Potential for carbon accrual in bioenergy feedstock fields

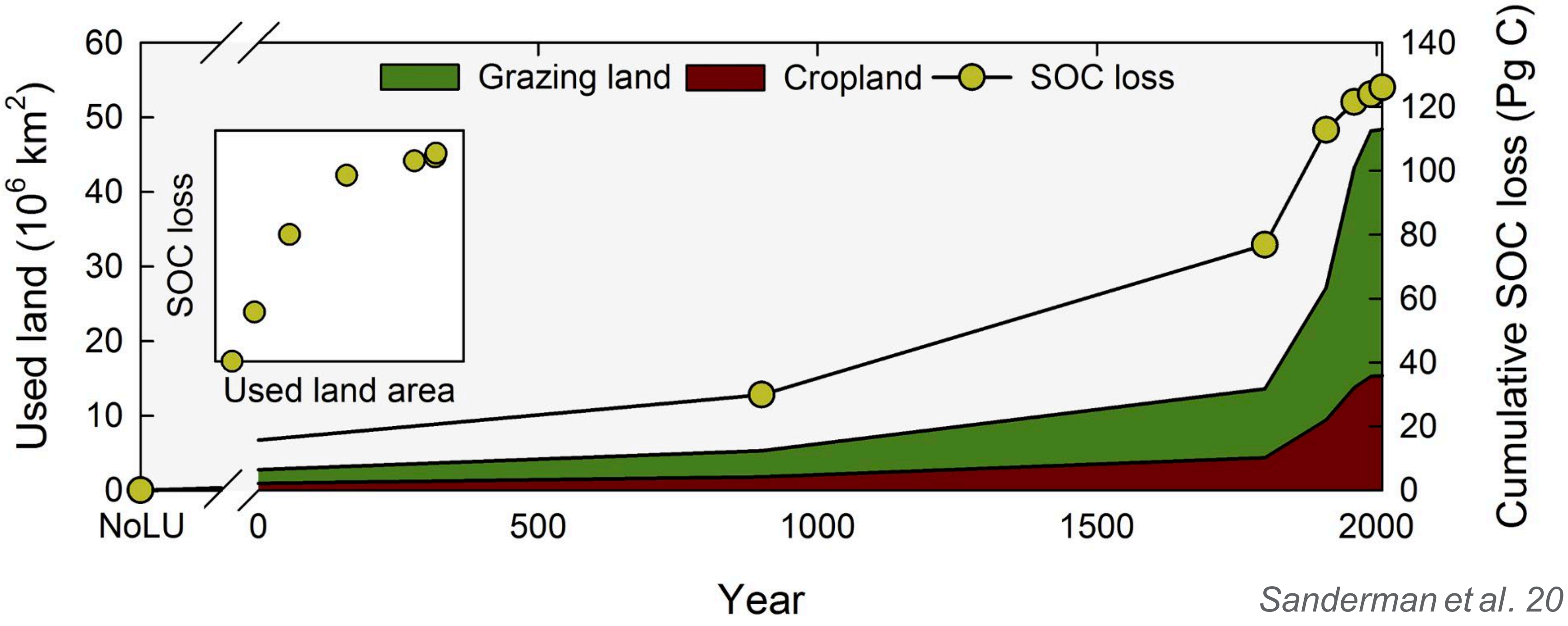
KIRSTEN HOFMOCKEL
Soil Microbiome Scientist PNNL

DOE' workshop on Bioenergy's Role in Soil Carbon Storage

March 28–29, 2022

Soil organic carbon storage and loss is massive

- SOM contains more C than the atmosphere and vegetation combined
- Over 110 Pg of carbon have been lost from surface soil
- This is roughly equivalent to 80 years' worth of present-day U.S. emissions

