Quantifying carbon under perennial biomass cultivation using natural abundance stable C isotopes and programmed pyrolysis

Gillespie, Adam[1], Grzesik, Richard[1], Beckman, Devon[1]., Buchanan, Serra-Willow[1]

[1] School of Environmental Sciences, University of Guelph, Ontario, Canada

agilles@uoguelph.ca

Objectives

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Evaluate how cultivar selection and soil texture mediate the depth distribution and stabilization of soil C pools.

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Evaluate how cultivar selection and soil texture mediate the depth distribution and stabilization of soil C pools.

1) **Quantify total soil carbon (TC) stocks** under different switchgrass cultivars across varying soil textures and depths.
2) Compare **particulate (POM) and mineral-associated (MAOM)** C pools.
3) **Quantify thermal stability** under different switchgrass cultivars across varying soil textures and depths.
4) **Assess the contribution of switchgrass-derived carbon** to bulk soil using natural abundance $\delta^{13}C$ isotopic signatures.

Study Design

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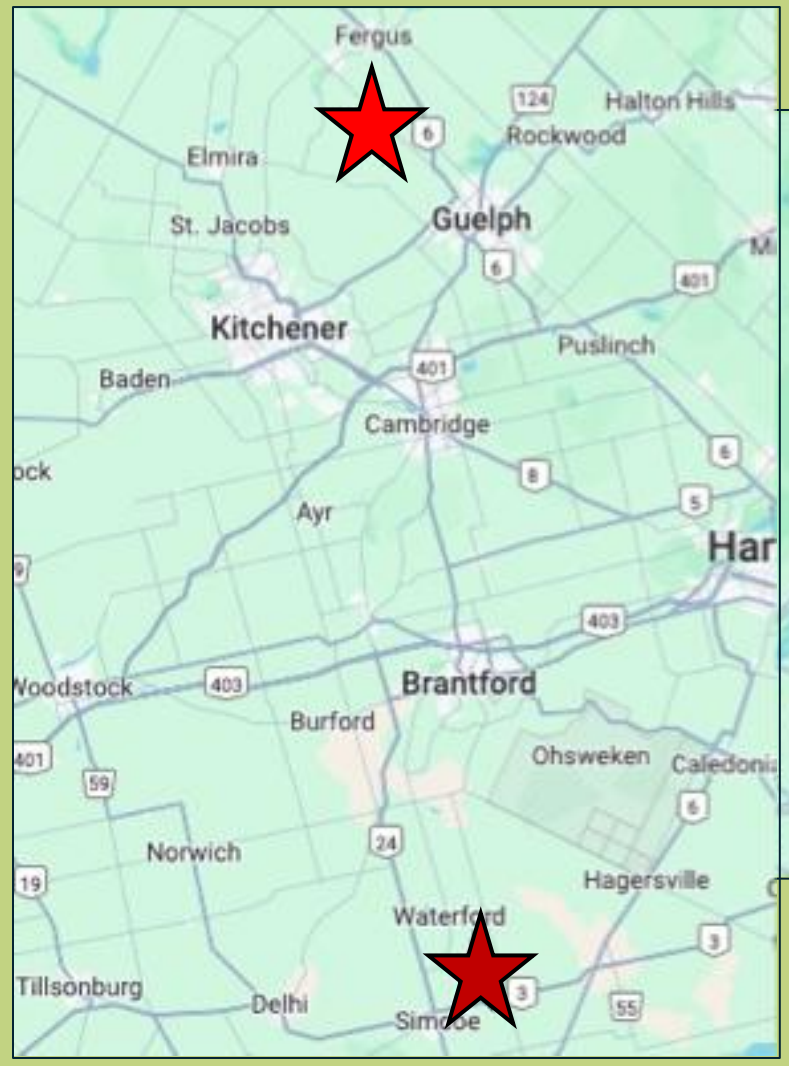
Ontario



Quebec

Locations:

- Ontario (2) and Quebec (1)
- Varying soil textures (coarse – medium – fine)

Upland Cultivars:

- Cave-in-Rock (most common)
- Big Rock
- Sundance

Methods

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Soil cores taken to 1m deep and separated into intervals:

