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^{13}C tracing reveals microbial drivers of root-zone carbon dynamics among prominent field crops

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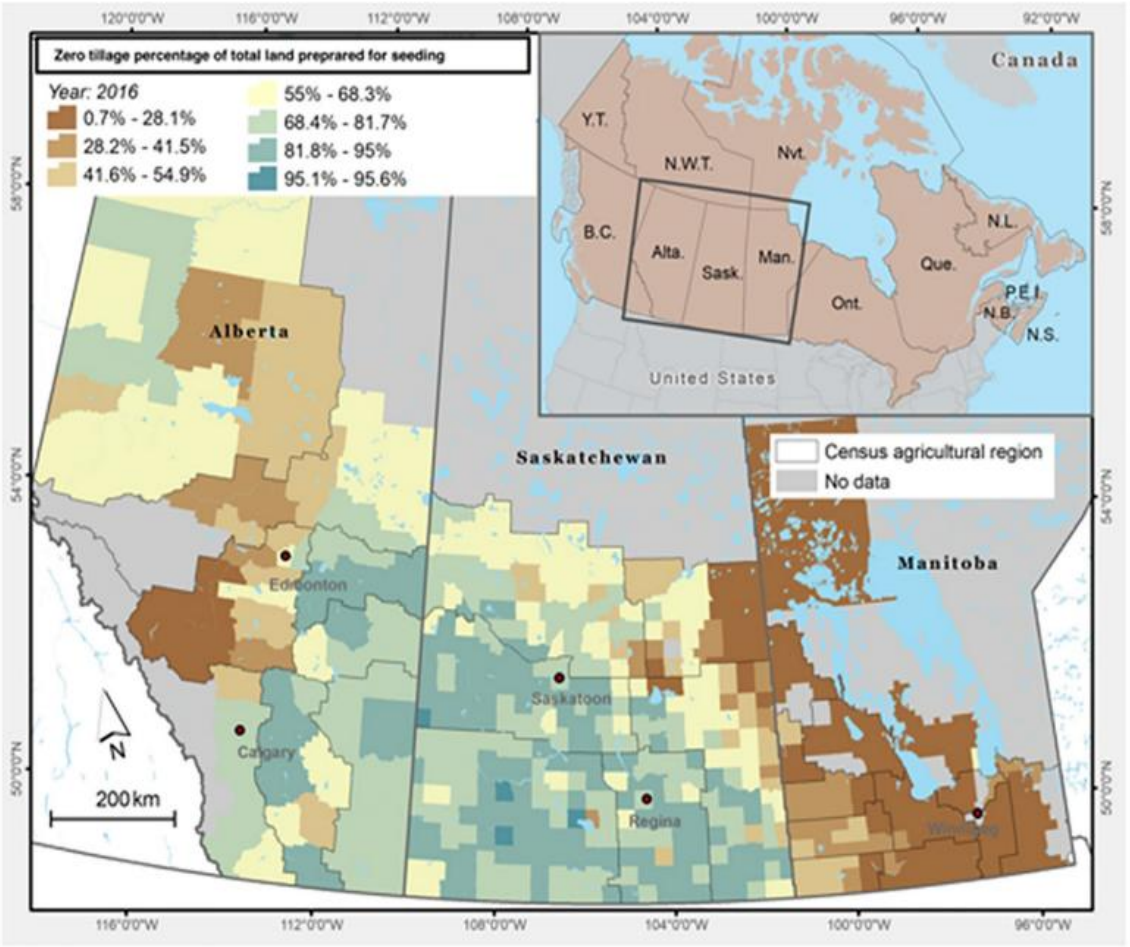
Canadian prairie soils are important for food security and soil carbon storage

Saskatchewan annual cropland: ~40M ac

- **Canola: 12M ac**
- **Spring wheat: 8M ac**
- **Field Pea: 0.7M ac**



Map: Awada et al. 2021 PLOS One

Soil organic matter: cornerstone of soil health

Soil organic matter

Promotes:

- good soil structure
- aggregate formation and stability

Regulates:

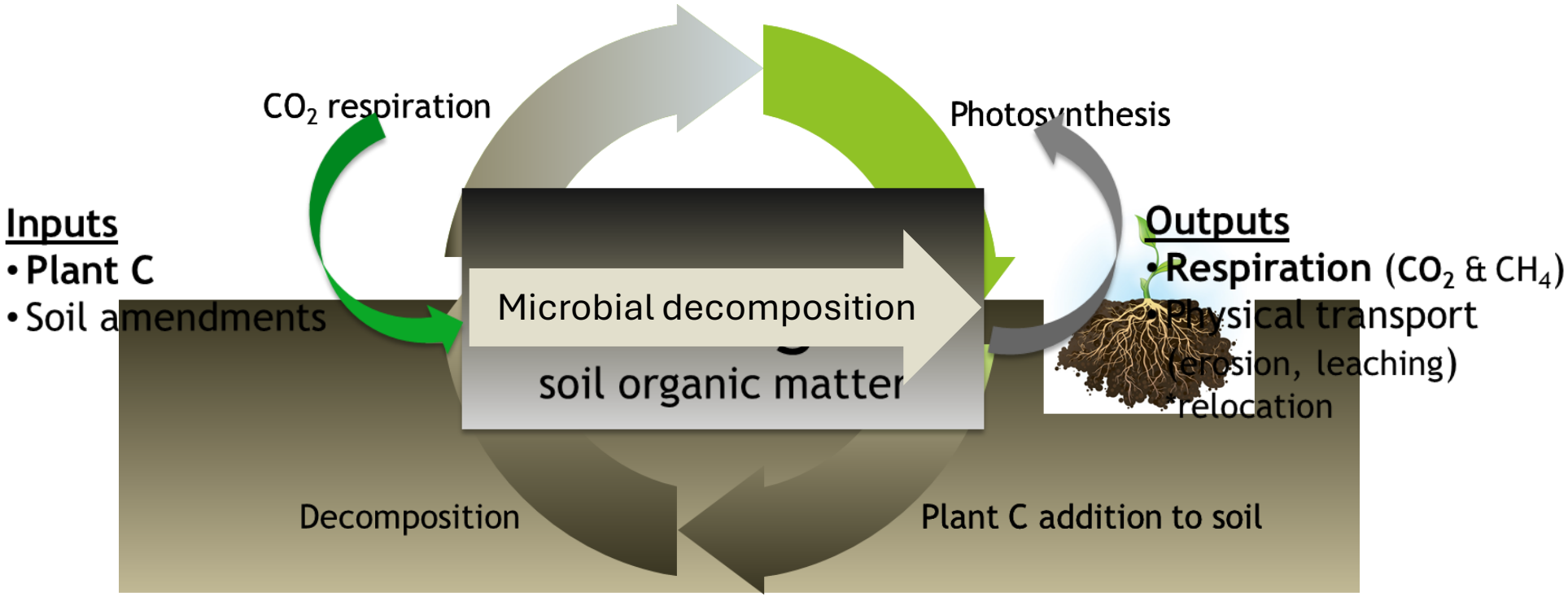
- soil moisture & nutrient cycling
- climate (C storage and GHG)

Is a source of:

- nutrients for plants and microbes
- energy (food) for microorganisms

provides resilience to stress

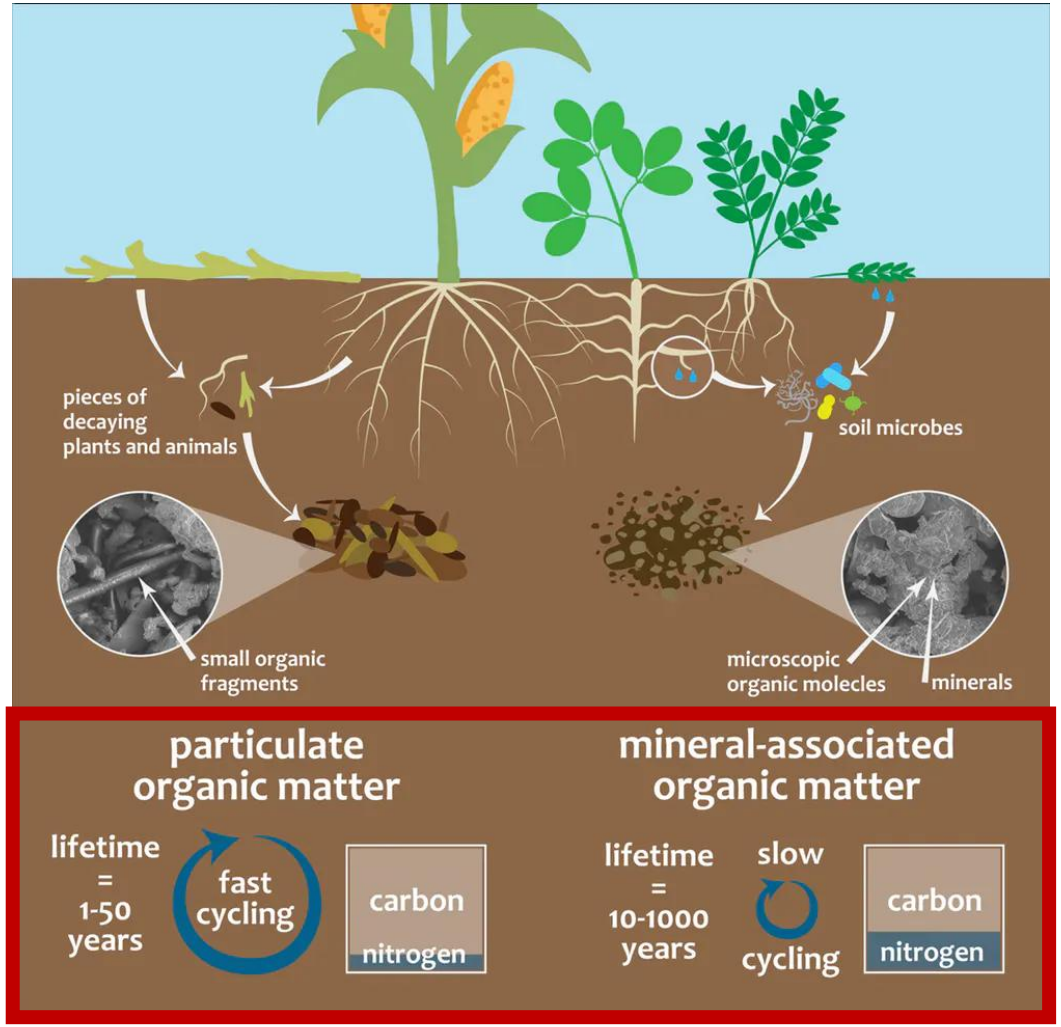
Soil organic matter is derived from plant matter



ODE TO ROT (J. Updike 1985)

" 'Let there be rot', and hence bacteria and fungi sprang into existence to dissolve the knot of carbohydrates photosynthesis achieves in plants, in living plants...
...Dead matter else would hold the elements in thrall -- nitrogen, phosphorus..."

Not all soil organic matter is created equally



https://theconversation.com/soil-carbon-is-a-valuable-resource-but-all-soil-carbon-is-not-created-equal-129175

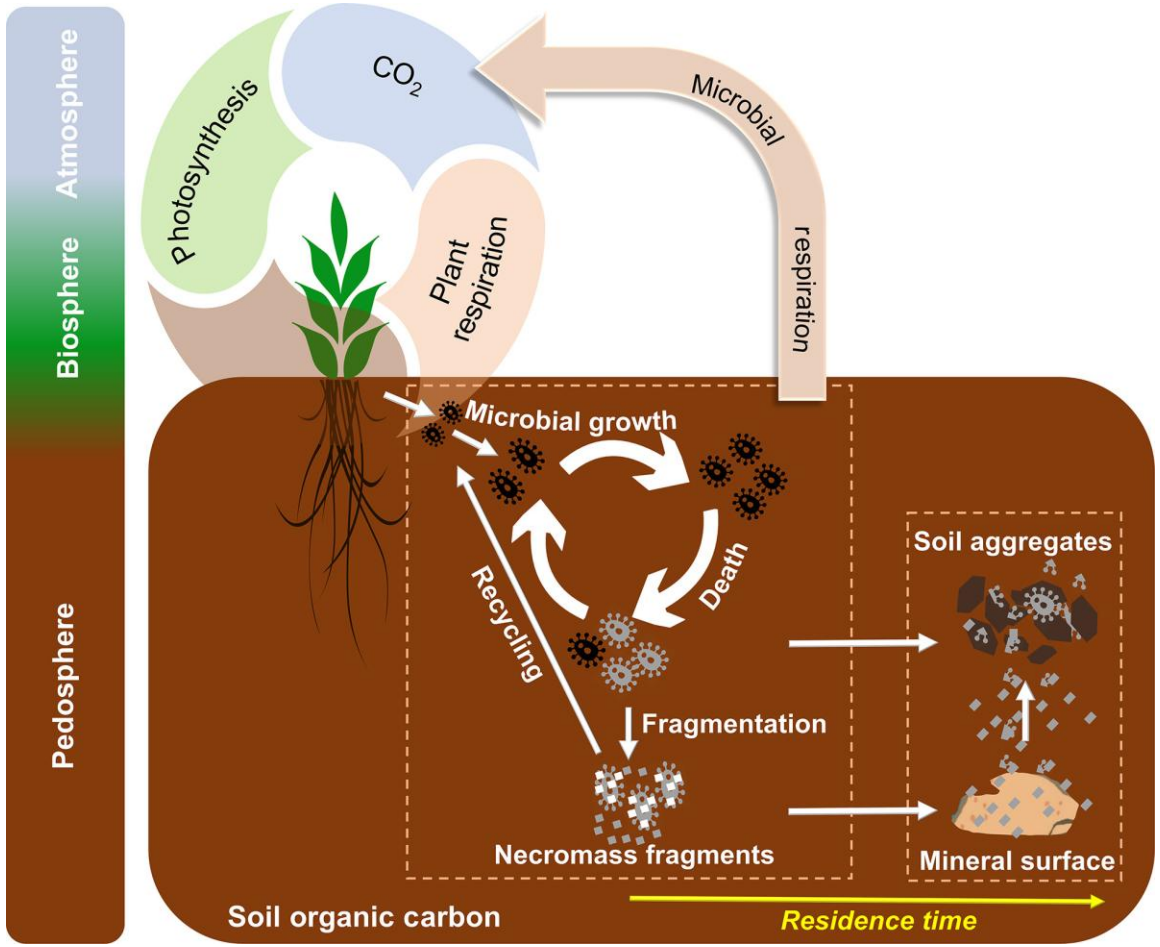
Particulate organic matter (POM):

