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Testing the relationship between carbon-use efficiency and soil carbon formation in rhizosphere and detritusphere microbial communities

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Disclaimer

Testing the relationship between carbon-use efficiency and soil carbon formation in rhizosphere and detritusphere microbial communities

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Goldschmidt 2021

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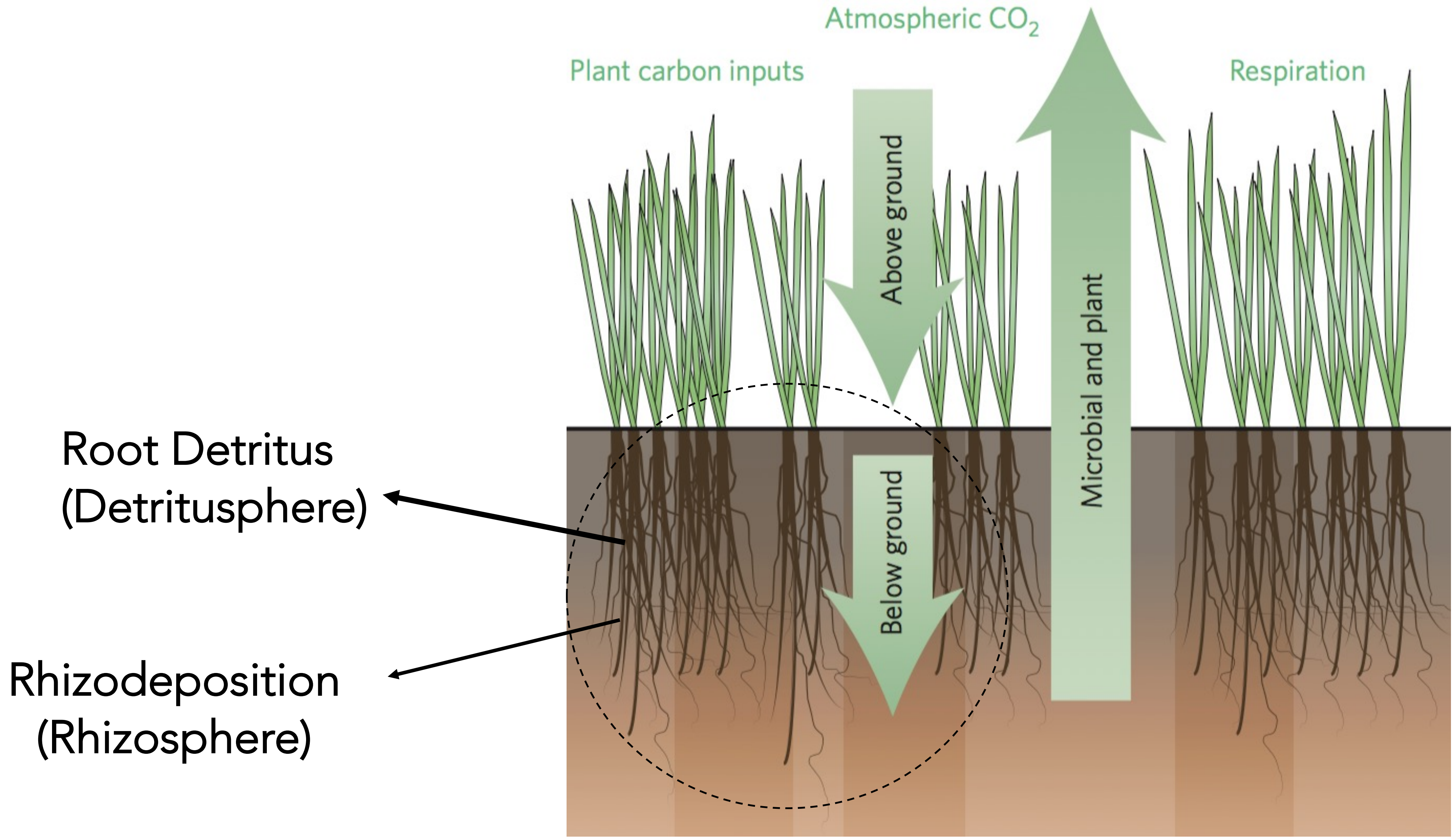
Soil organic carbon: Earth's largest terrestrial carbon pool

→ Soil organic carbon dynamics largely controlled by soil microbes



Bradford *et al*. 2016. *Nature Climate Change*.

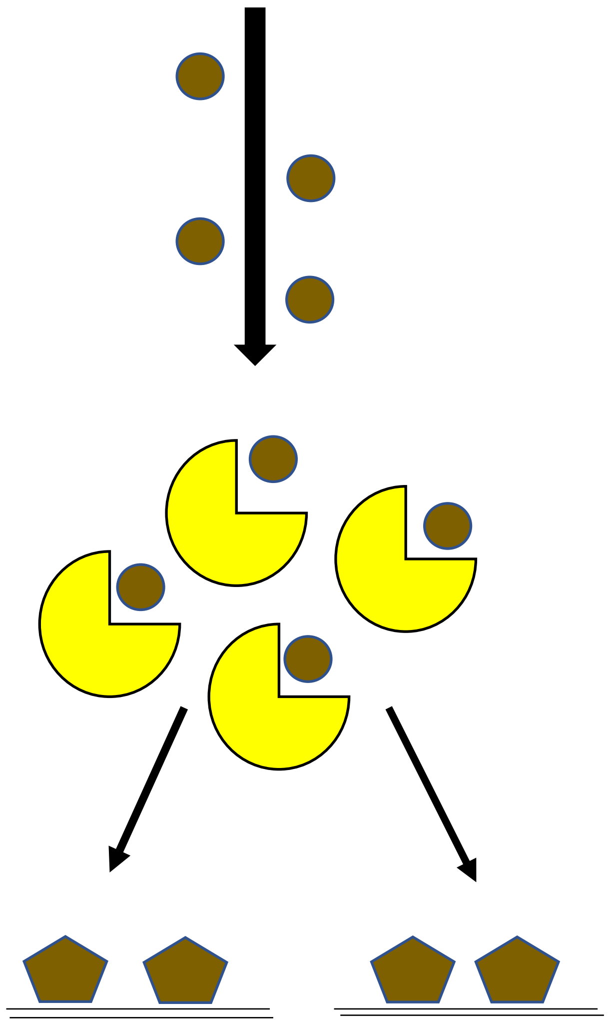
Soil microbes play a key role in <u>forming</u> SOC