0–15 cm

15–30 cm

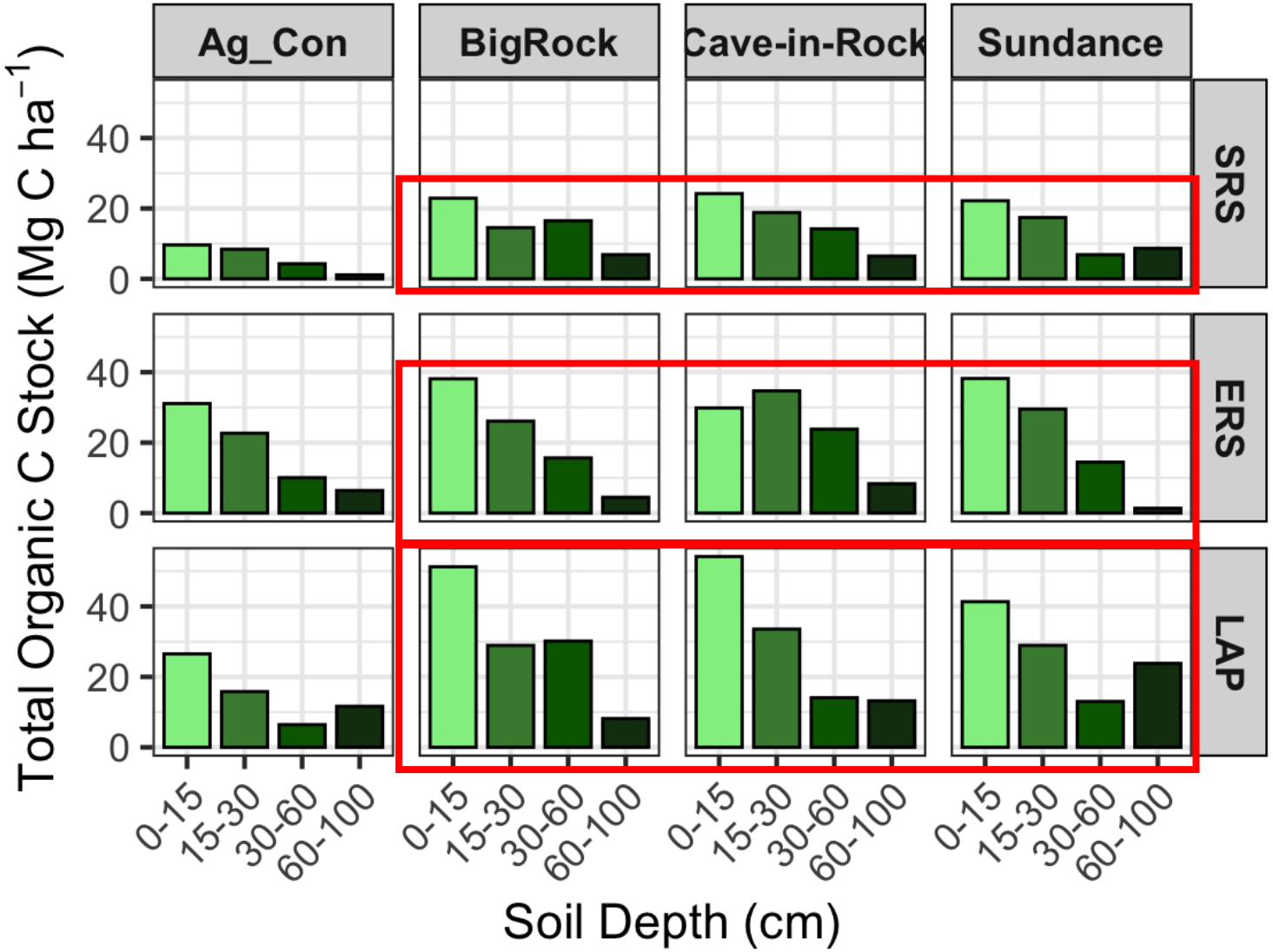
30–60 cm

60–100 cm

Air-dried, sieved, subsampled

Results:

1) Quantify soil organic carbon stocks



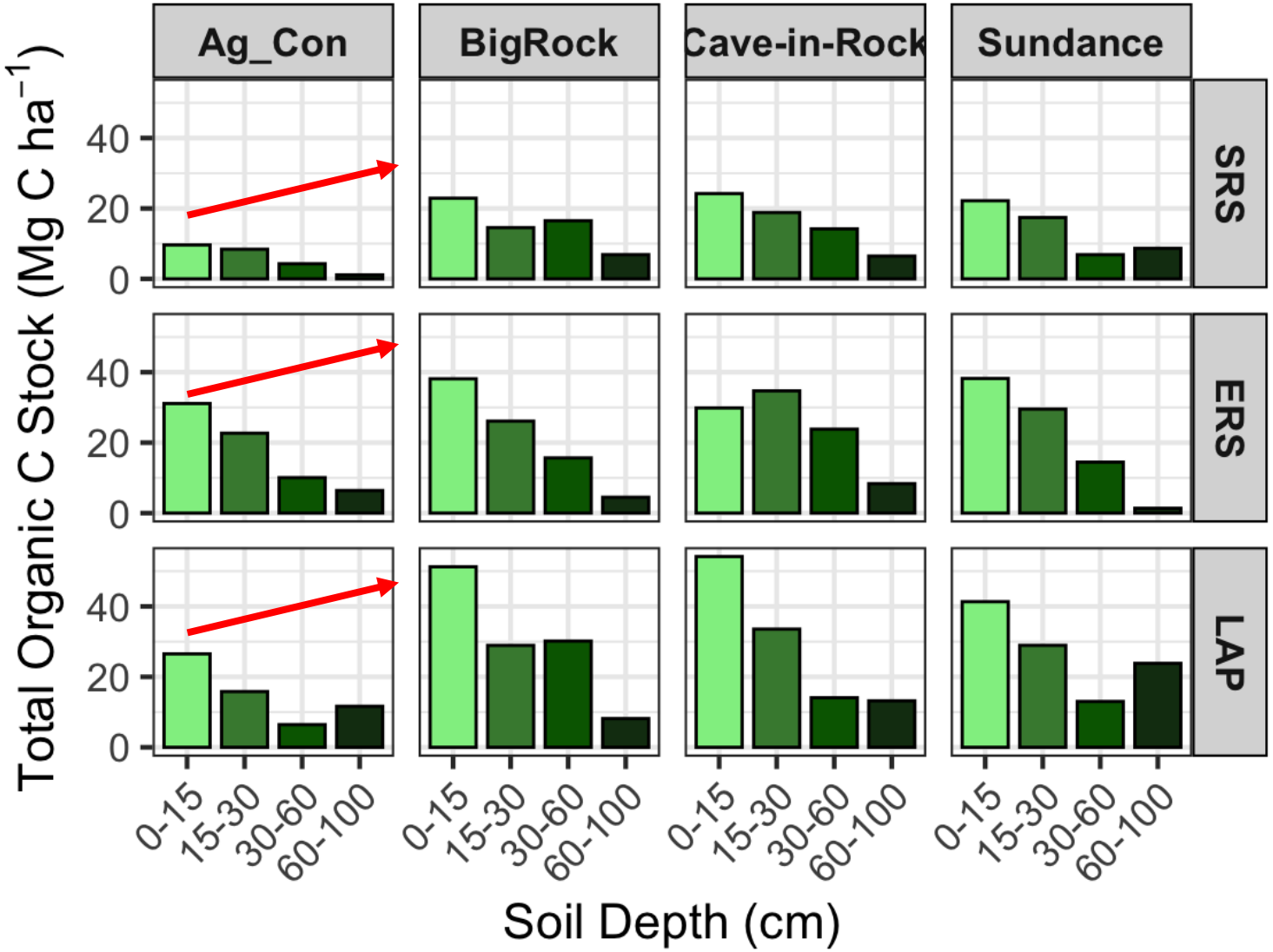
Depth significant

Sitewise small difference between cultivar

Cave-in-Rock and Big Rock had most impact

Results:

1) Quantify soil organic carbon stocks



Significant increase vs Ag control

Surface and mid-depths

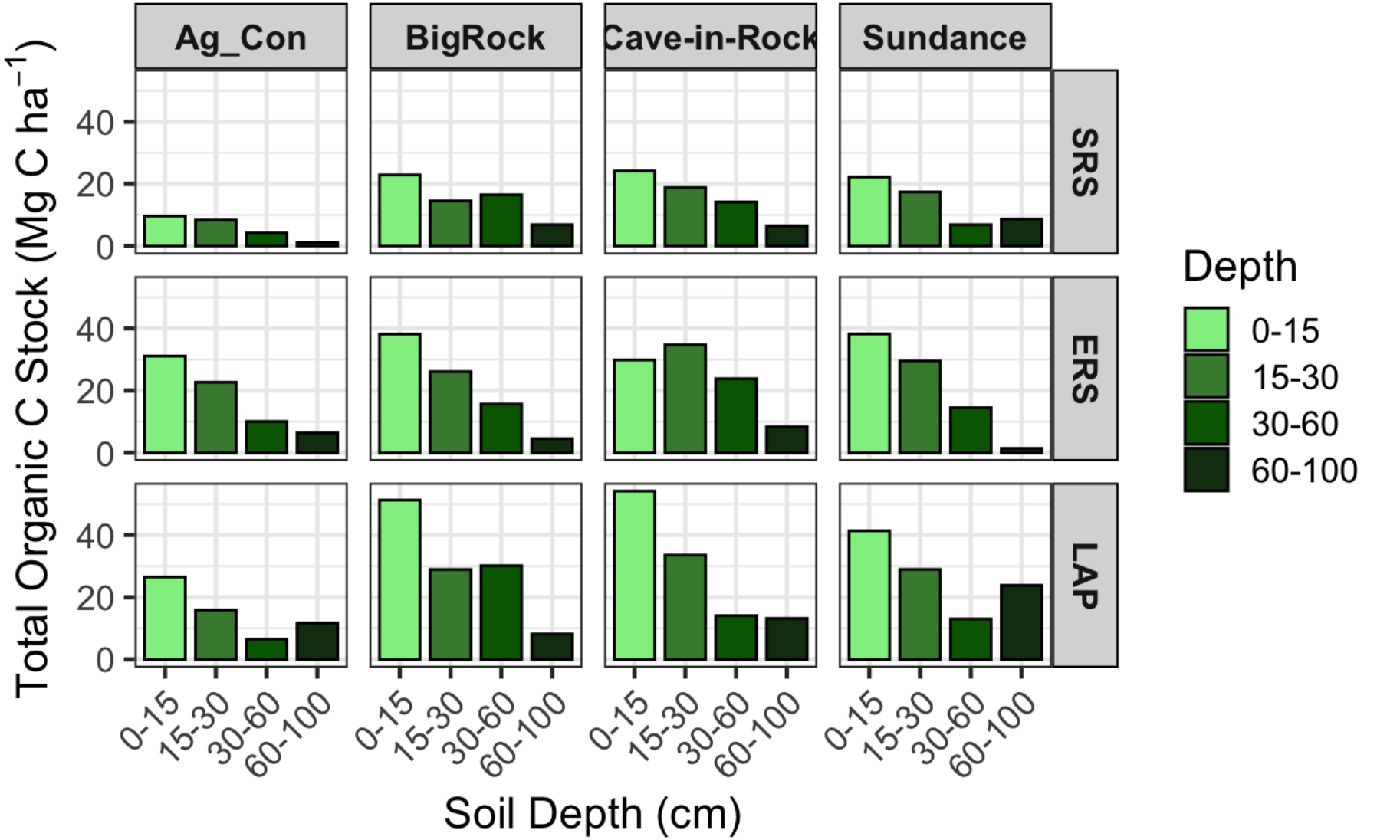
Texture dependent

Lighter texture: more C and farther down in profile

Clay: limited to surface

Results:

1) Quantify soil organic carbon stocks



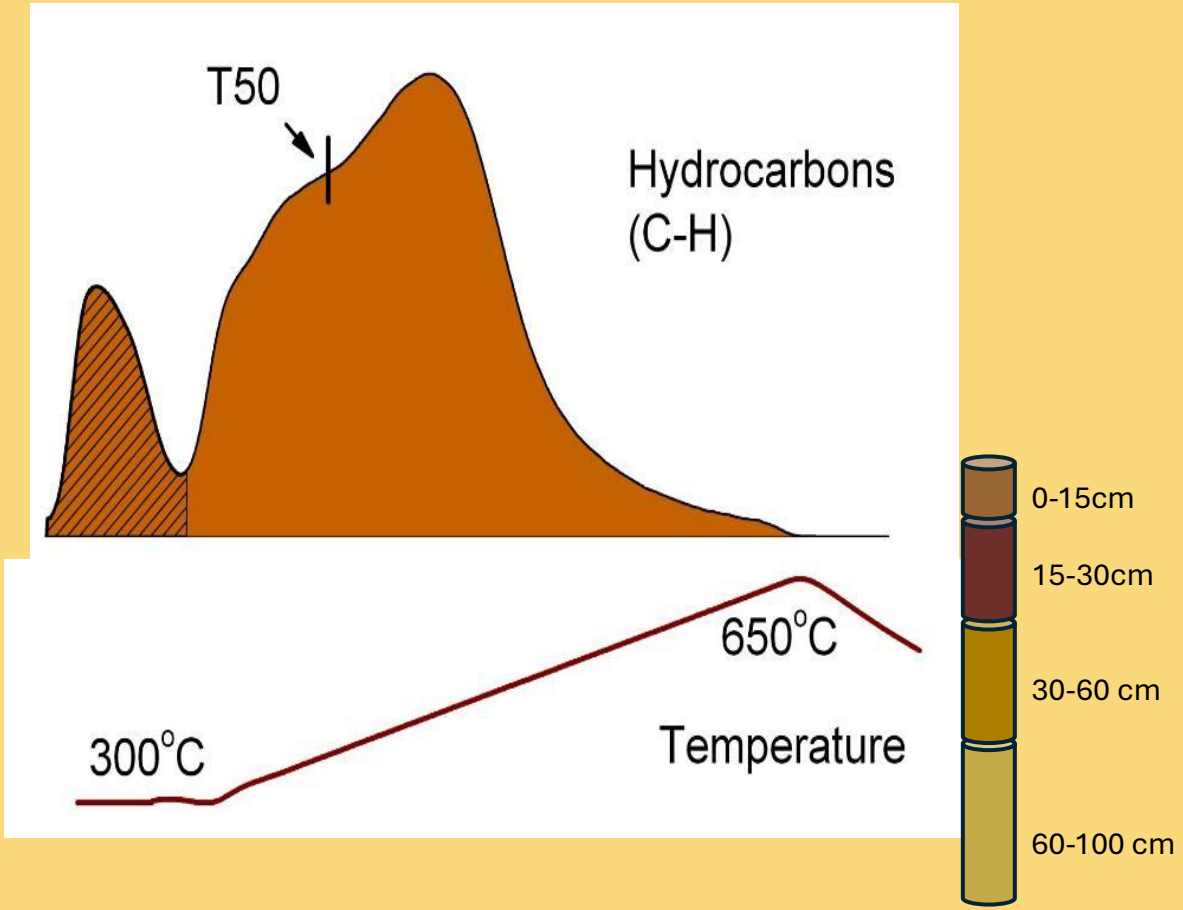
Increased C in soil with low baseline C

Or with limited stabilization

Interaction between texture and depth

‘Stability’ of C

Temperature-controlled pyrolysis



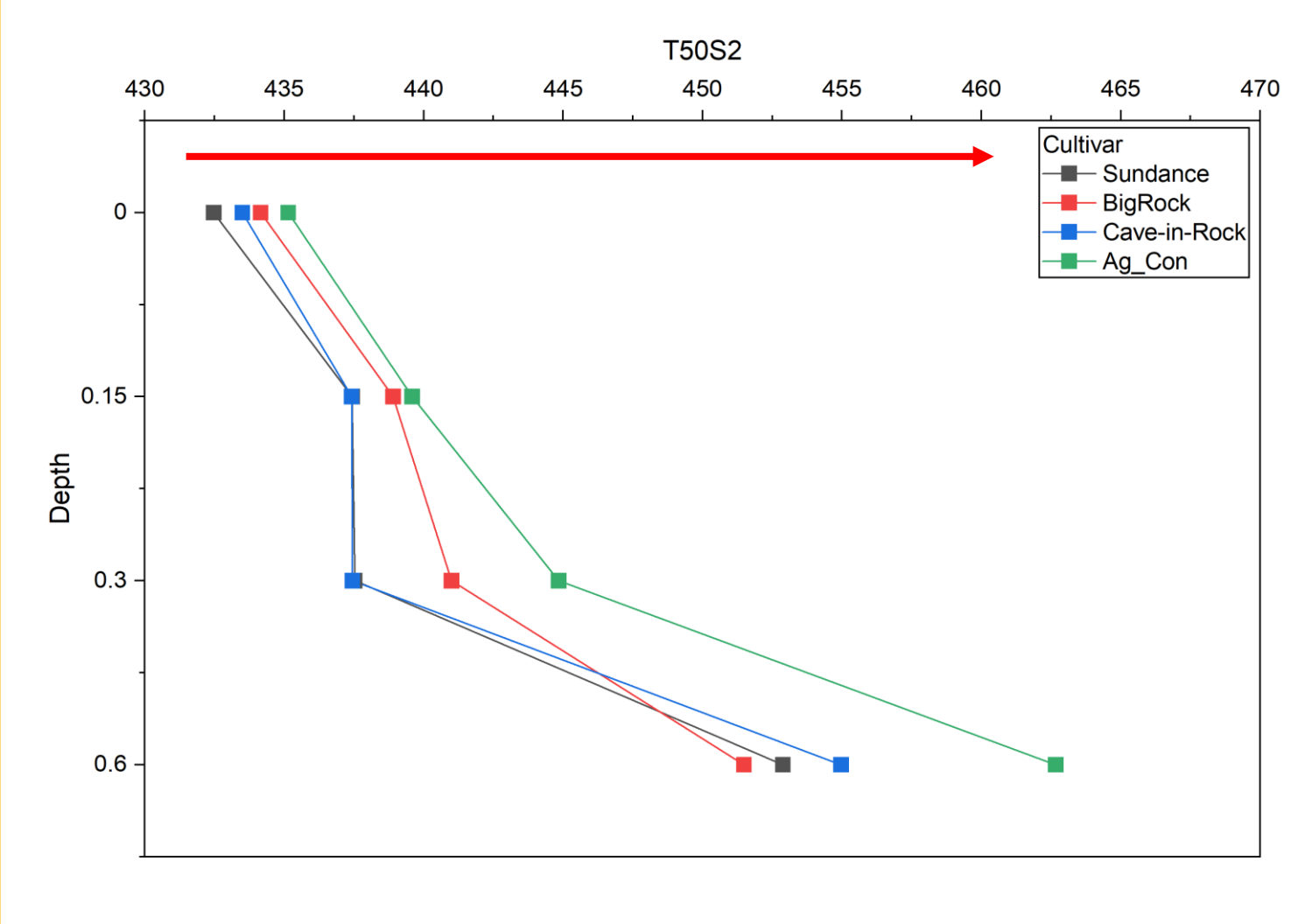
The term "stability of C" refers to how resistant carbon compounds are to decomposition.