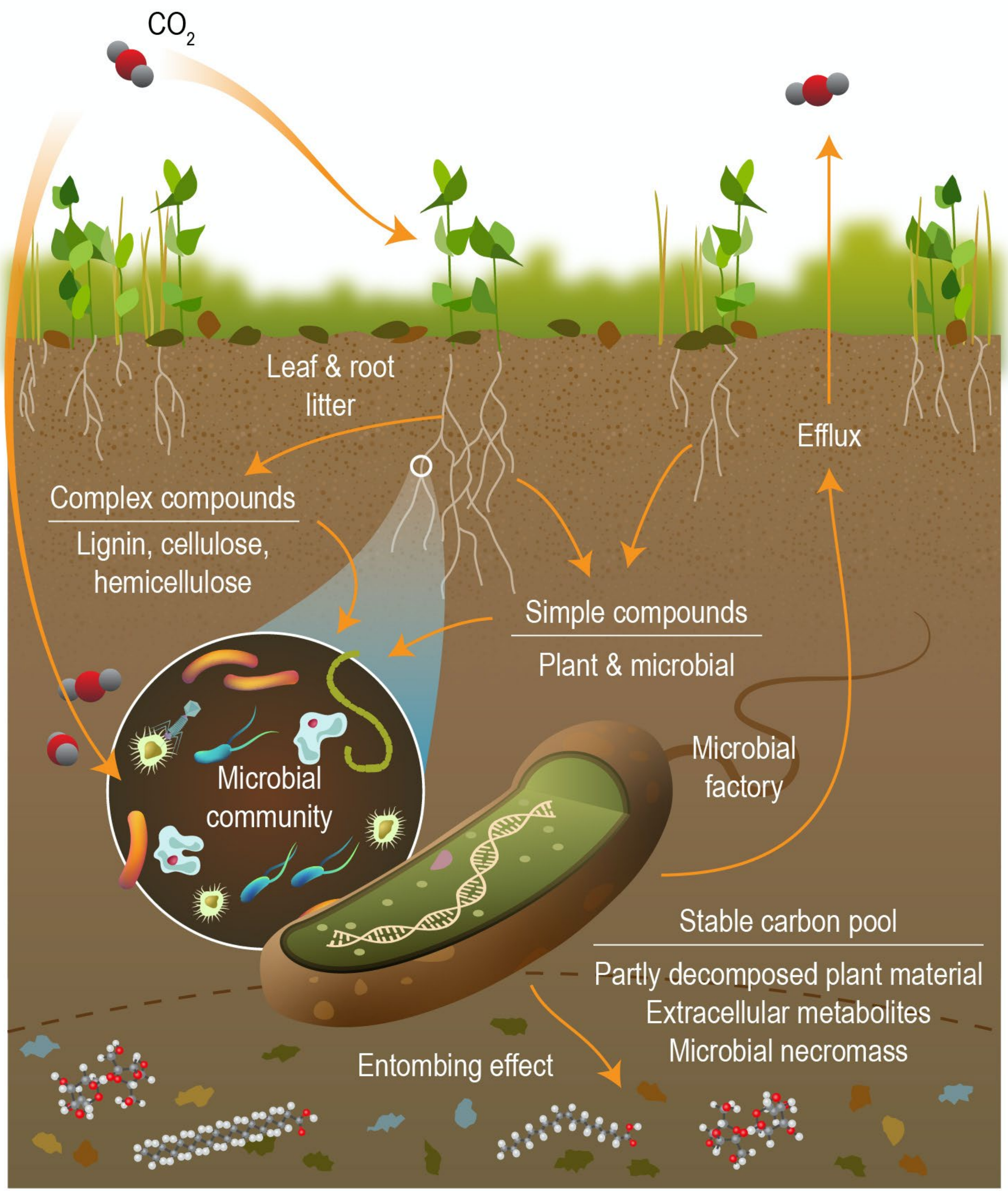


Sanderman et al. 2017 PNAS

Pacific Northwest
NATIONAL LABORATORY

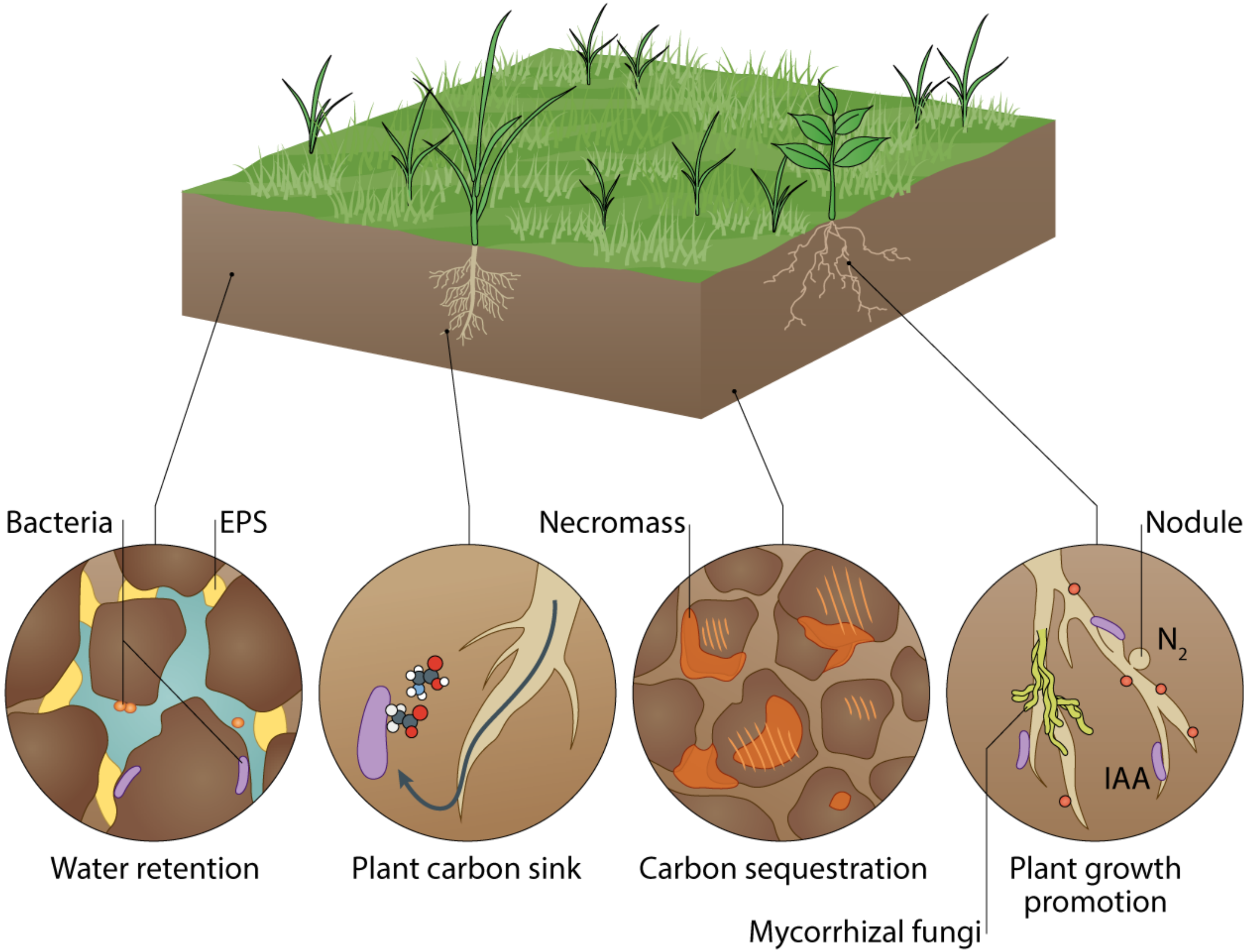
Soil C sequestration is part of the climate solution

- Soil is a sink for 2500 Gt of C
- Plants provide new C inputs to soils
- 24-60% of SOM of microbial origin
  (Deng and Liang 2022)