- primarily protected within aggregates

Mineral-associated organic matter (MAOM):

- protected by binding with clay minerals

Microbial necromass is preferentially stabilized



Liang et al 2019. Global Change Biology
DOI: 10.1111/gcb.14781

Microbial *necromass* is a large, important pool of organic carbon and nitrogen

In cropland:

- about 50% of soil organic carbon is microbial necromass
- about 60% of soil total nitrogen is microbial necromass

Tracking plant contributions (esp. roots) to large background pools in soil is challenging

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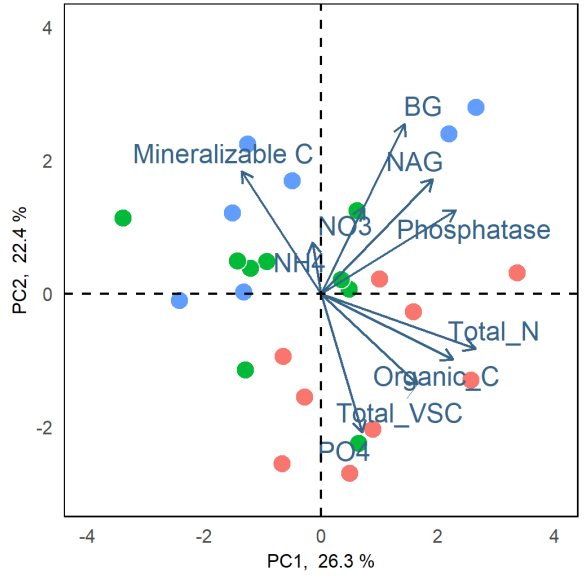
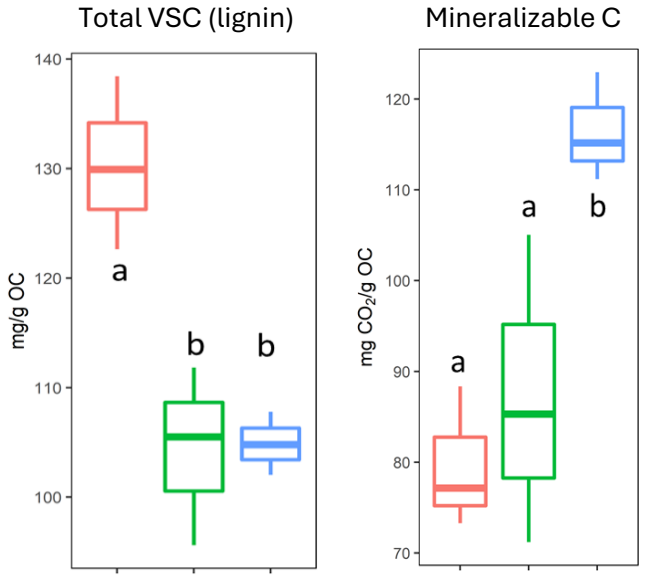
Diverse crop rotations influence the bacterial and fungal communities in root, rhizosphere and soil and impact soil microbial processes

Jennifer R. Town [a,*], Edward G. Gregorich [b], Craig F. Drury [c], Reynald Lemke [a], Lori A. Phillips [c], Bobbi L. Helgason [a,d]

Long term field study: ~25 years



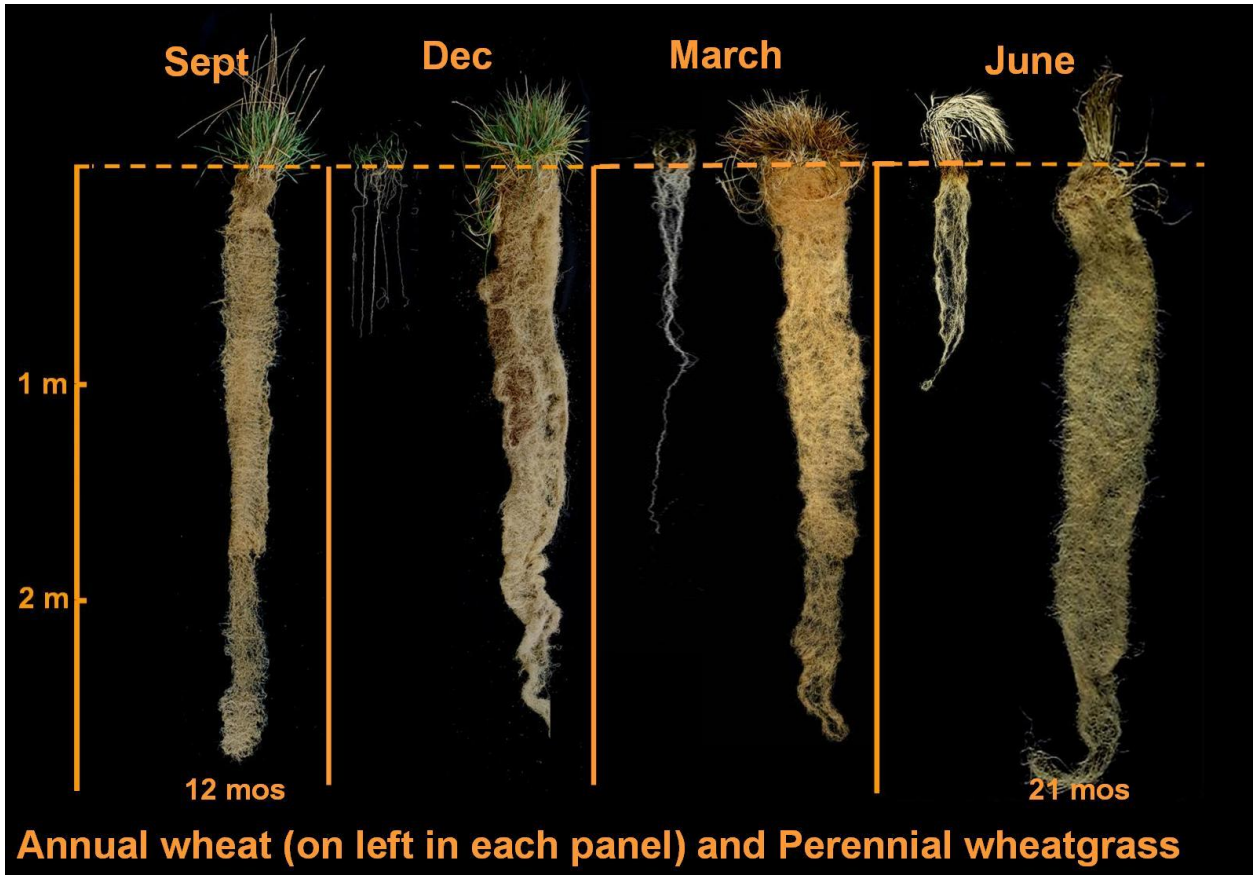


Continuous Wheat

Wheat after Pea

Wheat after Canola

Soil organic matter: what is the big deal with roots?

