{C_{added\ G}}} \quad (2)$$

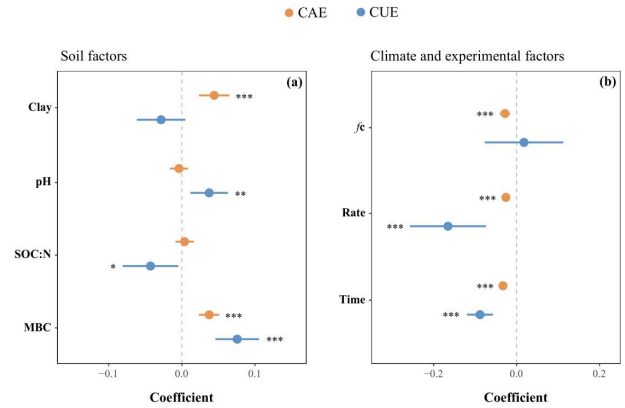
$$\mathrm{CUE} = \frac{\mathrm{MBC_G}}{\mathrm{MBC_G + CO_2\_C_G}} \quad (3)$$

$\mathrm{CO_2\_C_G}$ represents the amount of CO_2 derived from glucose, $\mathrm{C_{added\ G}}$ denotes the total amount of glucose added, Residual $\mathrm{C_G}$ refers to the amount of glucose remaining in the soil, and $\mathrm{MBC_G}$ indicates the microbial biomass carbon derived from glucose.

Table 1. Start Properties of soils used in the sorption experiment and the sorption percentage of glucose.

Sample	Location	Ecosystems type	SOC (%)	Clay (%)	pH	$\delta^{13}C_{initial}$ (‰)	$\delta^{13}C_{treatment}$ (‰)	Sorption percentage (%)
NM0305	Inner Mongolia	Temperate grassland	1.26	0.80	7.65	-23.51	-23.71 ± 0.06	<0.01
P821	Tibet	Alpine grassland	3.83	7.60	6.97	-23.87	-24.06 ± 0.06	<0.01
SJ-1	Heilongjiang	Wetland	4.49	9.60	5.10	-27.23	-27.06 ± 0.03	0.02
HHMC2	Fujian	Wetland	1.49	10.00	6.30	-24.45	-23.91 ± 0.03	0.06
JHH-2	Yunnan	Tropical forest	1.43	15.40	5.52	-27.69	-27.45 ± 0.08	0.02
FY-W	Heilongjiang	Wetland	8.16	15.50	5.26	-28.98	-27.93 ± 0.21	0.08
DJH-D-3	Hubei	Wetland	25.61	3.14	4.27	-27.97	-24.36 ± 0.12	0.19
JX1	Jiangxi	Subtropical broad-leaved forest	0.70	9.25	4.13	-21.85	-21.33 ± 0.06	0.02
NM1	Inner Mongolia	Temperate grassland	14.35	3.84	6.19	-27.73	-25.72 ± 0.14	0.08
NM2	Inner Mongolia	Temperate grassland	6.33	2.66	6.48	-26.48	-25.93 ± 0.24	0.02
NM3	Inner Mongolia	Temperate grassland	2.69	2.08	6.62	-26.38	-25.16 ± 0.28	0.06
NM4	Inner Mongolia	Temperate grassland	2.41	1.22	7.02	-24.96	-24.33 ± 0.12	0.03
NM5	Inner Mongolia	Temperate grassland	1.47	1.87	7.49	-23.84	-23.93 ± 0.05	<0.01
Z1	Beijing	Temperate mixed forest	2.45	1.73	7.32	-24.16	-24.26 ± 0.51	0.01
Z2	Beijing	Temperate mixed forest	1.88	3.66	7.79	-26.91	-26.57 ± 0.12	0.01
Z5	Beijing	Temperate mixed forest	2.81	2.08	7.51	-26.77	-26.50 ± 0.16	0.01





Results and Discussion

- The sorption of glucose to soil can be considered negligible, allowing the calculation of CAE based on the ^{13}C-labeled glucose addition experiment.
- CAE and CUE exhibit distinct ecological patterns and are regulated by different factors. In contrast to microbial CUE which is mainly regulated by factors influencing microbial physiological processes (particularly substrate availability), CAE is jointly regulated by factors that influence microbial growth (e.g., MBC and climate) and residue preservation (e.g., clay content).

Conclusion

Calculating CAE based on ^{13}C-labeled glucose addition experiments provides a novel and effective approach to assess MCP efficiency. Given the observed decoupling between CAE and CUE, incorporating CAE into soil carbon models may offer new insights into predicting future SOC dynamics under climate change.

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