More stable forms of carbon contribute to long-term carbon storage in soil, which is crucial for soil health and climate change mitigation.

Programmed pyrolysis: Heating soil under a programmed temperature ramp can teach us about the thermal stability of soil organic matter.

Results:

3) **Quantify thermal stability** under different switchgrass cultivars across varying soil textures and depths.



T-50

Temperature at which 50% of C has pyrolyzed

Higher = more stable

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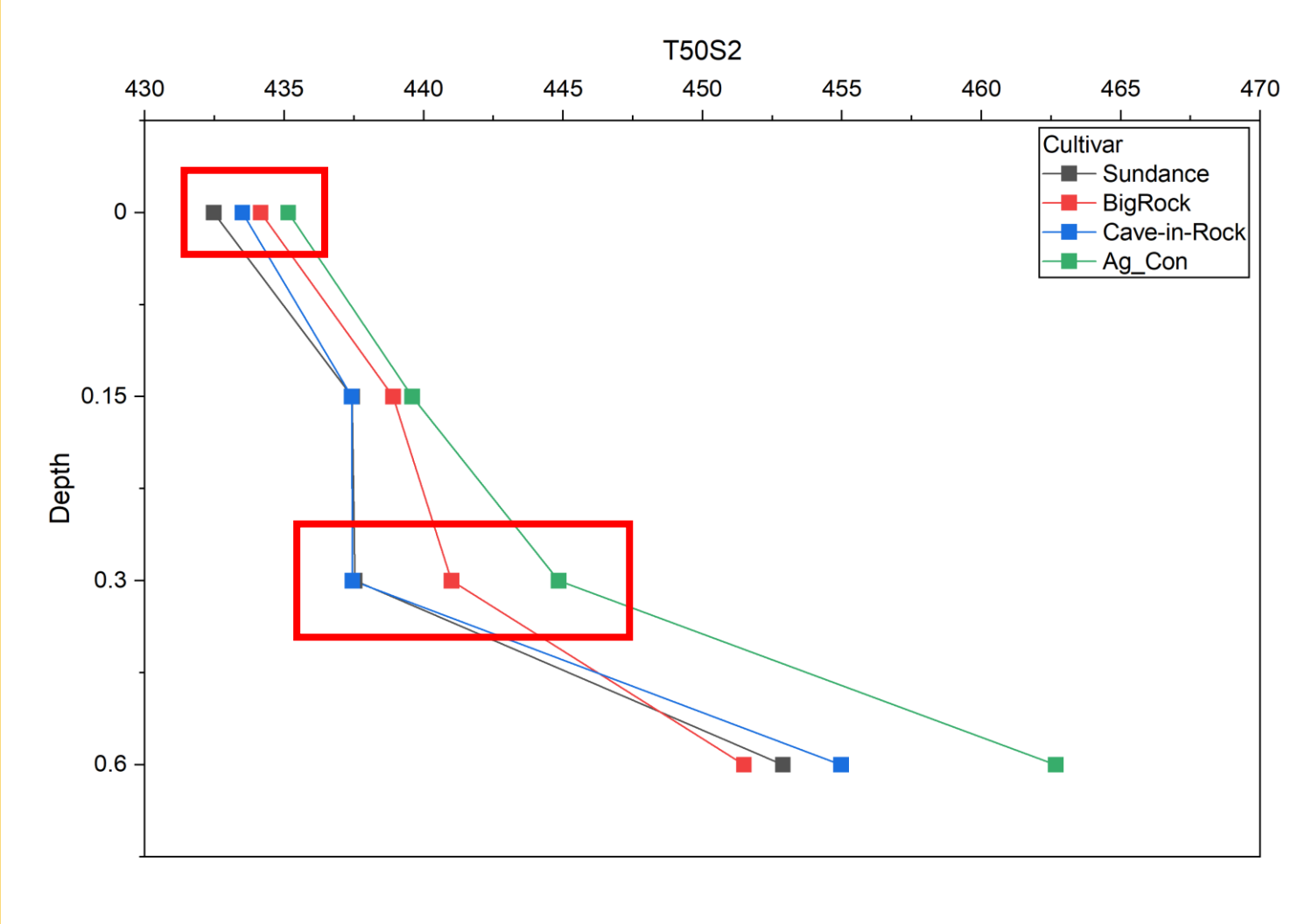