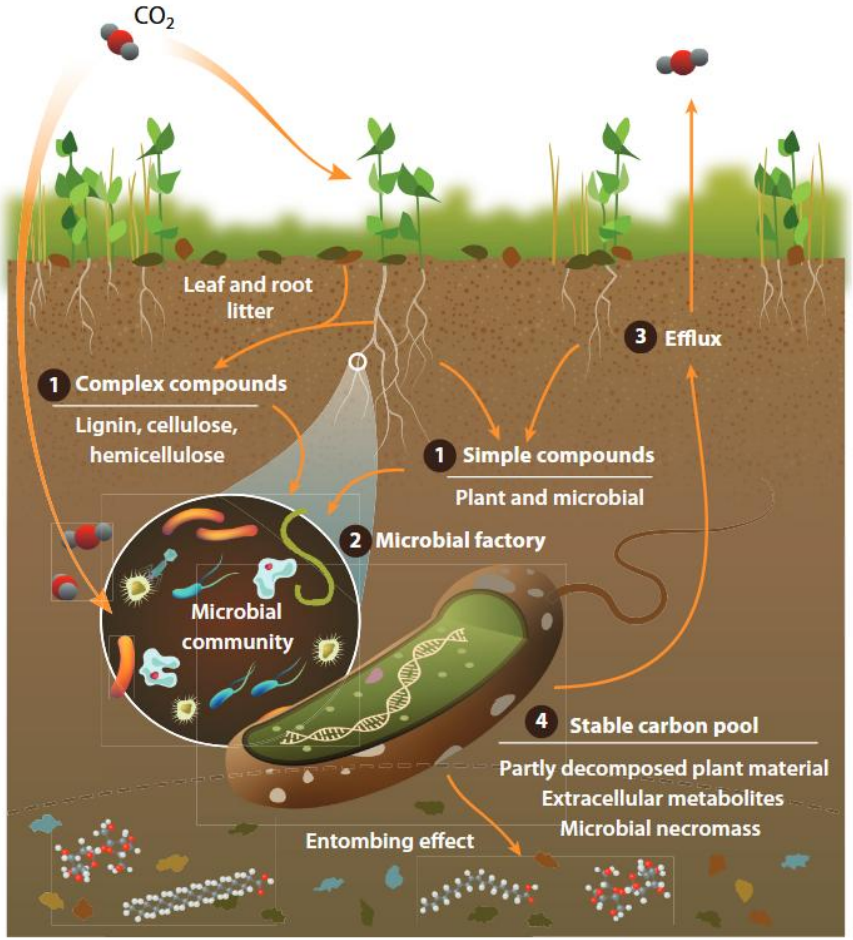


upload.wikimedia.org/wikipedia/commons/a/a7/4_Seasons_Roots.jpg

Roots can contribute up to 80% as much C as aboveground biomass (e.g., Fan et al. 2019).

Emerging evidence that root C is preferentially stabilized (e.g., Sokol et al 2019).

Root-derived carbon is important for soil fertility and soil C persistence



Naylor et al., 2020.

What is the relative quantity of rhizodeposit C of key crops?

What proportion of rhizodeposit C is used for microbial growth vs. storage?

What can this tell us about how rhizodeposits and microbes interact to affect soil fertility?

^{13}C tracing: the atmosphere-plant-microbe-soil continuum

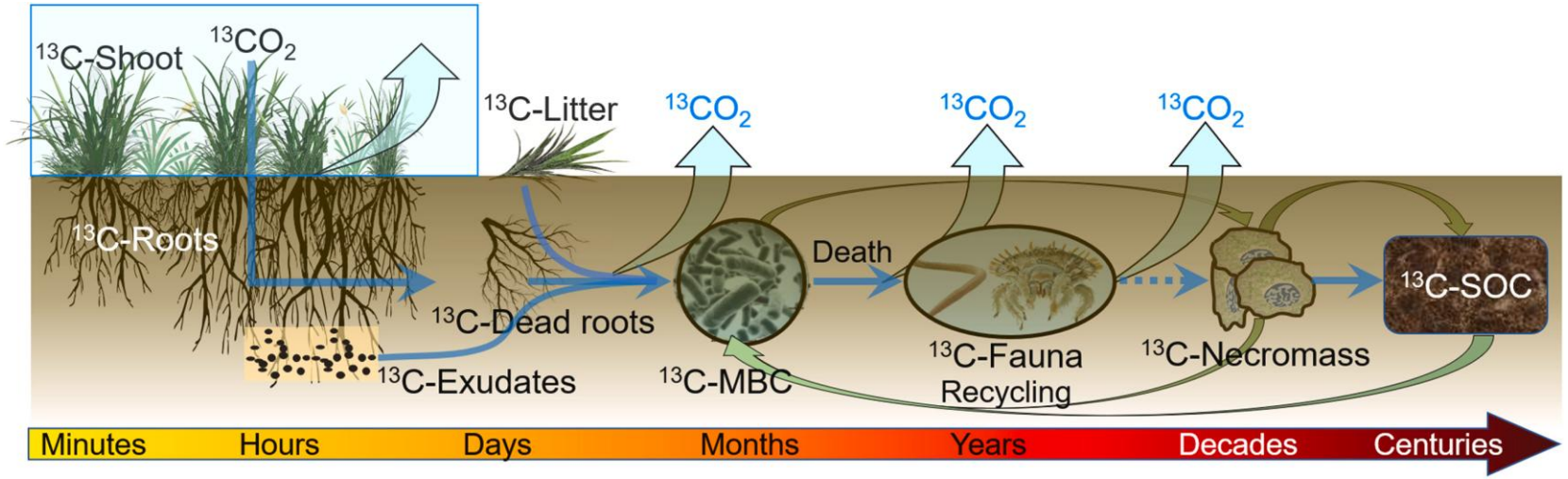
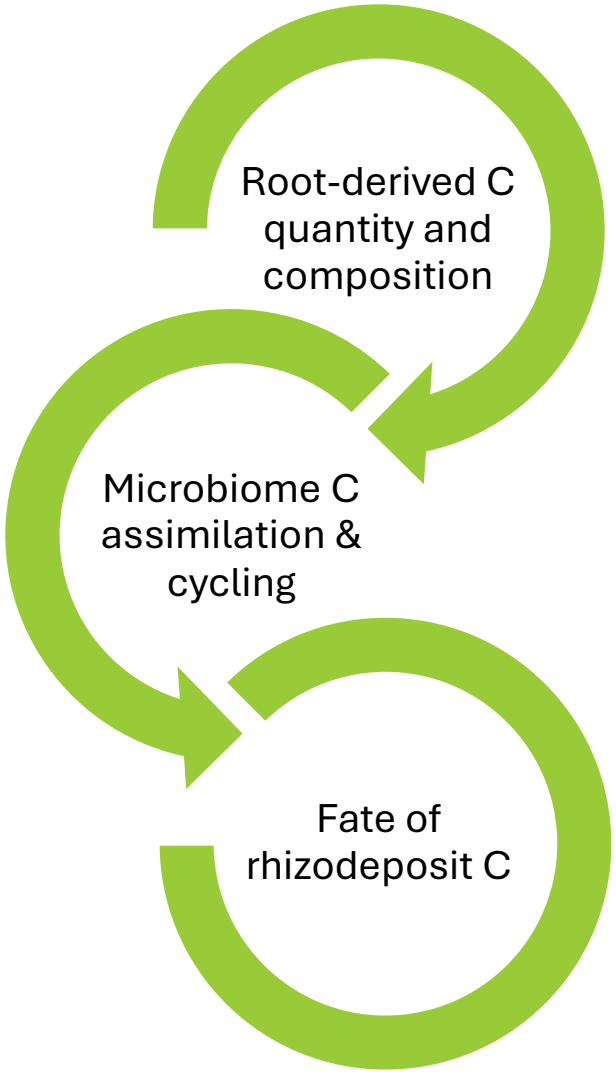
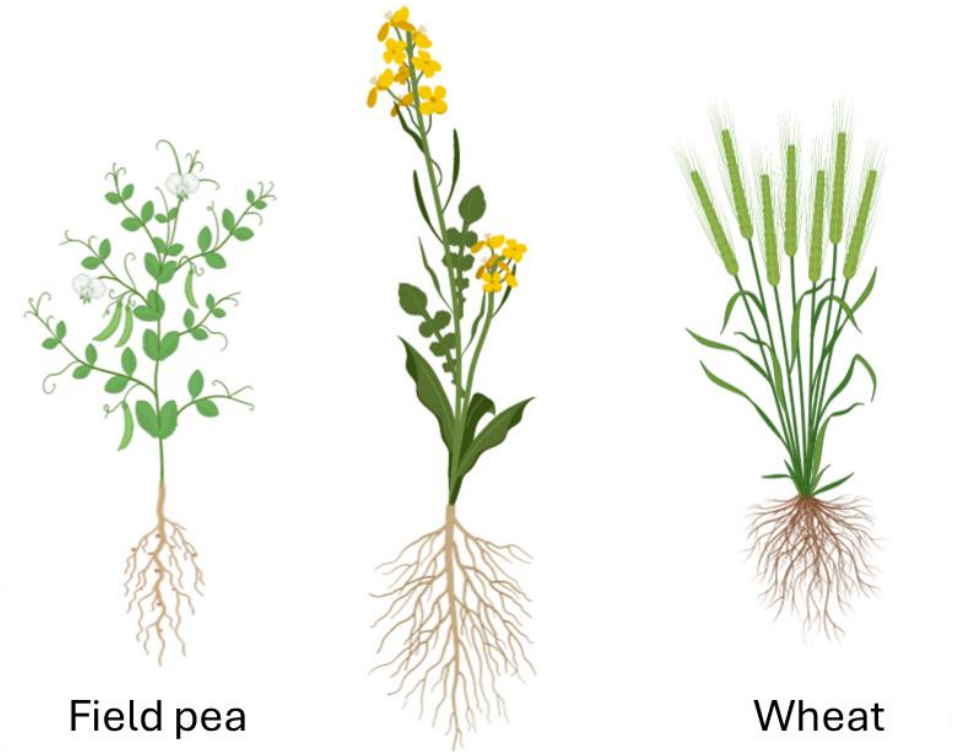