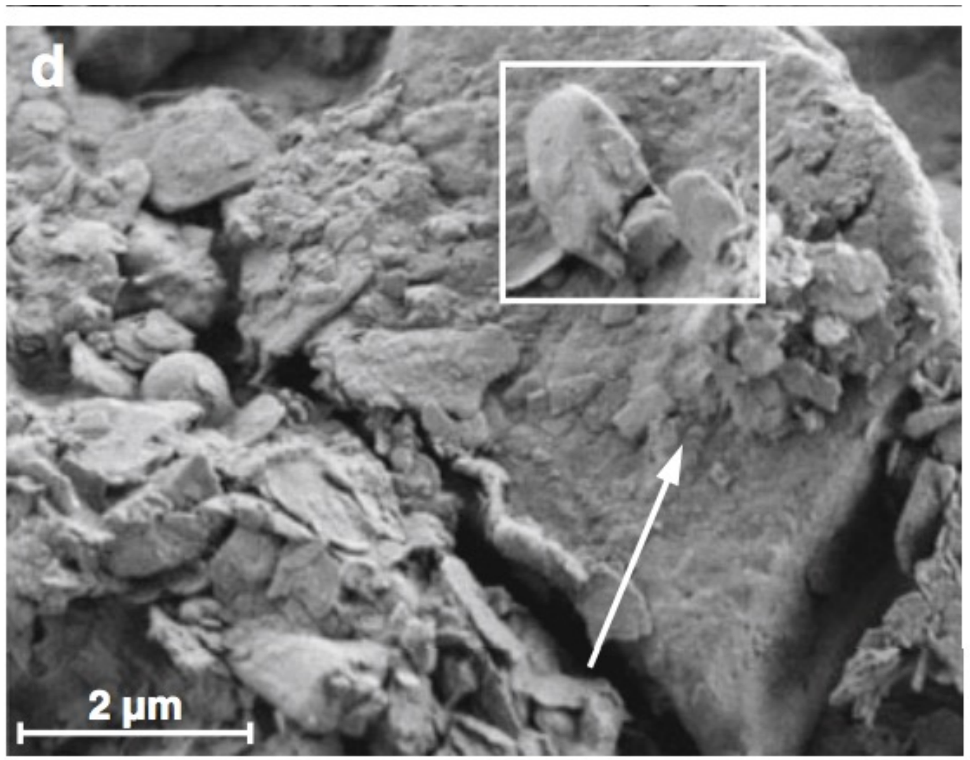
→ As much as 50-80% of SOC derived from microbial necromass via **'soil microbial carbon pump'**

Plant Carbon Inputs

Microbial Assimilation, Growth, Death

Microbial-Derived, Mineral-Associated Organic Matter (MAOM)



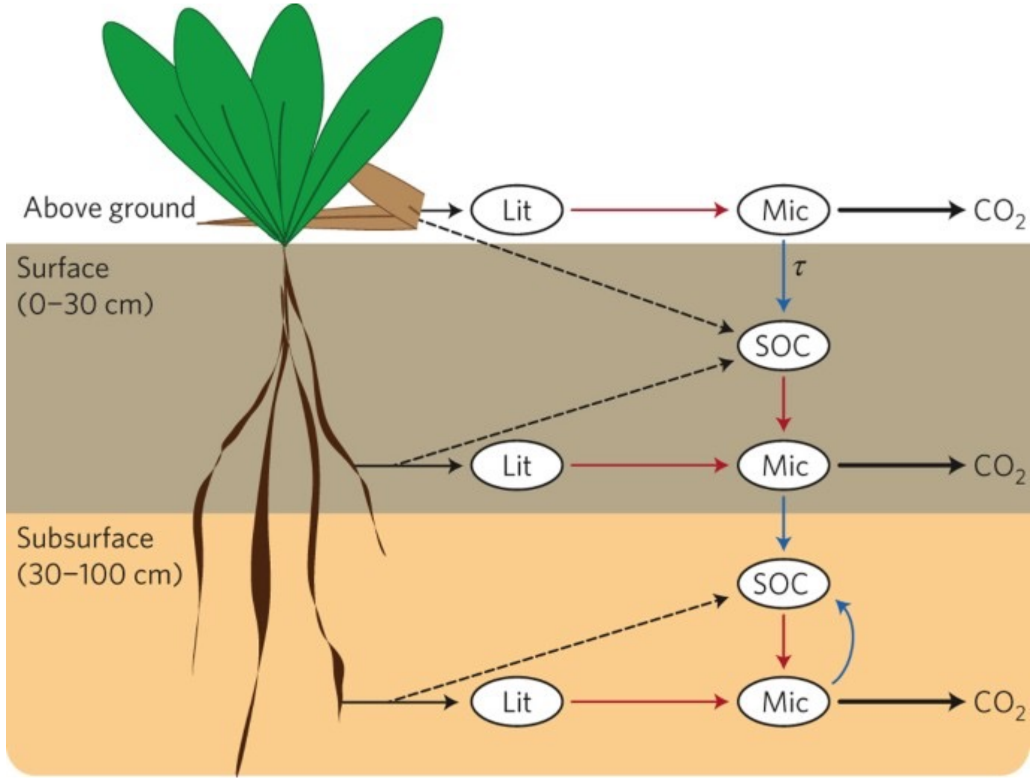


Miltner *et al.* 2011

Critical need: identify microbial traits that predict soil carbon formation for global carbon models

nature climate change
LETTERS
PUBLISHED ONLINE: 28 JULY 2013 | DOI: 10.1038/NCLIMATE1951

Global soil carbon projections are improved by modelling microbial processes



Wieder et al. 2013

Overwhelming focus to date on a single trait: **carbon-use efficiency** (C allocated to growth vs. CO_2 respired)

'Soil microbial carbon pump'