Naylor et al. 2020 ARER

Soil microbes contribute to C sequestration

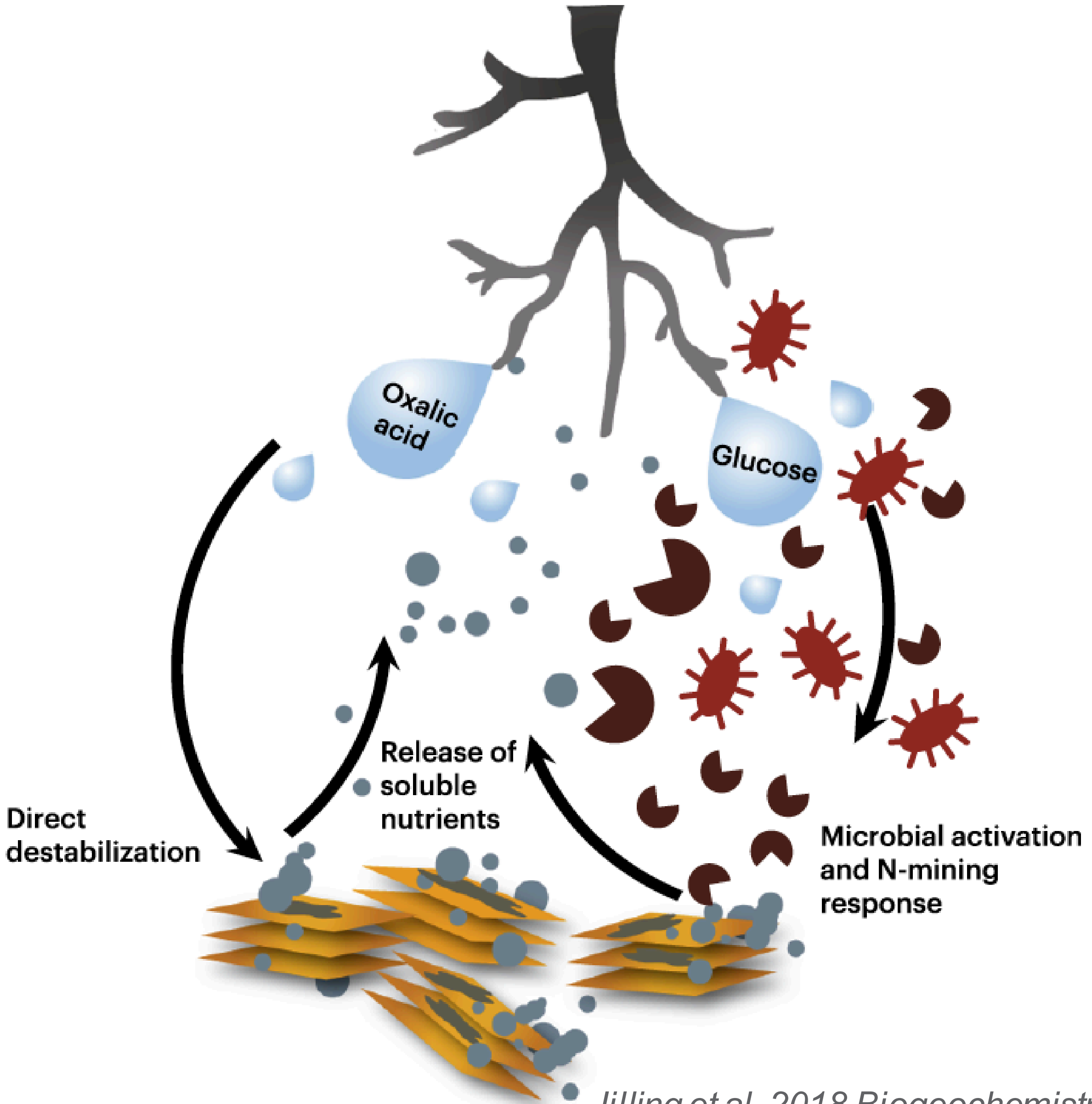


Jansson & Hofmockel. Nature Microbiology Reviews. 2019

Pacific Northwest
NATIONAL LABORATORY

Mineral associations regulate C persistence

- Accrual of CO_2 relies on microbial metabolism of plant inputs
- Necromass sequestration depends on organomineral complexes