Image: Pang et al. 2021 Rhizosphere

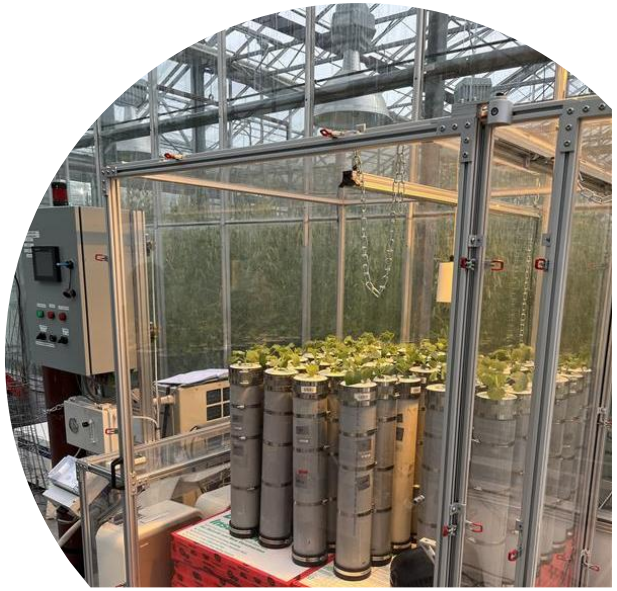
Characterizing root C inputs and microbial soil C cycling in major field crops





Ph.D. Candidate
Mostafa Hojati

Objective: quantify and track the fate of rhizodeposit carbon in canola, wheat and pea

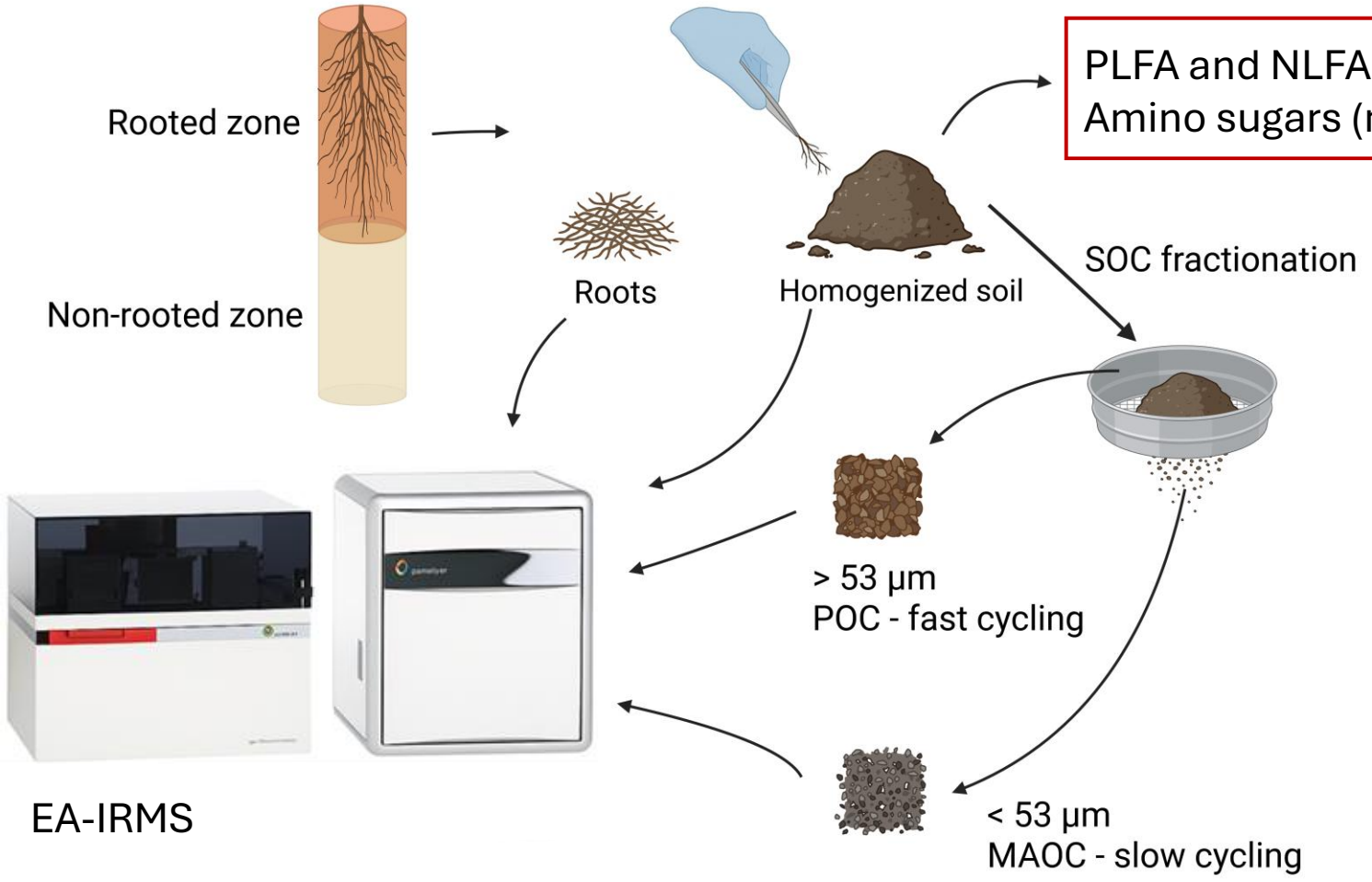


Pulse labeling with $^{13}CO_2$:

- 2 days per week
- 5 hours per day
- 420 ppm; 35 atom% $^{13}CO_2$

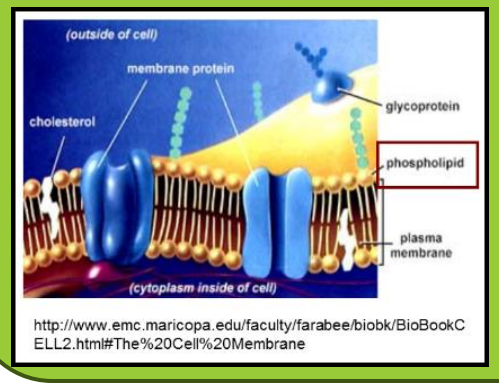
Soil type	Clay (%)	Sand (%)	Silt (%)	CEC (meq 100 g^{-1})	pH	TOC (%)	Total N (%)	C:N
Goodale	19	47	34	27	7.9	1.8	0.196	9.2
Central Butte	23	41	36	30	7.6	2.0	0.185	10.8

^{13}C determined in roots, bulk soil and POM/MAOM fractions

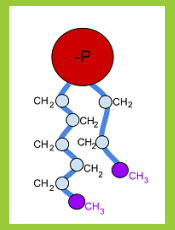


Compound-specific fatty acid (PLFA/NLFA) & amino sugar analyses

Living cell microbial biomarkers

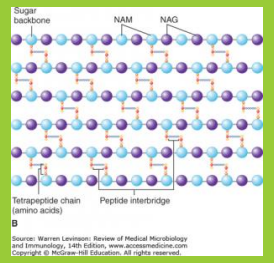


http://www.emc.maricopa.edu/faculty/farabee/biobk/BioBookCELL2.html#The%20Cell%20Membrane

