# Exploring the energetics of soil microbial metabolism under substrate limitation


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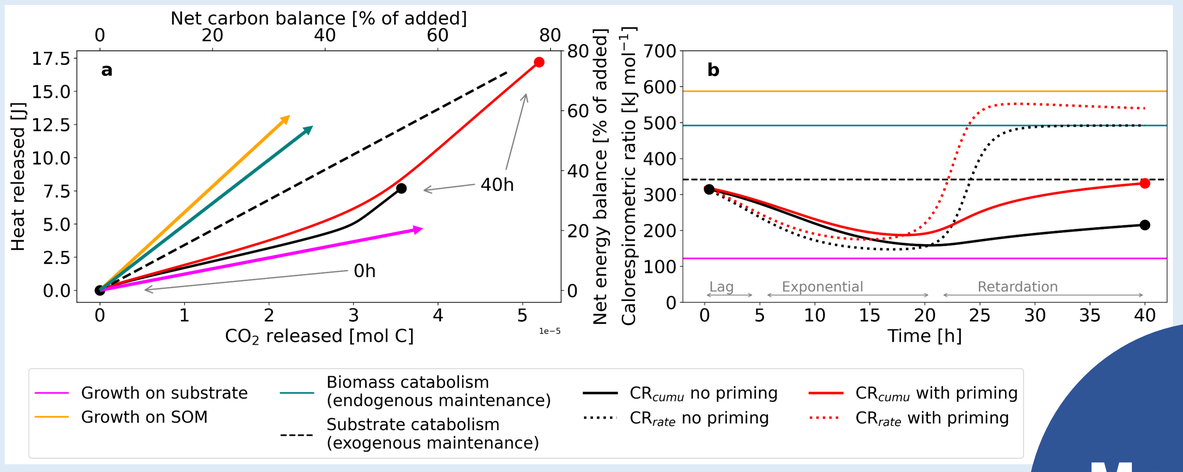


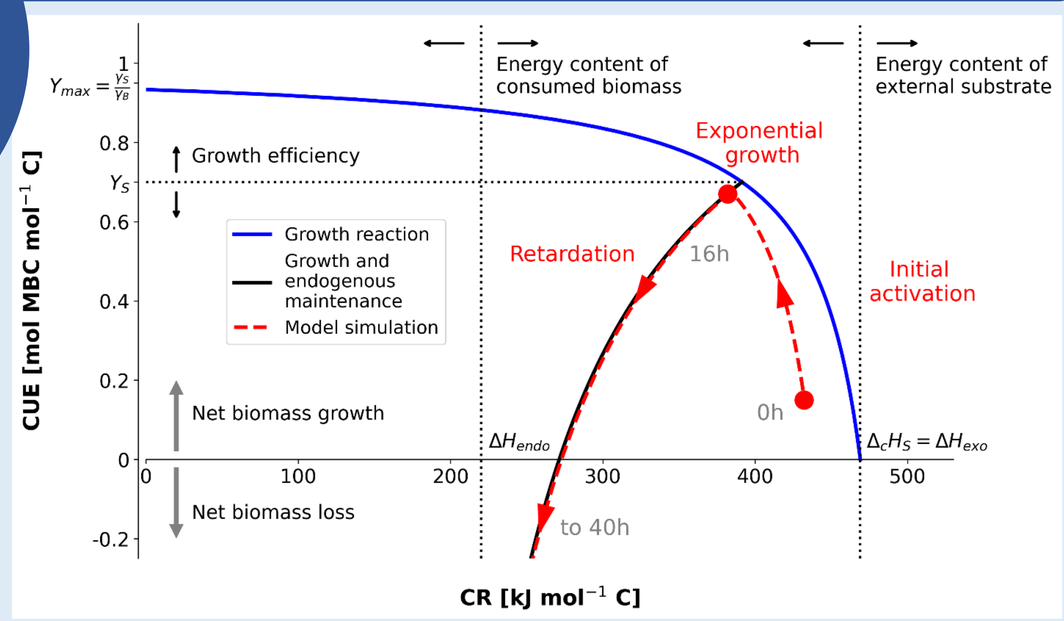

## Modeling Results

### The calorespirometric ratio (CR) of heat to $CO_2$ release reflects microbial metabolism

In a plot of cumulative heat release against cumulative $CO_2$ release after the addition of a labile substrate, model simulations trace a trajectory that captures the **net carbon (C) and energy balance** of the soil system over time (panel **a**).
The direction of the trajectory at any timepoint is determined by the **dominant metabolic processes** currently performed by microorganisms in the soil and corresponds to the value of the **CR** (panel **b**).
After substrate depletion (20 h), the simulations illustrate the effect of a shift from growth metabolism towards **endogenous maintenance** fueled by biomass consumption (black) or the **decomposition of SOM** (priming, red).