- Opportunity to optimize microbial metabolism and necromass



Jilling et al. 2018 Biogeochemistry

How do plant-microbe-mineral interactions influence soil C sequestration?

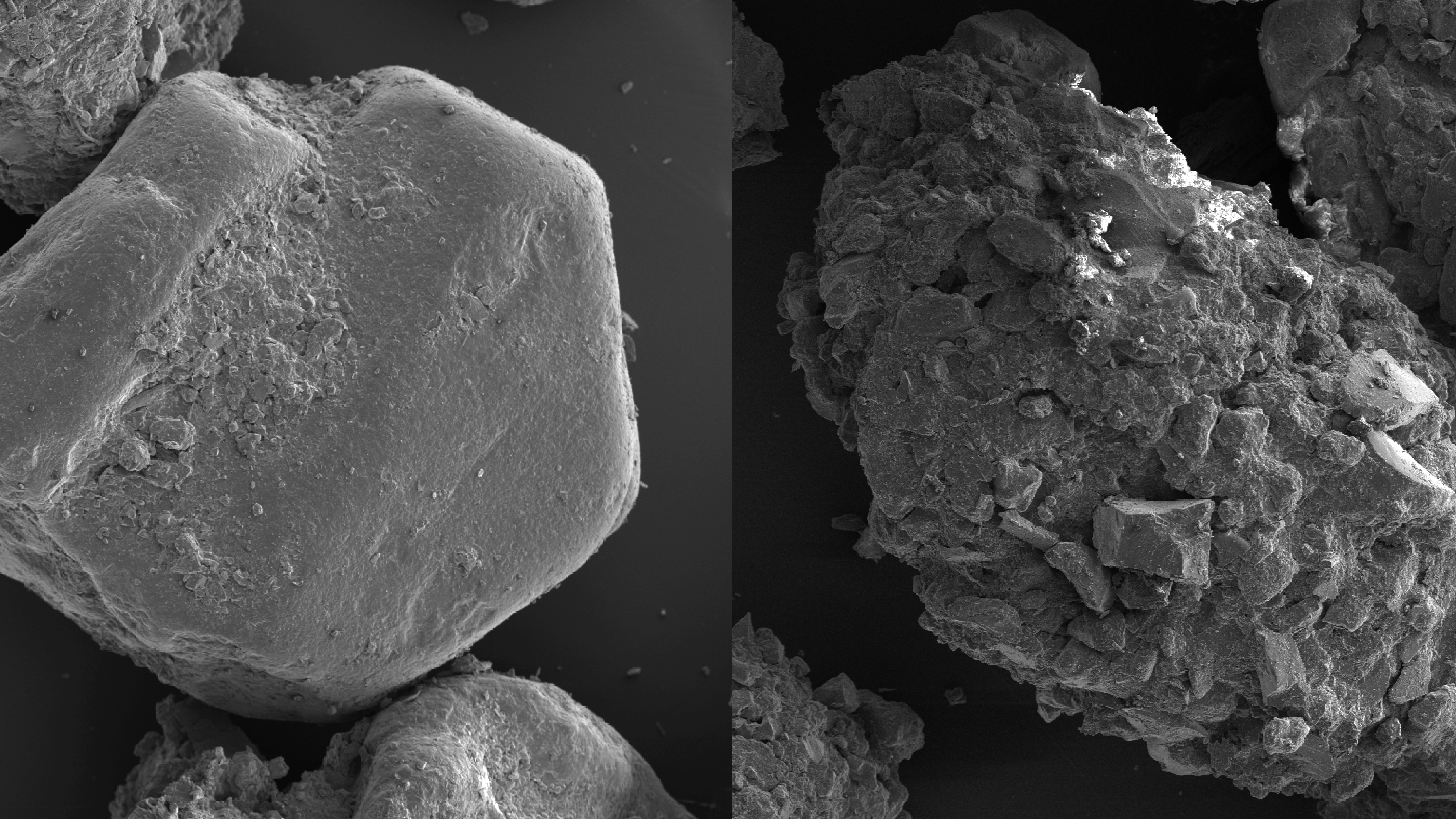
- Are certain microbes more influential in producing biomass/necromass?
- Do bioenergy cropping systems favor C accumulation?
- What is the influence of the soil habitat on microbial necromass retention?