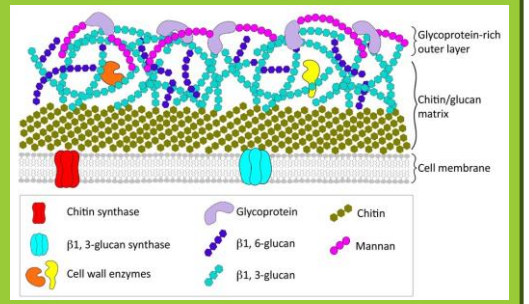


Total/^{13}C Phospho- and neutral-lipid fatty acids

Dead cell (necromass) microbial biomarkers



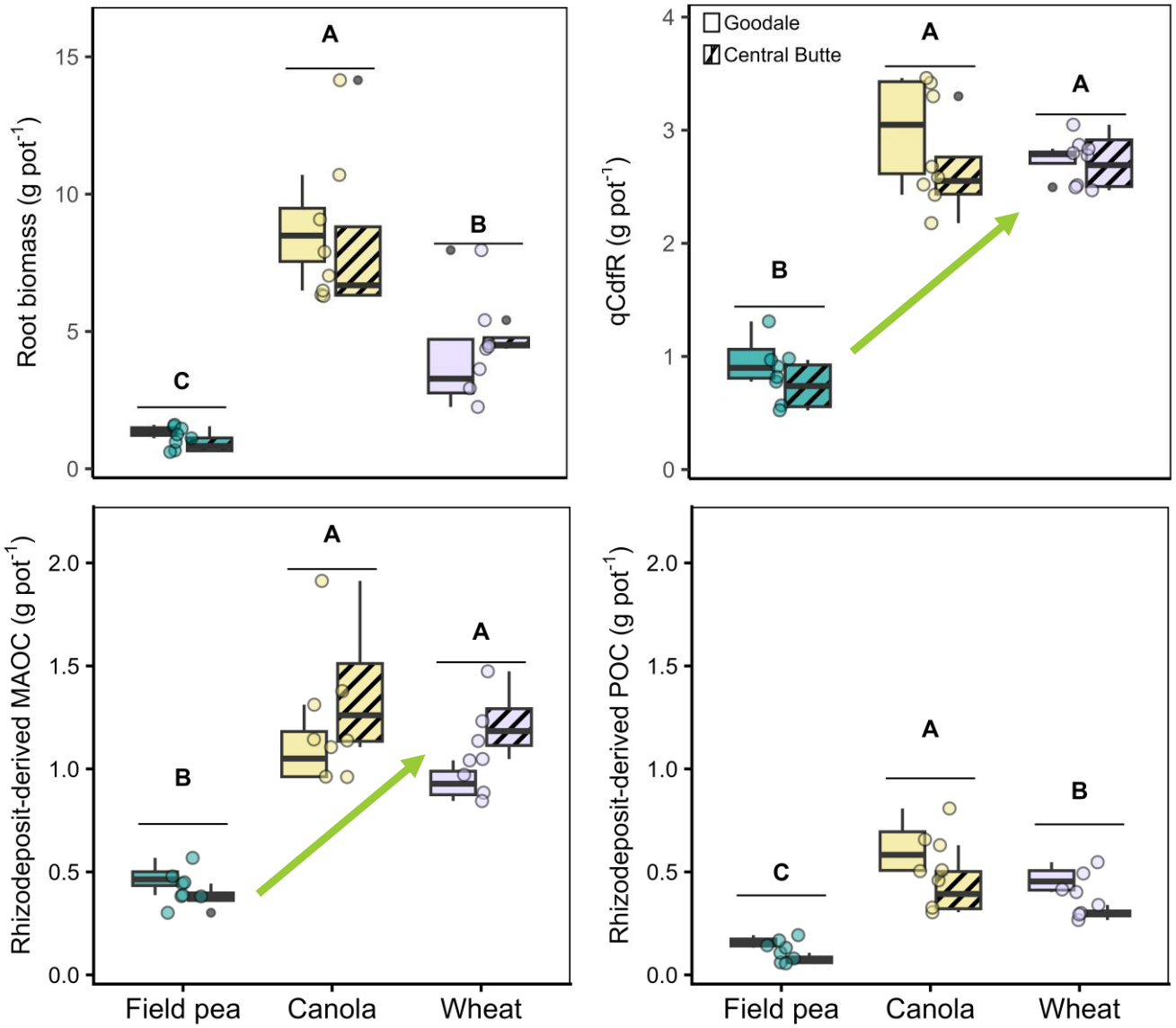
Amino sugars



Geoghegan et al. 2017 Trends in Microbiol. 25:957-967

Root & rhizodeposit C at plant maturity

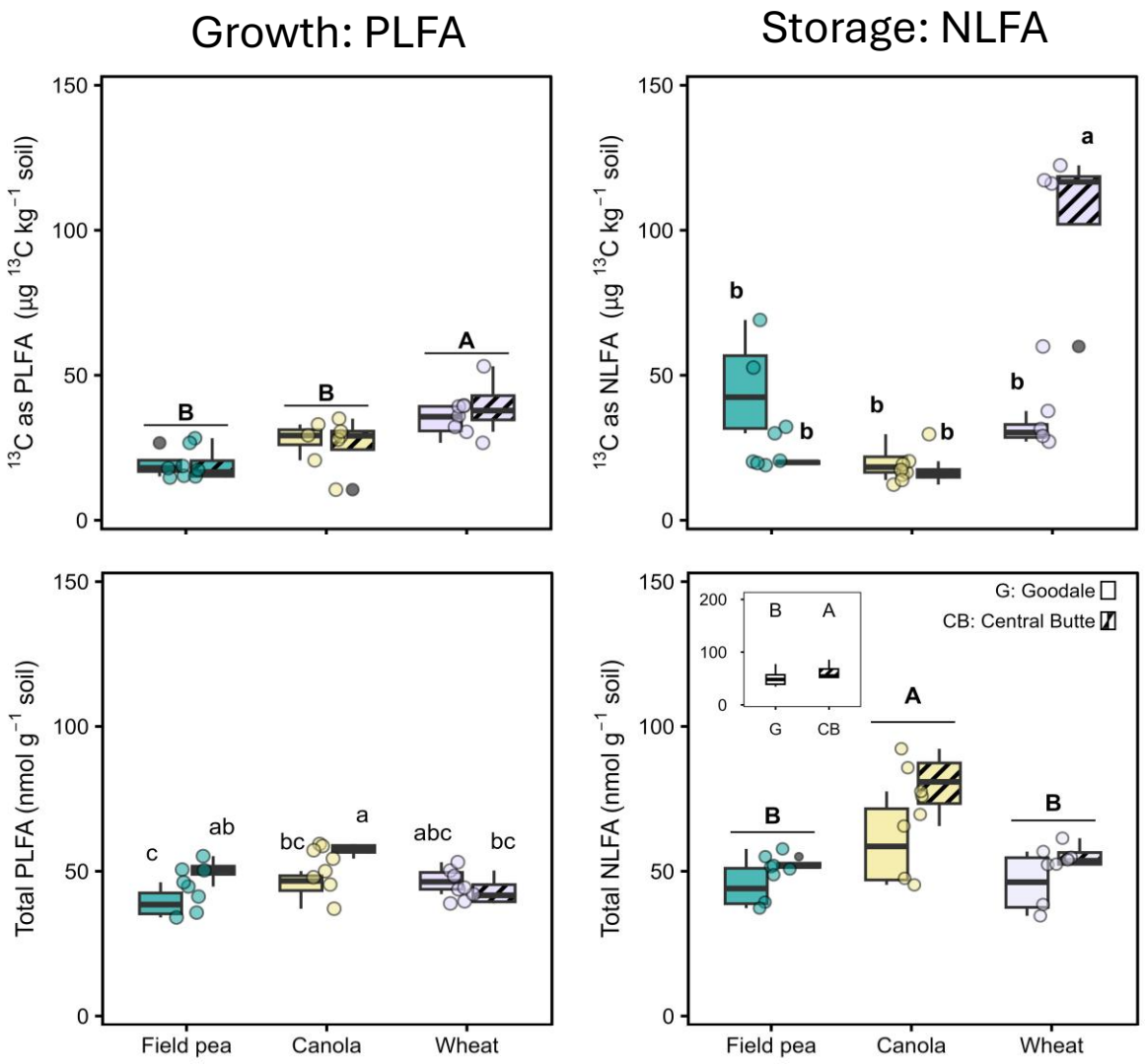
canola, wheat >> pea



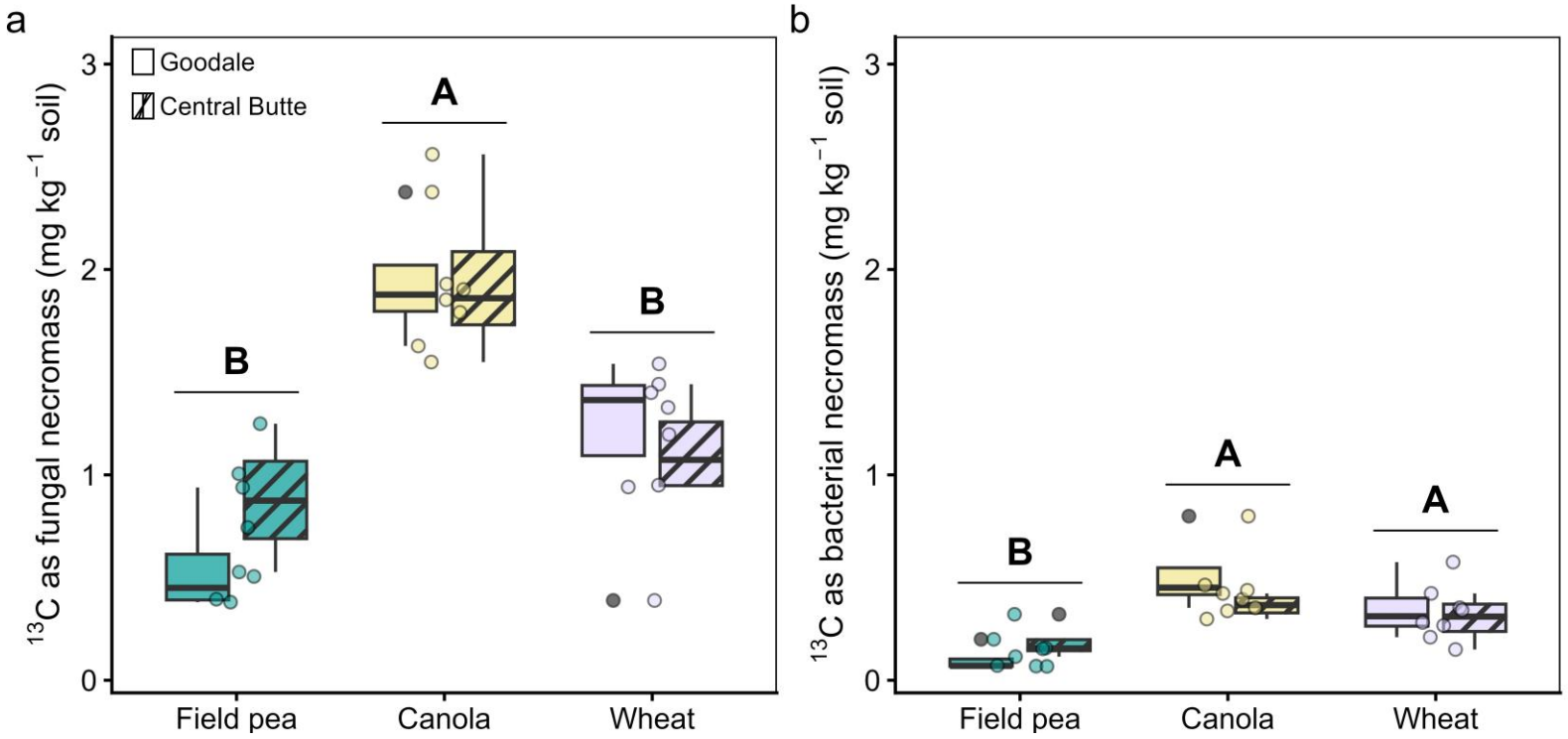
Canola and wheat rhizodeposit C was *3 times* greater than pea