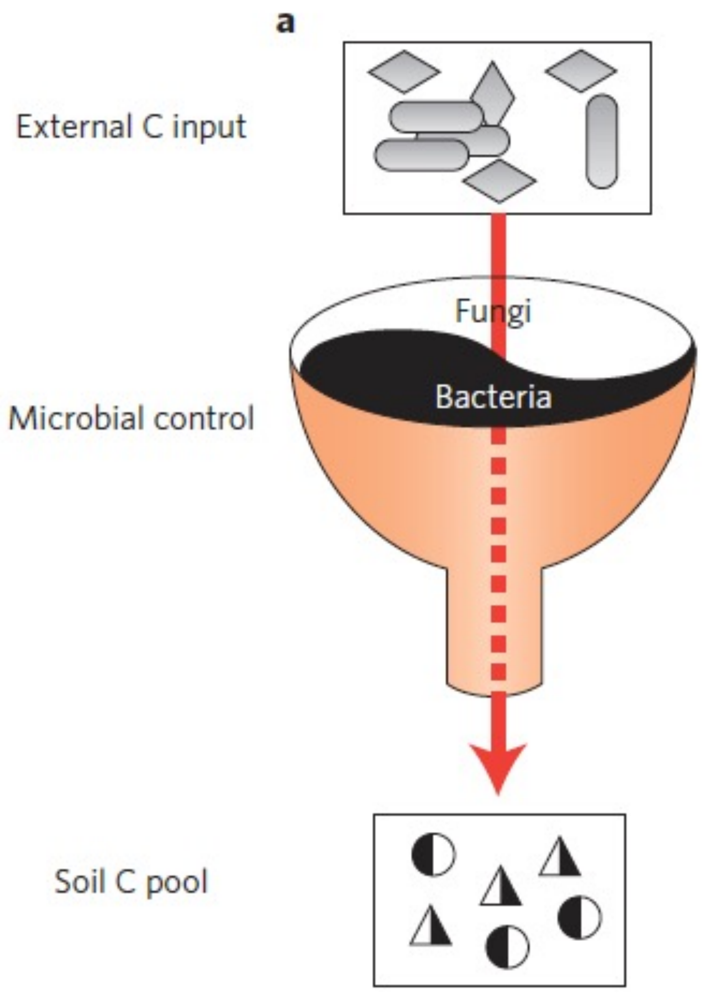
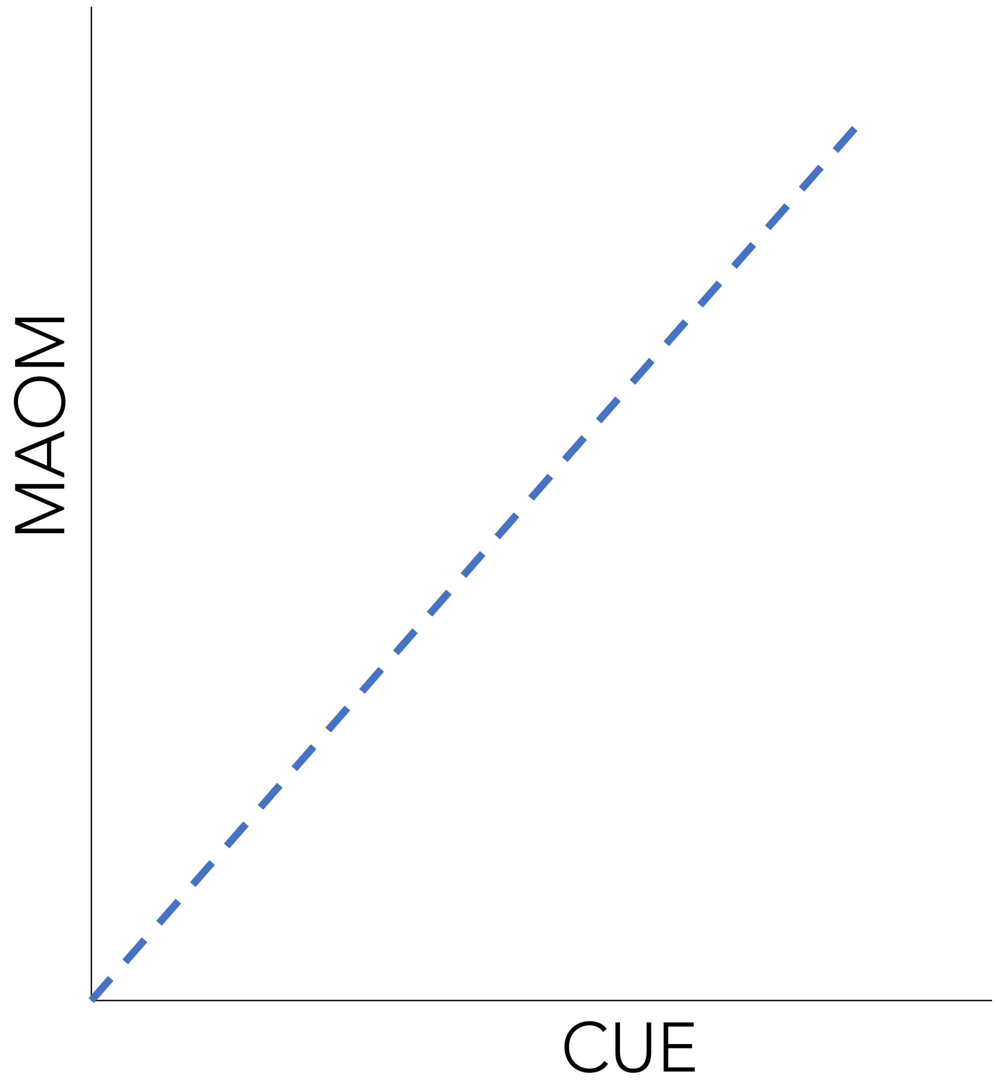


Figure: Liang et al. 2017

Theorized positive relationship btw. CUE and MAOM



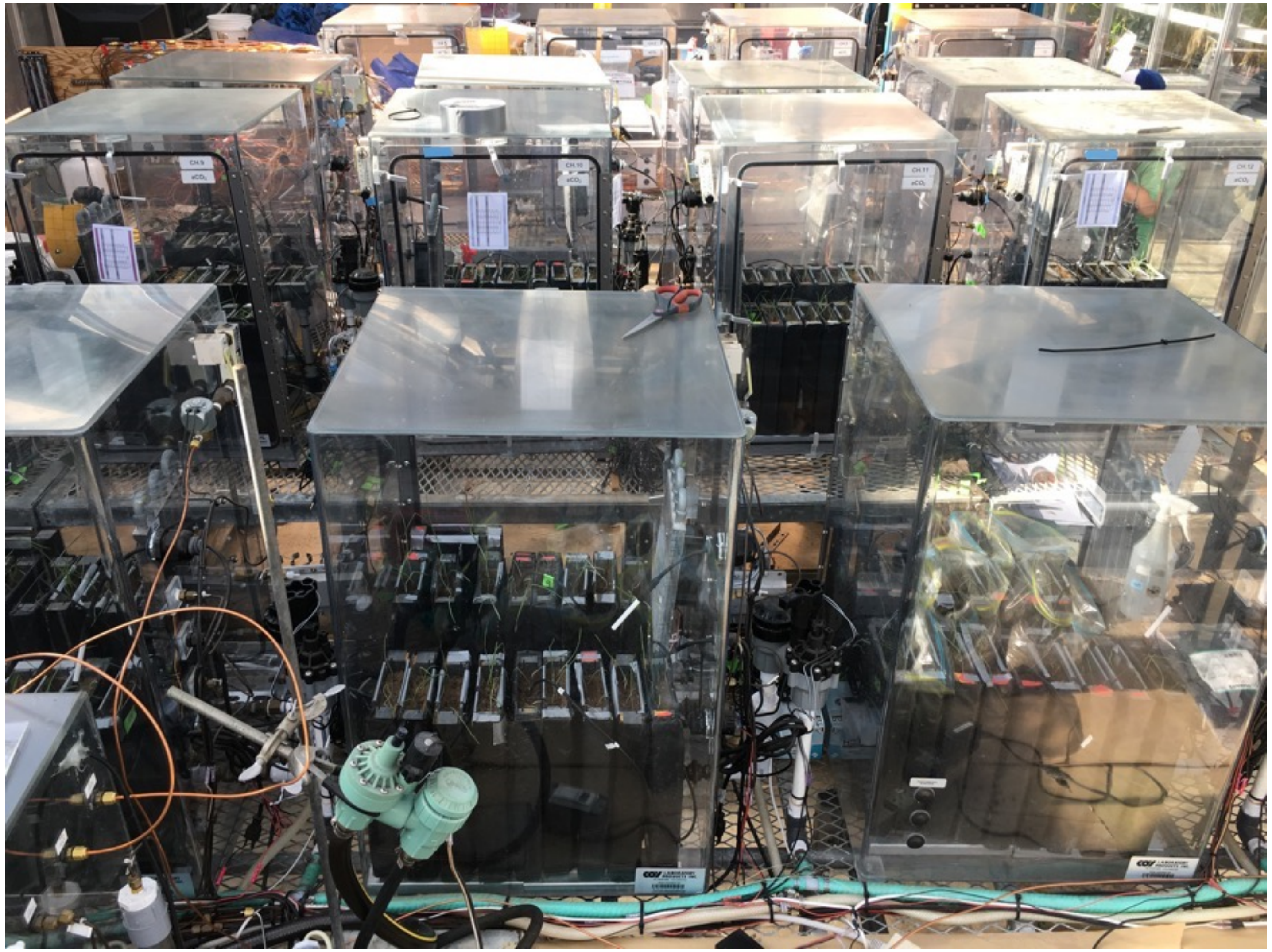
Key Motivating Research Questions:

(1) Evidence for theorized positive relationship between carbon-use efficiency and MAOM formation?