Great Lakes Bioenergy Research Center (GLBRC)

Kellogg Biological Station (KBS) in Michigan
Sandy Loam

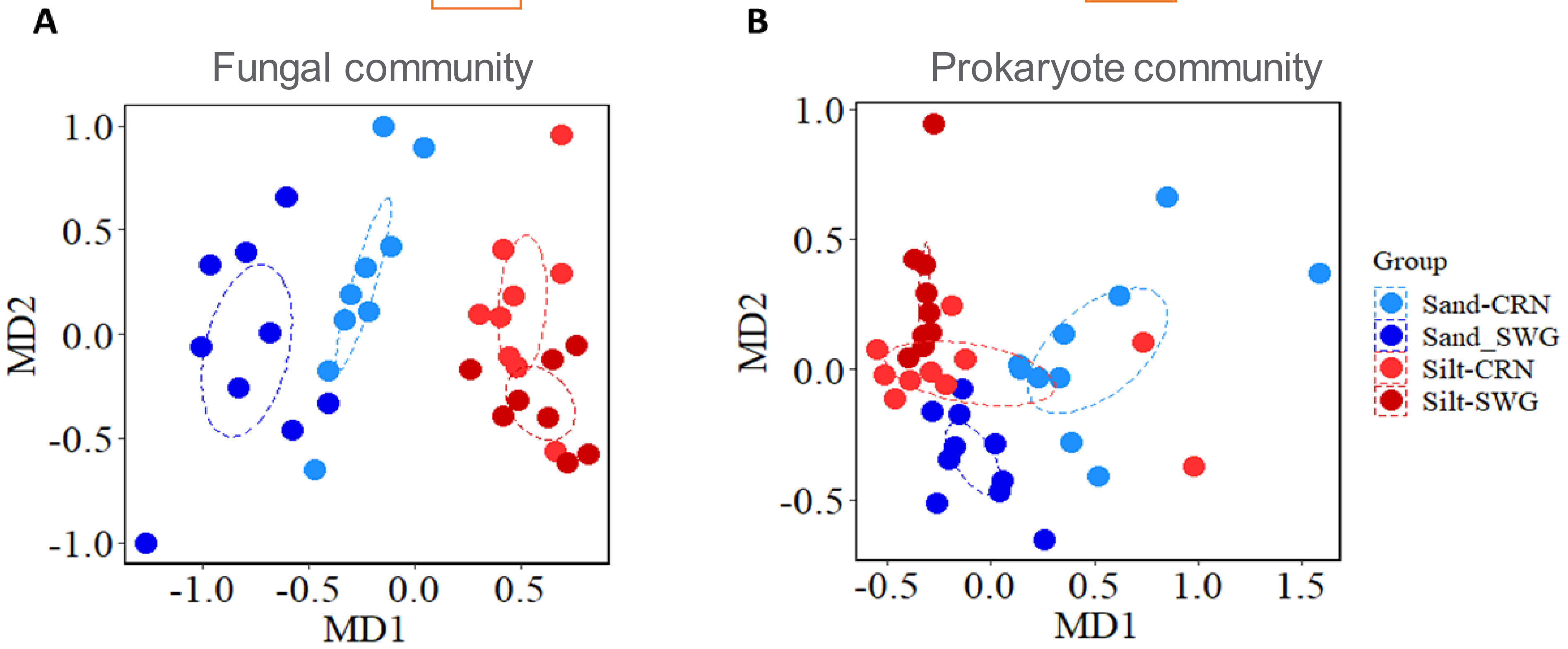
Arlington Agricultural Research Station (AARS) in Wisconsin
Silt Loam