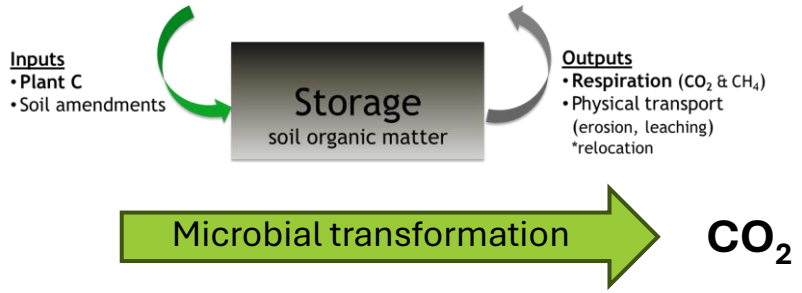
Translated to greater mineral-associated and particulate C

Microbial use of root-derived ^{13}C



Necromass ^{13}C differed between crops – greater for fungi than bacteria; highest in canola



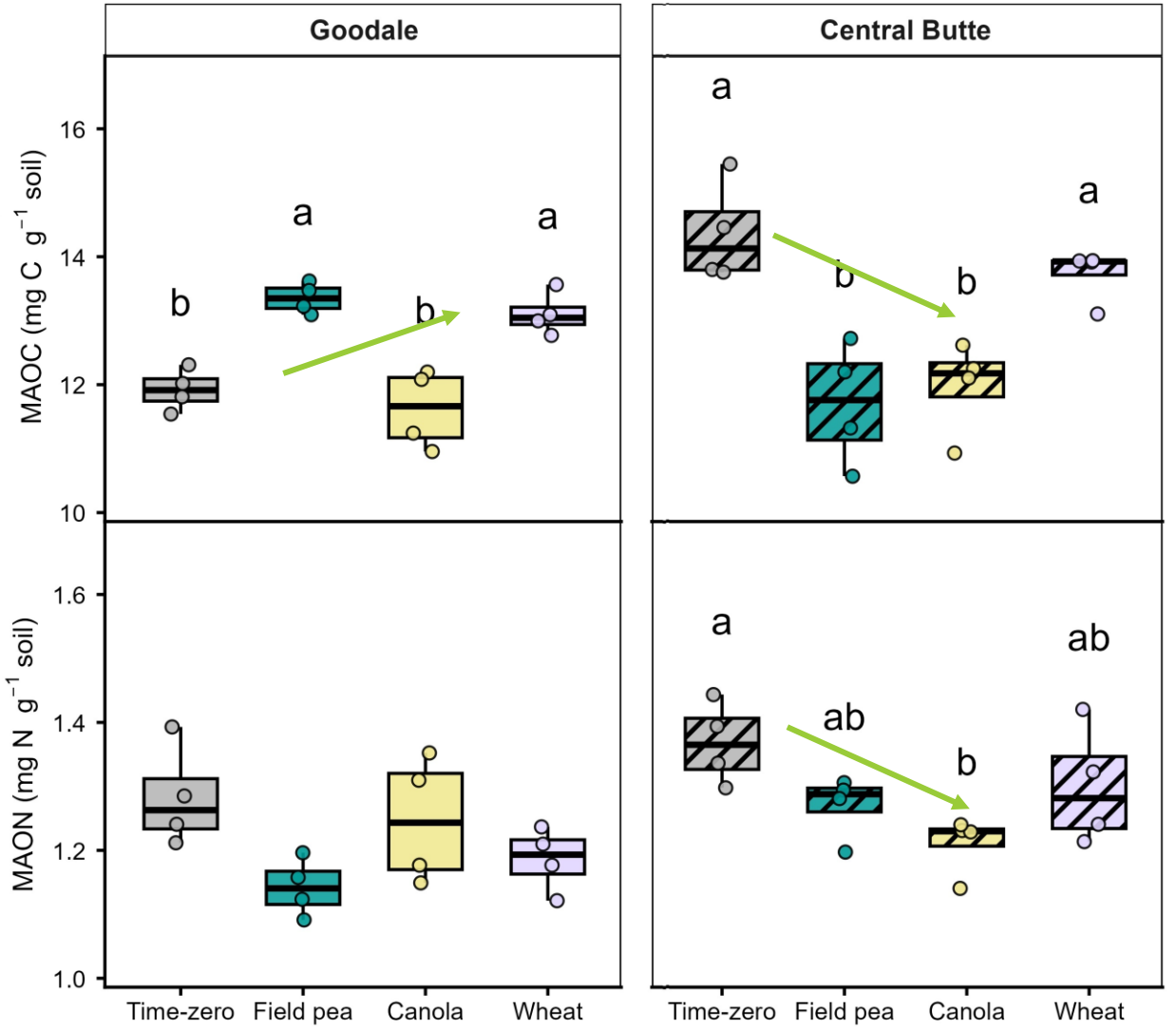


Important role of crop-specific microbial community-level rhizodeposit carbon assimilation, turnover and potentially, C persistence

Canola rhizodeposits cause C and N "*priming*"

In Goodale soil wheat and pea rhizodeposits increased mineral-associated C (MAOC)

Canola caused priming of MAOC and MAON in Central Butte soil



Multiple ^{13}C tracing: insight into mechanisms of root-derived C turnover and fate

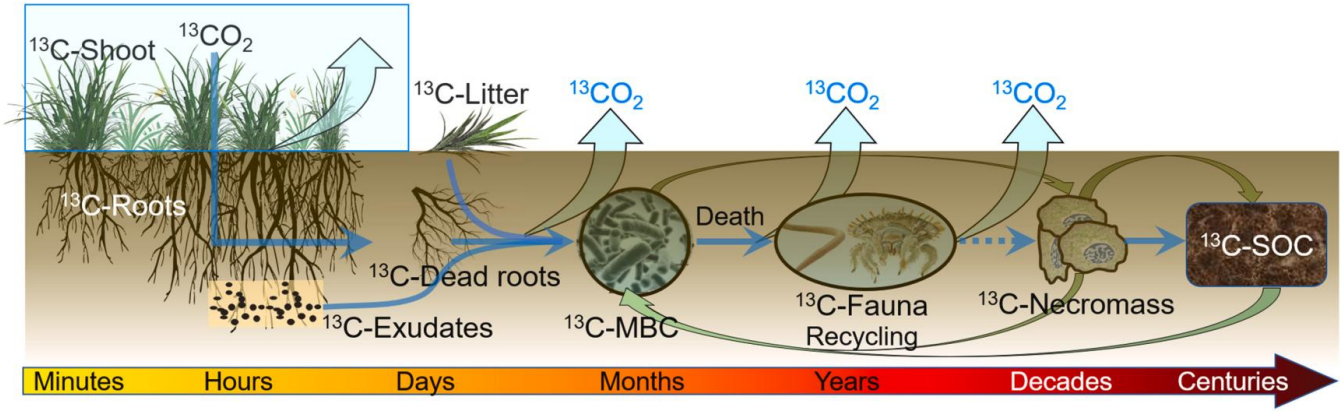


Image: Pang et al. 2021 Rhizosphere

- **High carbon input alone (canola) did not guarantee net soil carbon storage**

- **Soil-specific microbial transformation determined rhizosphere C and N cycling from important field crops**

Persistence of rhizodeposit C?

Acknowledgements

Ph.D. Candidate
Mostafa Hojati

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