(2) Are there <u>other</u> microbial traits that better predict MAOM

(3) Does the importance of different microbial traits vary in distinct habitats of the soil – i.e. rhizosphere versus detritusphere?

^{13}C-Labeling Greenhouse Experiment of *Avena barbata*:
Rhizosphere and detritusphere dynamics under 'normal moisture' vs. drought



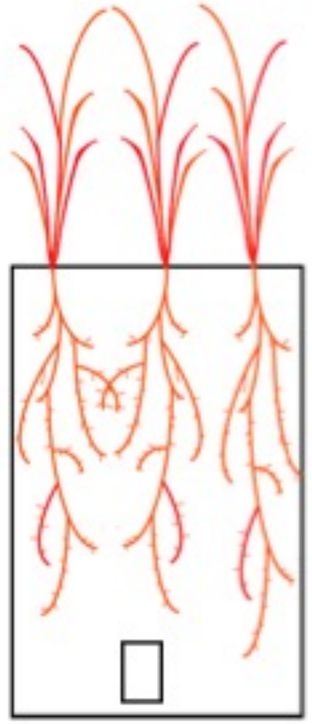
'EPIC' $^{13}CO_2$-Labeling Chambers at UC Berkeley

Normal Moisture (~15%) vs Drought (~8%)

Two key microbial habitats of carbon transformations: (1) **rhizosphere** and (2) **root detritusphere**

(1) Rhizodeposition Only

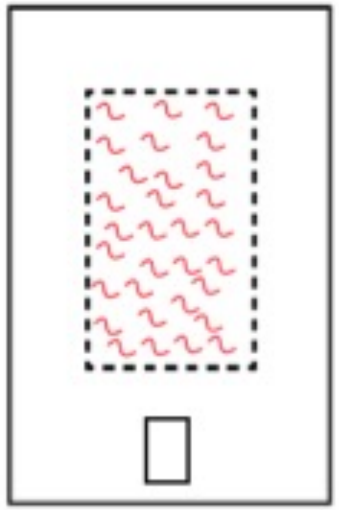
^{13}C-rhizodep.



Rhizosphere = soil clinging to roots

(2) Detritus Only

^{13}C-root litter



Root detritusphere = soil + root detritus inside mesh bag

Measurements: MAOM and Microbial Traits

1) **^{13}C-MAOM:** combined density and physical fractionation (Soong et al. GCB 2015)

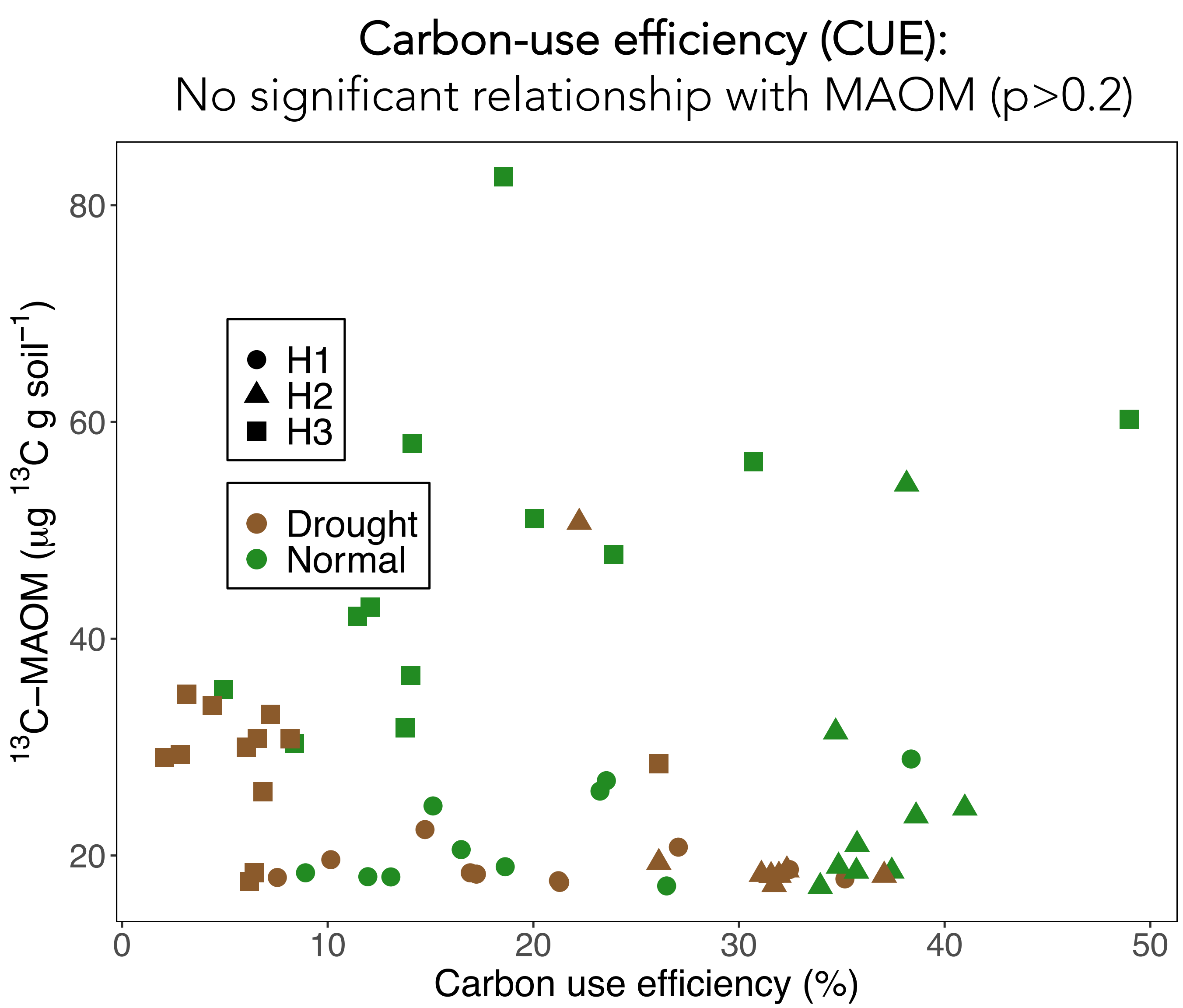
2) **Carbon-use efficiency (CUE)** – ^{18}O-H_2O method (Spohn *et al*. 2016 SBB)