Sampled 5 field replicates of switchgrass and corn at each site in 2017
(9 years after establishment)



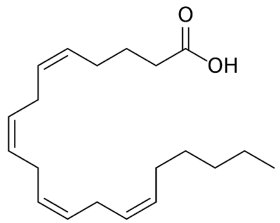
Soil type impacts community composition more than cropping system

DNA Fall	ITS: Site r^2 = 0.20 Crop r^2 = 0.07	16S: Site r^2 = 0.13 Crop r^2 = 0.08
DNA Spring	ITS: Site r^2 = 0.20 Crop r^2 = 0.13	16S: Site r^2 = 0.27 Crop r^2 = 0.10
RNA Spring	ITS: Site r^2 = 0.14 Crop r^2 = 0.09	16S: Site r^2 = 0.29 Crop r^2 = 0.13



Kasanke et al. 2021 GCBB

Mortierella highly prevalent across systems



arachidonic acid

Filamentous saprotrophs noted for industrial arachidonic acid production and rock phosphate solubilization

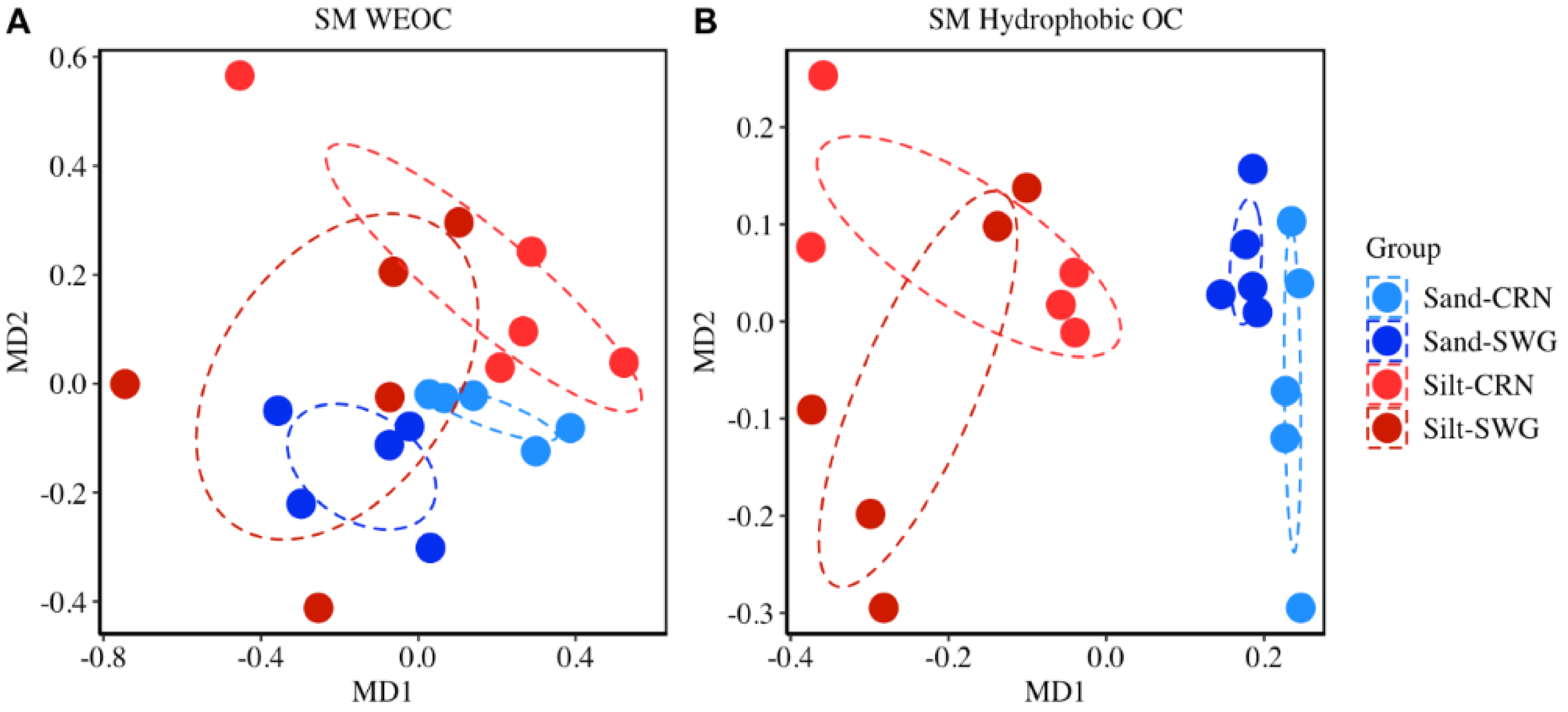
Dominant ITS OTUs							
Silty Switchgrass				Sandy Switchgrass			
OTU	ID	Similarity	Rel. Abund. (Mean ± Stdev)	OTU	ID	Similarity	Rel. Abund. (Mean ± Stdev)
4	*Mortierella hyaline*	100%	11.9 ± 14.5%	19	*Mortierella exigua*	100%	17.0 ± 12.5%
1	*Morterela* sp.	99%	11.1 ± 3.6%	12	*Mortierella beljakovae*	94%	7.4 ± 12.5%
151	*Mortierella camargensis*	98%	6.3 ± 2.5%	22	*Mortierella beljakovae*	95%	5.3 ± 8.0%
16	*Heydinia alpine*	100%	5.6 ± 11.0%	17	*Phallus rugulosus*	98%	4.2 ± 9.3%
10	*Mortierella* sp.	100%	4.2 ± 1.5%	14	*Mortierella elongata*	100%	4.1 ± 4.5
Silty Corn				Sandy Corn			
1	*Mortierella* sp.	99%	7.1 ± 4.4%	14	*Mortierella elongata*	100%	15.1 ± 16.1%
151	*Mortierella camargensis*	98%	6.4 ± 6.7%	19	*Mortierella exigua*	100%	9.0 ± 6.0%
21	*Solicoccozama terreus*	100%	5.0 ± 2.5%	10	*Mortierella* sp.	100%	8.5 ± 17.9%
4	*Mortierella hyaline*	100%	4.4 ± 5.0%	16	*Heydinia alpine*	100%	3.8 ± 5.1%
16	*Heydinia alpine*	100%	4.2 ± 3.6%	84	*Exophiala pisciphila*	96%	3.6 ± 1.3%