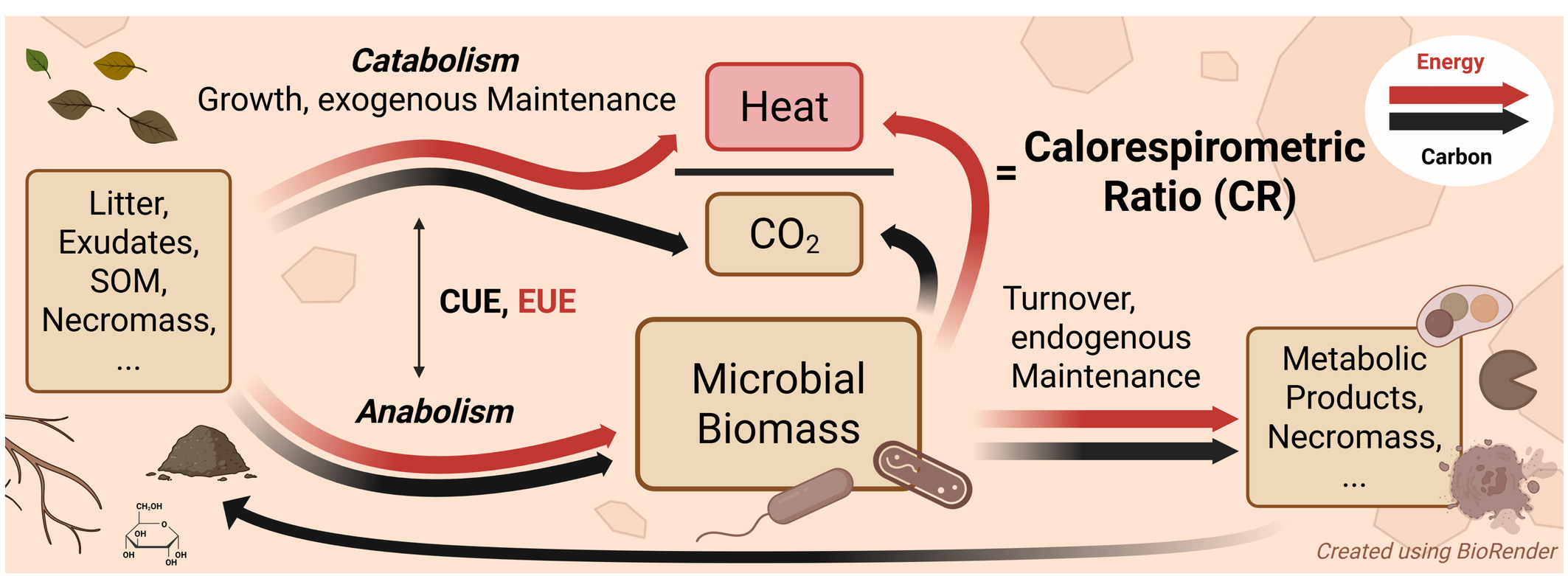
For a simple aerobic **growth reaction**, the connection between microbial C use efficiency (CUE) and CR is well established (blue).
However, both **exogenous maintenance** fueled by external substrate as well as **endogenous maintenance** fueled by biomass cause systematic deviations from this relationship (red dashed trajectory).
While both cause a **drop in CUE**, the effect on CR depends on the **energy contents** of the consumed compounds (vertical lines).