3) **Microbial biomass carbon** (MBC) – chloroform fumigation extraction

3) **^{13}C-extracellular polymeric substances (EPS)** – bulk EPS extract from soil via cation exchange resin (Redmile-Gordon *et al*. 2014 SBB)

4) **Extracellular enzyme activity** - BG, BX, CBH, NAG, P (Kaiser et al. 2010)

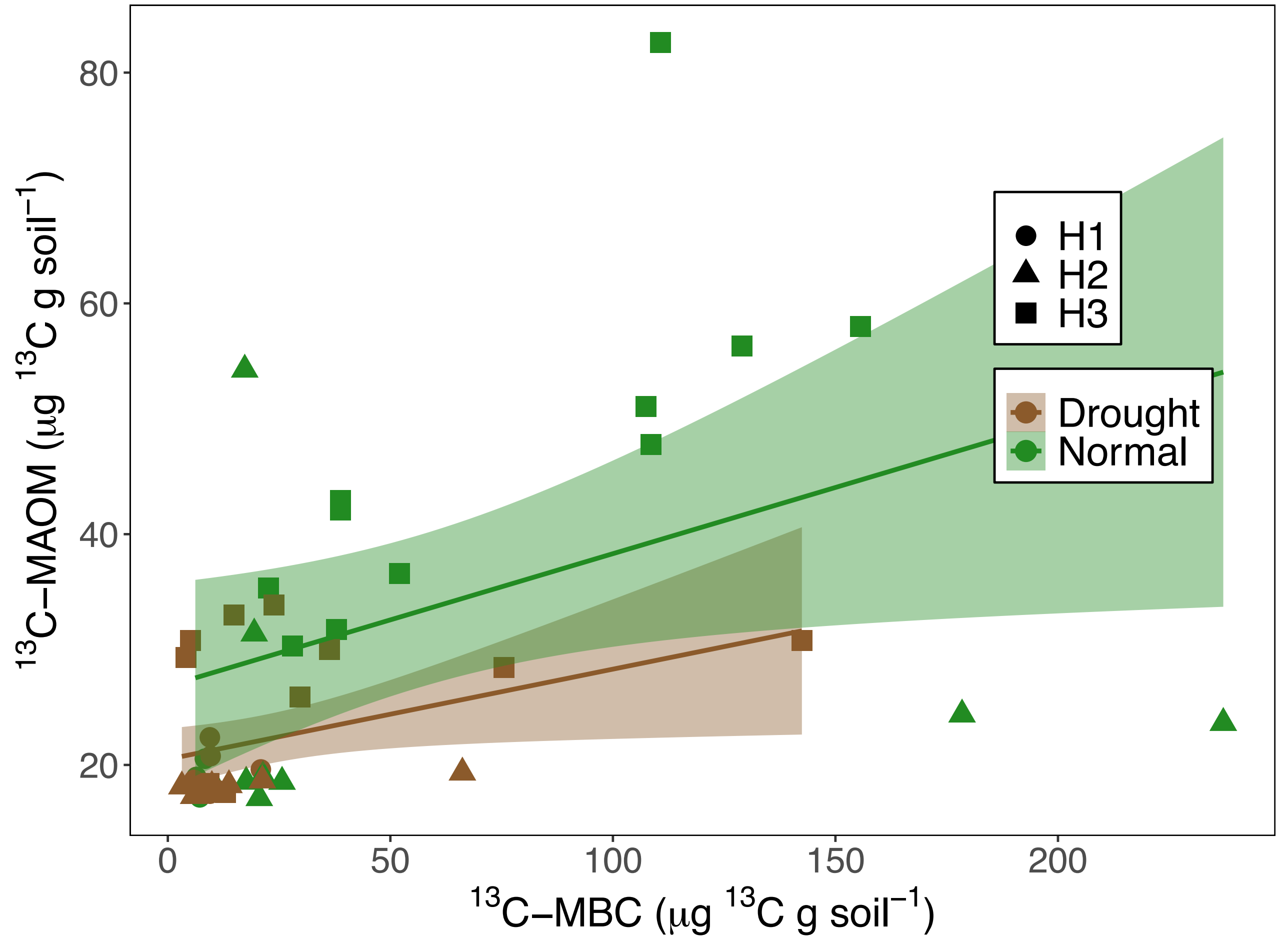
In the rhizosphere:
No significant relationship between CUE and ^{13}C-MAOM



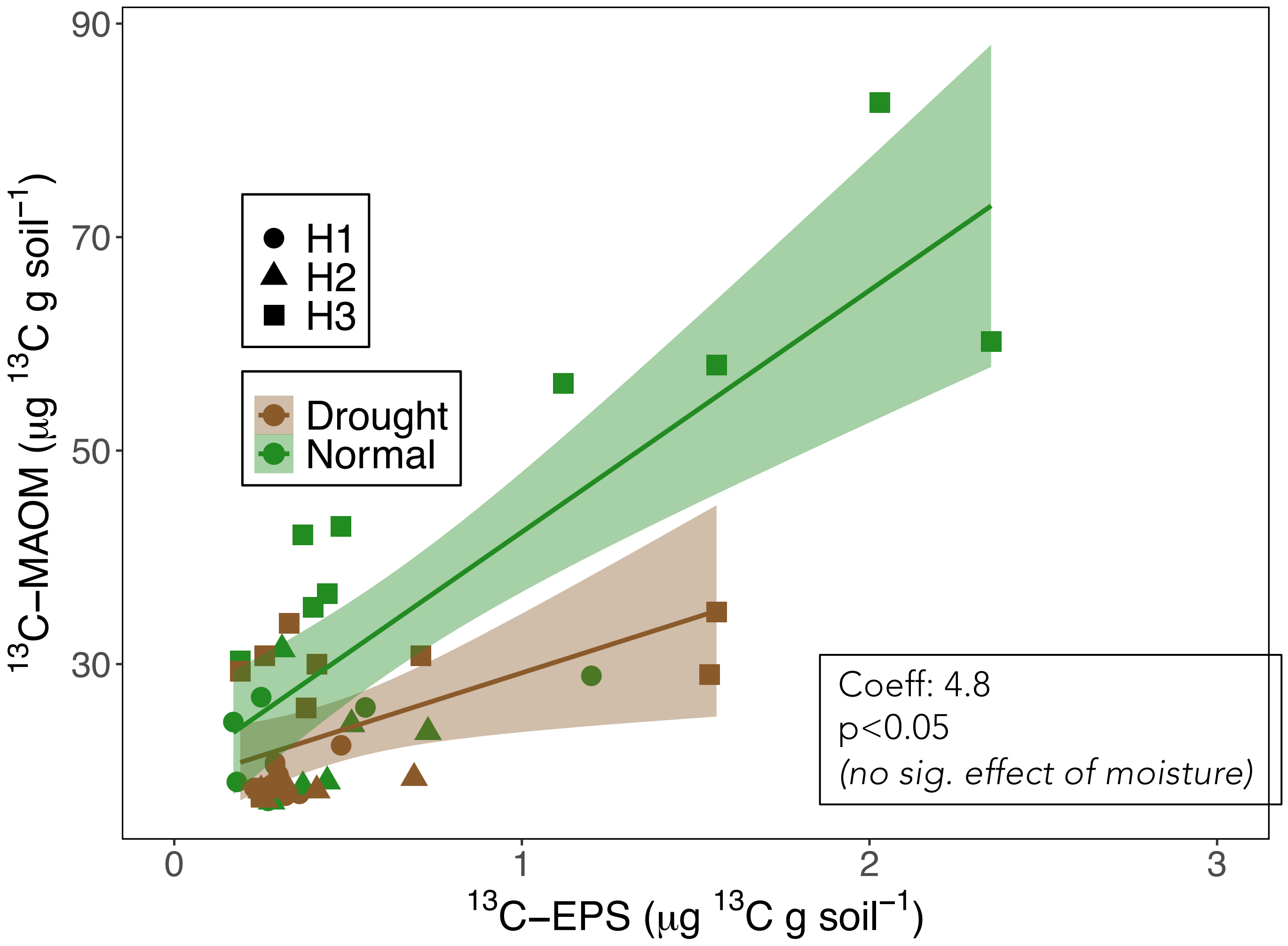
H1= 4 weeks; H2 = 8 weeks, H3= 12 weeks | EPS = Extracellular Polymeric Substances | MAOM = mineral-associated organic matter