Kasanke et al. 2021 GCBB

Biotic and Abiotic Effects on Soil Organic C

WEOC: Site r^2 = 0.09 Crop r^2 = 0.18

$CHCl_3$: Site r^2 = 0.28 Crop r^2 = ns



FTICR-MS data from small aggregates

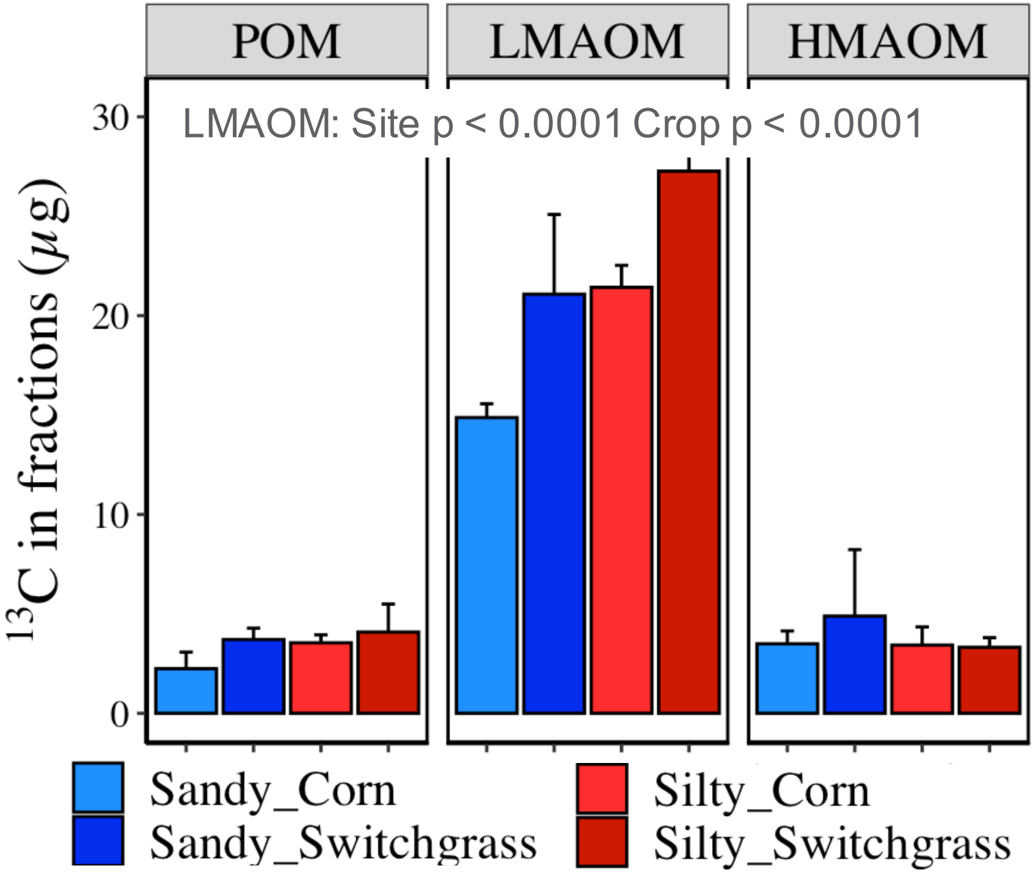
Kasanke et al 2021 GCBB

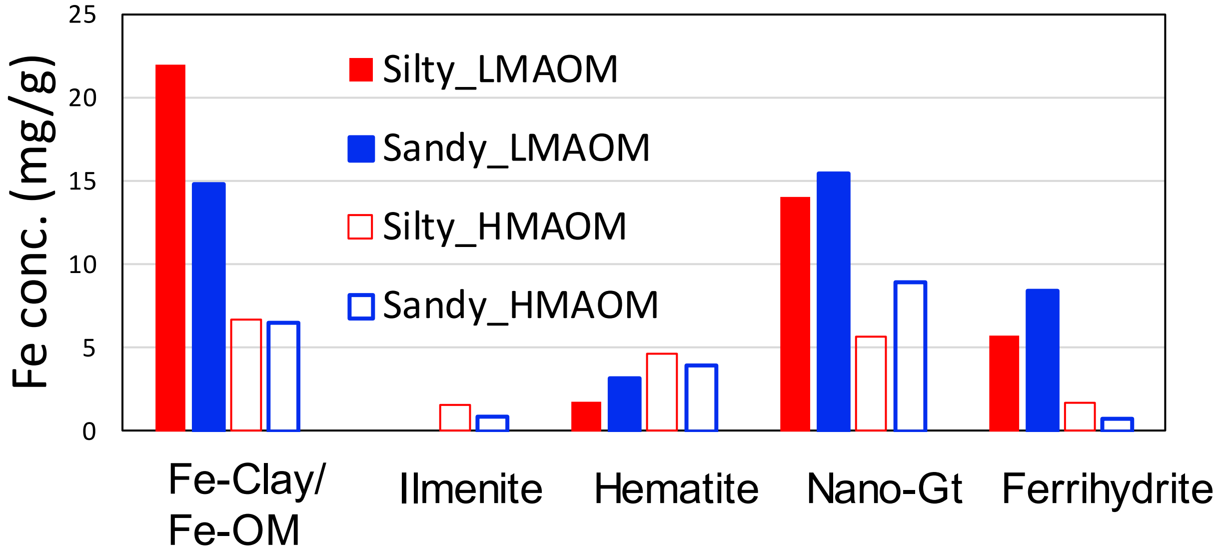
Greatest necromass accumulation in LMAOM

Particulate

Light Mineral Associated

Heavy Mineral Associated





Zhao et al 2022 in prep

After 8 years, no significant change in C or N accrual

		%C		%N	
		2 year *	8 year	2 year *	8 year
Sand	Corn	1.23 ± 0.09	1.18 ± 0.38	0.11 ± 0.01	0.09 ± 0.04
	Switchgrass	1.21 ± 0.07	0.92 ± 0.13	0.09 ± 0.01	0.10 ± 0.01
Silt	Corn	2.61 ± 0.12	2.17 ± 0.31	0.27 ± 0.02	0.20 ± 0.03
	Switchgrass	2.30 ± 0.11	2.22 ± 0.37	0.23 ± 0.02	0.22 ± 0.03

Increased EEA in SWG soils may offset the proposed carbon sequestration benefits of using switchgrass instead of corn as a biofuel crop

** From Jesus et al. 2016*

Kasanke et al 2021 GCBB

Concluding remarks

- Plant-microbe interactions strongly influence bioavailable carbon
- Edaphic properties regulate the sink capacity
- Greatest accumulation of microbial-derived necromass was in light mineral associated organic matter fraction that is enriched in high concentrations of amorphous iron-bearing minerals
- Need to consider mass balance of entire system, including hydrologic transport to deep soil horizons

Thank You

Kirsten Hofmockel
Chris Kasanke
Qian Zhao
Sarah Leichty
Allison Thompson
Montana Smith
Trinidad Alfaro

Jim Moran
Nick Huggett
Tom Wietsma
Andrew Lipton
Alice Dohnalkova
Ravi Kukkadapu

GREAT LAKES BIOENERGY RESEARCH CENTER

Sarah Roley
Lawrence Oates
Gregg Sandford
Randy Jackson
Phil Robertson

This research was supported by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research program under award *FWP* 68292, and EMSL Exploratory Research Project 51095


SOIL ECOLOGY SOCIETY
2022 Biennial Meeting
UNEARTHING IT.
May 17 - 19
Pacific Northwest
NATIONAL LABORATORY