Sandy Loam
(Simcoe RS)

Ag control highest

Switchgrass lower

Notice at 30 cm

Results:

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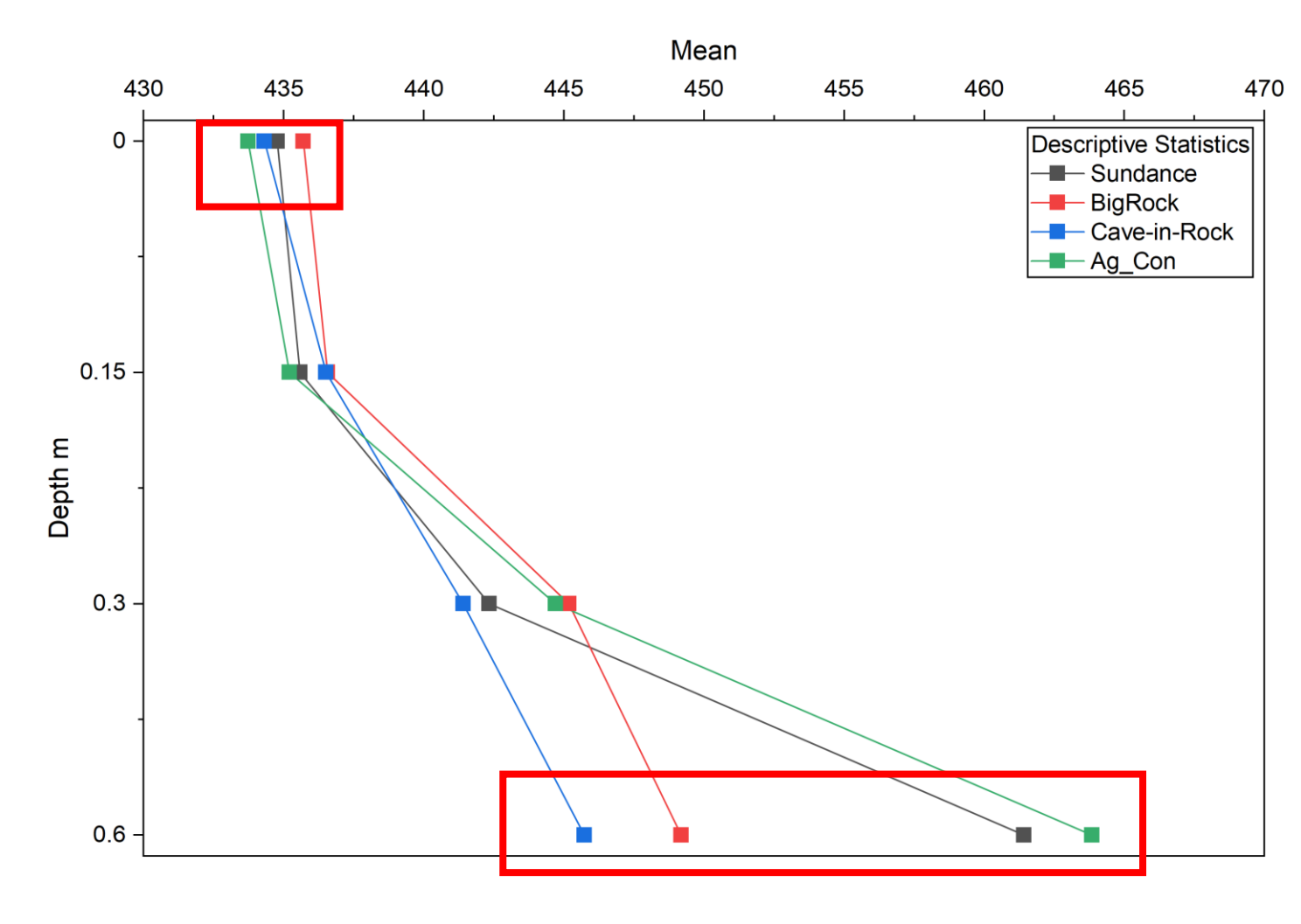