In the rhizosphere: total yield of ^{13}C-MBC (intracellular C) of ^{13}C-EPS(extracellular C) positively associated with ^{13}C-MAOM

^{13}C-Microbial Biomass Carbon
Significant positive relationship



^{13}C-Extracellular Polymeric Substances (EPS)
Significant positive relationship

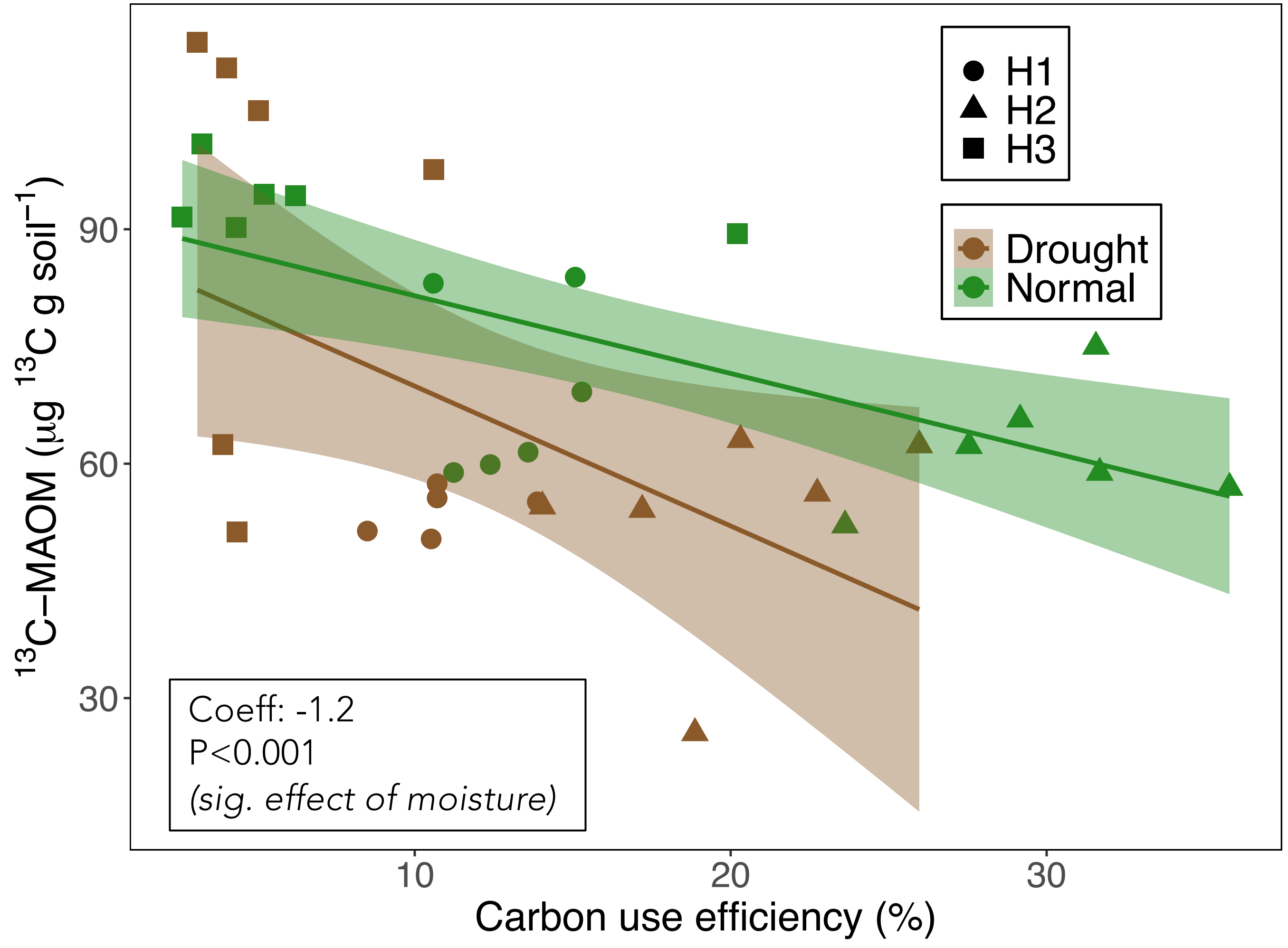


H1= 4 weeks; H2 = 8 weeks, H3= 12 weeks | EPS = Extracellular Polymeric Substances | MAOM = mineral-associated organic matter

In the detritusphere: Carbon-use efficiency, ^{13}C-EPS, ^{13}C-MBC are all <u>negatively associated</u> with ^{13}C-MAOM formation