### Exogenous and endogenous maintenance alter the relationship between CUE and CR

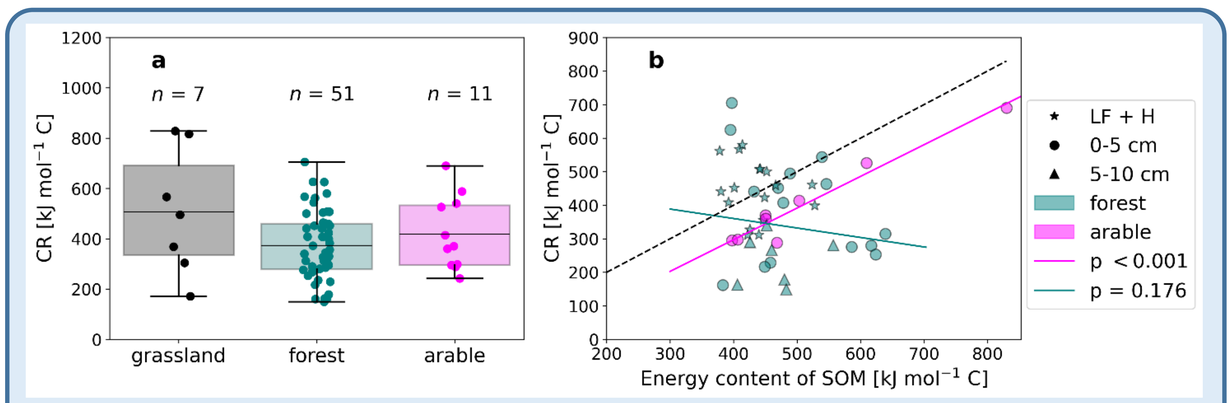



## Introduction

All microbial transformations of **organic matter** in soils are tightly linked to parallel **energy flows**.
Using dynamic modeling and a literature review, we investigated this coupling for microbial maintenance processes fueled by external substrates or internal biomass.



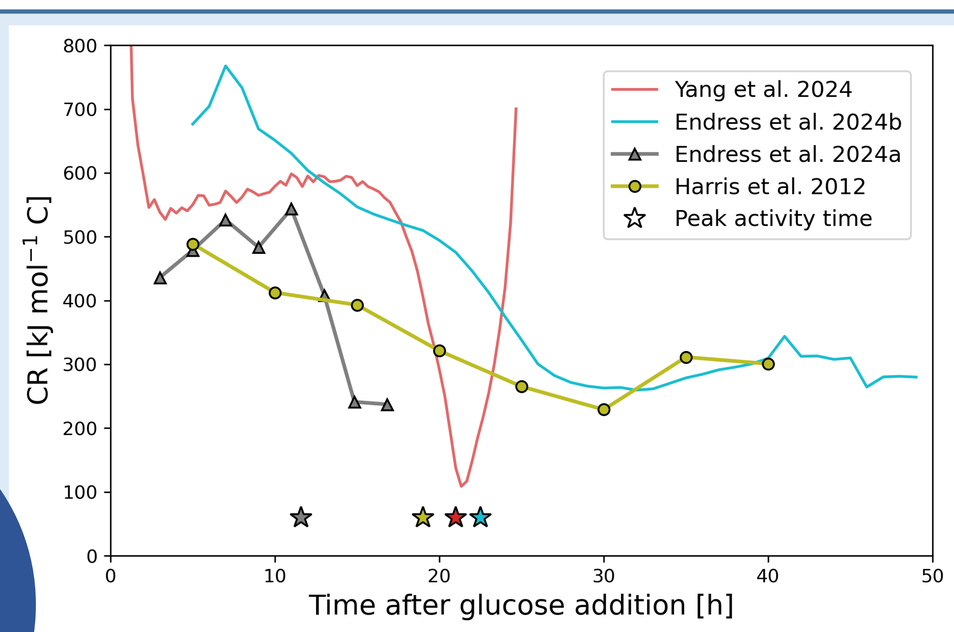

## Empirical Evidence




### Maintenance metabolism in arable soils is closely related to the energy content of SOM

A **literature compilation** of CR measurements obtained from **unamended** soil samples (*n* = 8 studies) and thus corresponding to basal metabolism reveals a **wide range** of values but **no effect of land use** (panel **a**)**.** This reflects the high diversity of chemical compounds and metabolic pathways in unamended natural soils.

In the four studies that also measured the **energy content of SOM** via thermal analysis, we find **no relationship** between the CR of basal metabolism and SOM energy content across all soils (panel **b**). However, in the one study featuring **arable soils** (*n* = 8 soils), the CR of unamended samples follows a **close linear relationship** with SOM energy content (pink), indicating that microbes utilized SOM slighly less rich in energy than the average SOM in these soils.




### CR dynamics after glucose addition exhibit consistent temporal patterns across studies

Across four independent studies that monitored CR after the addition of **glucose**, the CR dynamics all showed a **significant drop** from initially high values (400-600 kJ $mol^{-1}$ C) to lower values (200-350 kJ $mol^{-1}$ C). In all studies, this drop also occurred around the **time of peak activity** (star markers), when glucose was **depleted** and microbes entered the **retardation phase** and thus primarily performed **maintenance**.

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