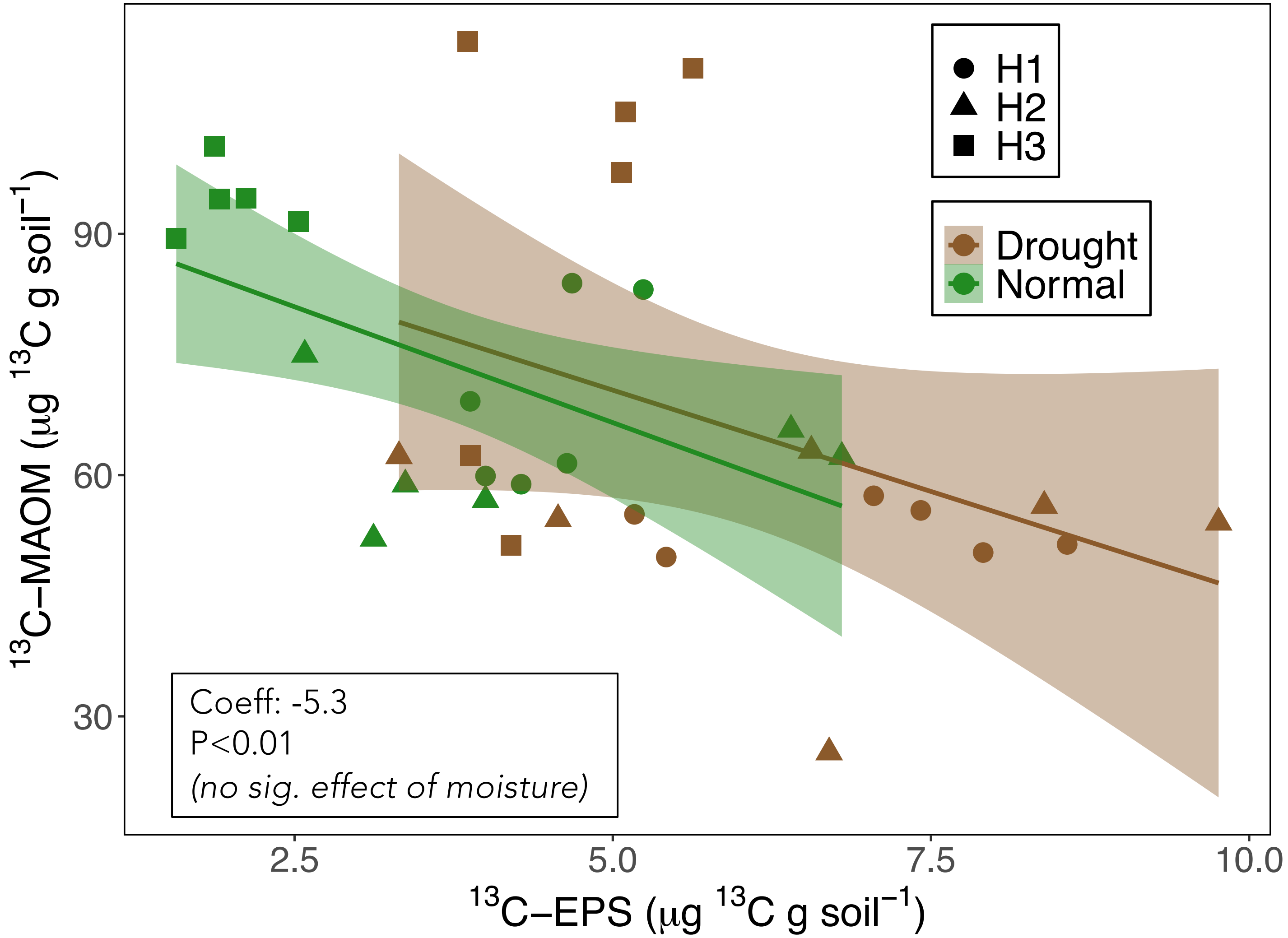
Carbon use efficiency (CUE)

Significant negative relationship



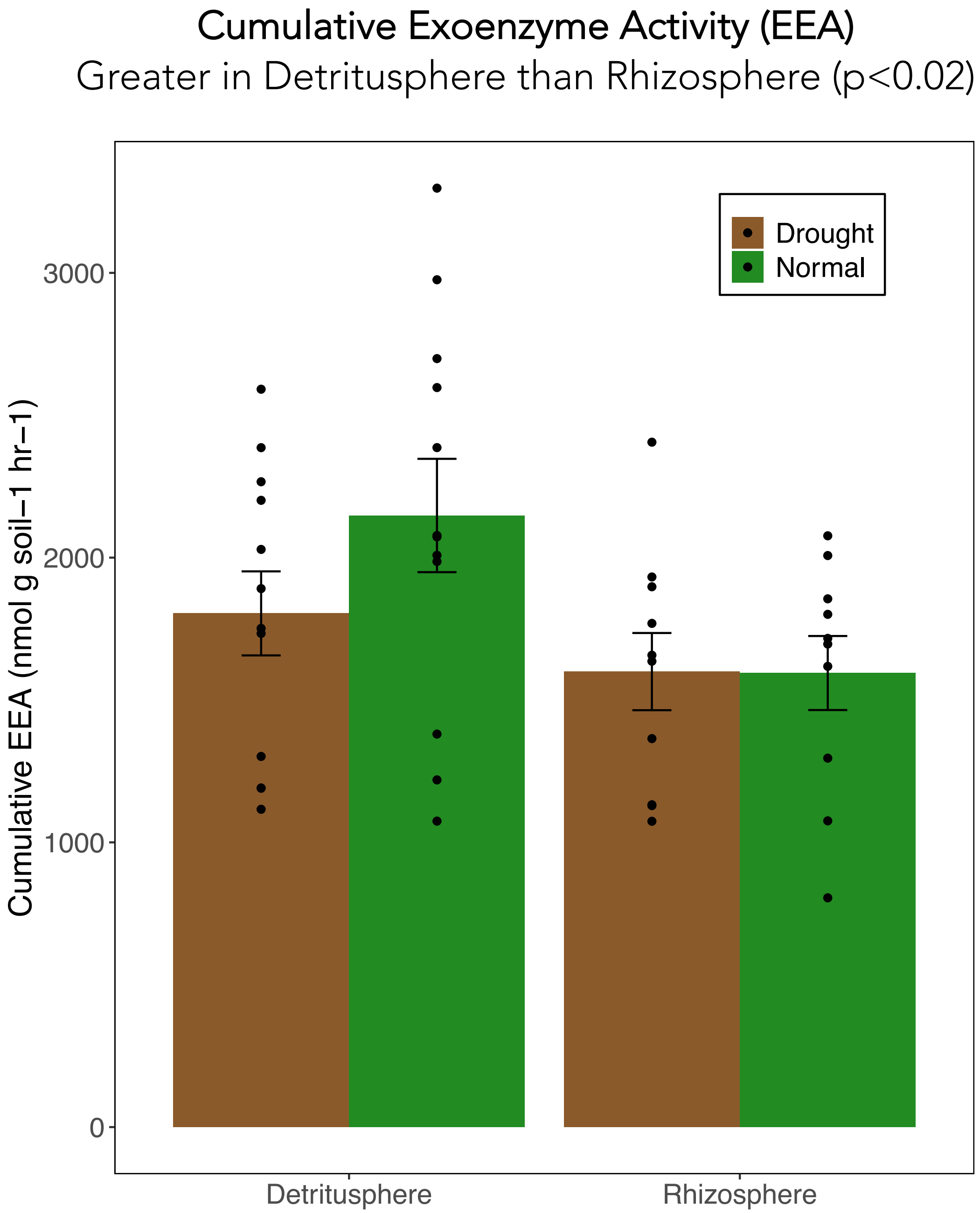
^{13}C-Extracellular Polymeric Substances (EPS)

Significant negative relationship



H1= 4 weeks; H2 = 8 weeks, H3= 12 weeks | EPS = Extracellular Polymeric Substances | MAOM = mineral-associated organic matter

Greater cumulative exoenzyme activity in detritusphere vs. rhizosphere:
distinct traits and formation pathways of MAOM in different habitats?



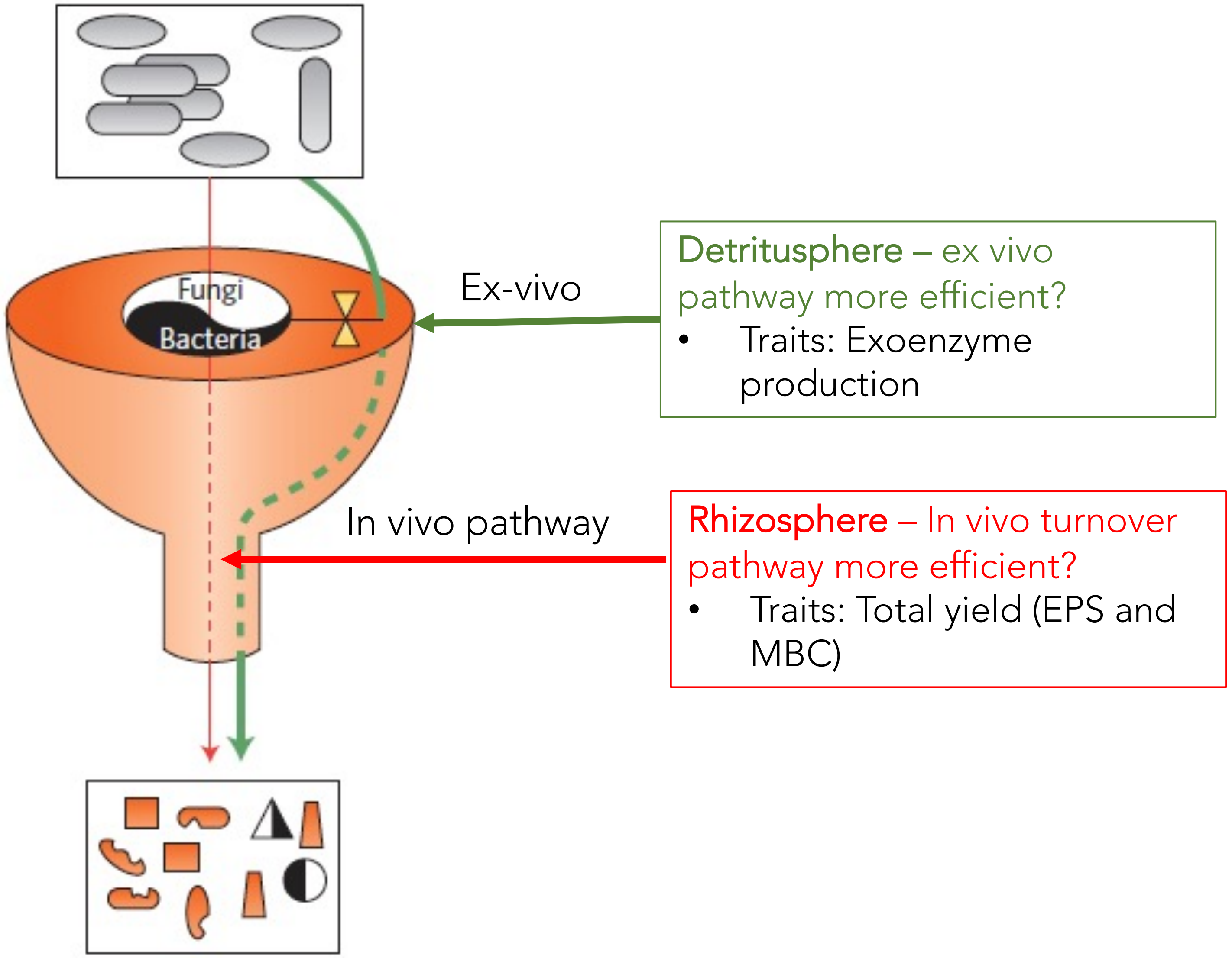


Figure: Liang et al. 2017

Key Take-Home Message: distinct traits associated with MAOM in rhizosphere vs detritusphere

1) Carbon-use efficiency was <u>not positively associated</u> with MAOM formation in rhizosphere or detritusphere

2) **Rhizosphere traits**: total biomass yield (EPS and MBC)

3) **Detritusphere traits:** resource acquisition (cumulative exoenzyme activity)

4) Future research should focus on a broader suite of microbial traits to model the role of microbes in MAOM

Acknowledgements & Funding

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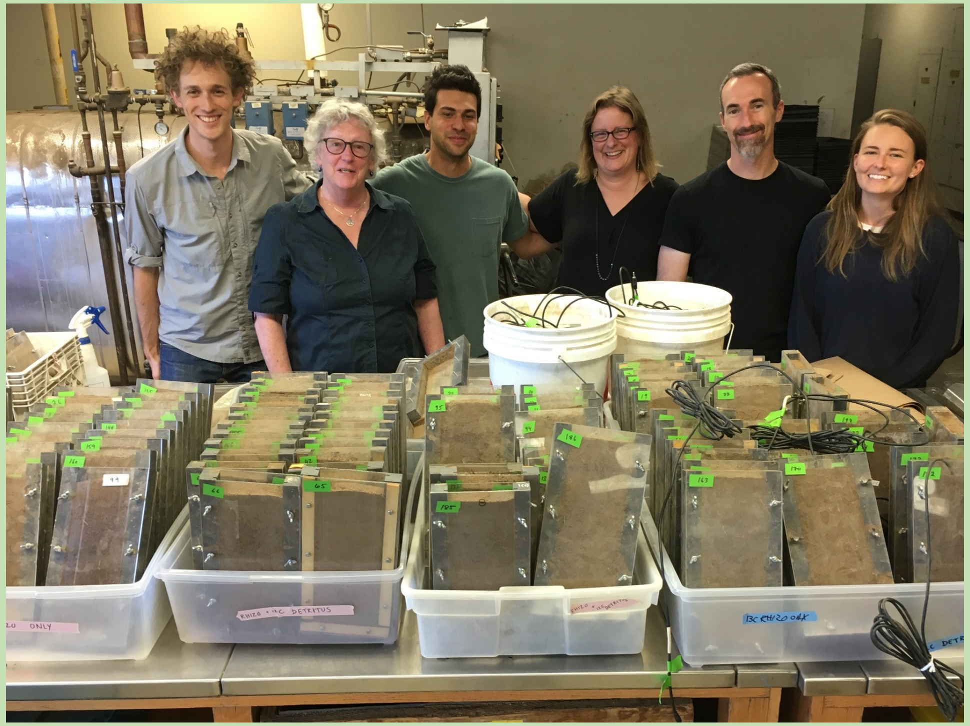
Website: https://sc-programs.llnl.gov/biological-and-environmental-research-at-llnl/soil-microbiome



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