Silt Loam
(Elora RS)

All similar

Notice at 60 cm

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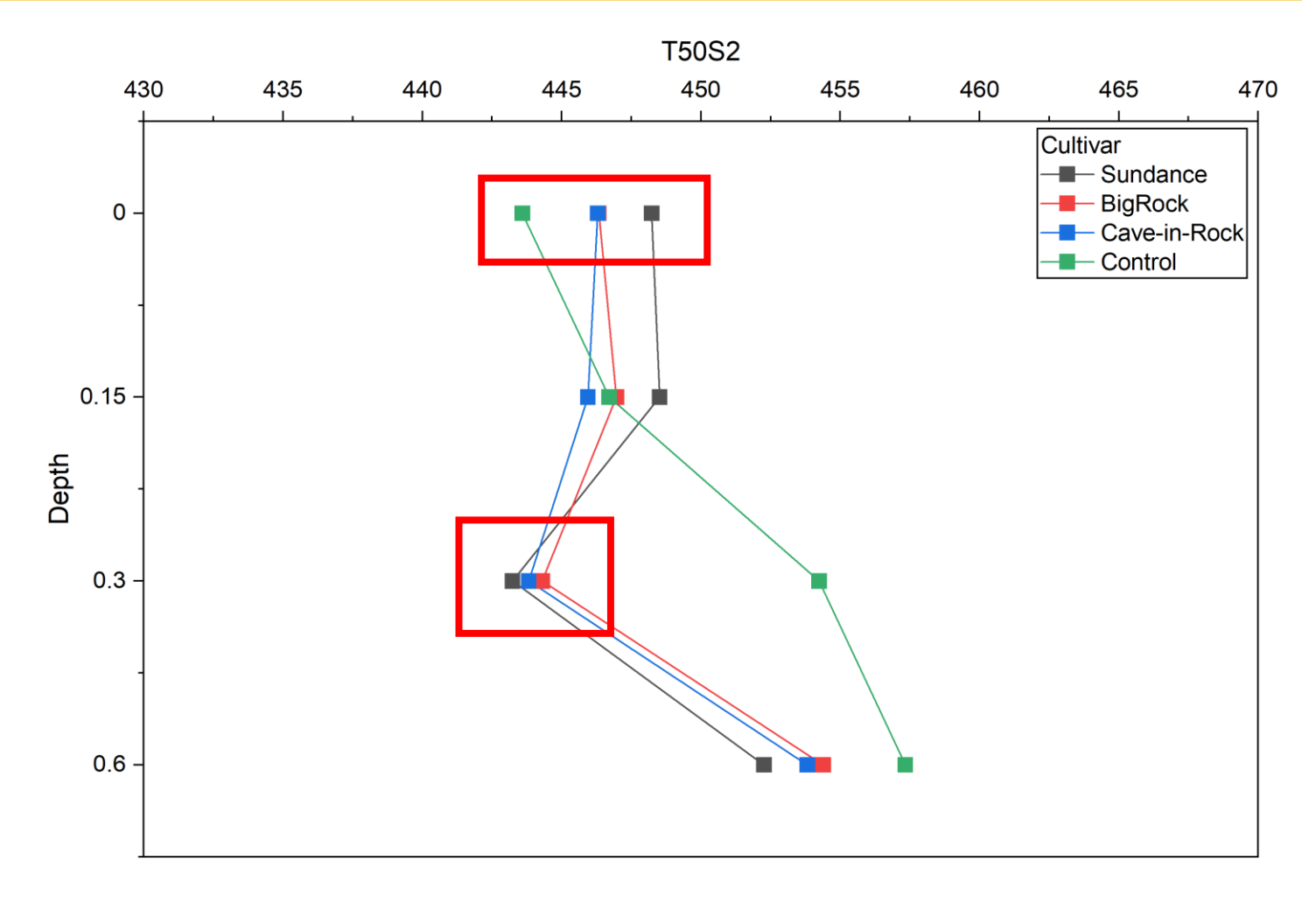


Clay
(La Pocatière)

Ag control lowest

Contrasting with depth

Notice at 30 cm

Results:

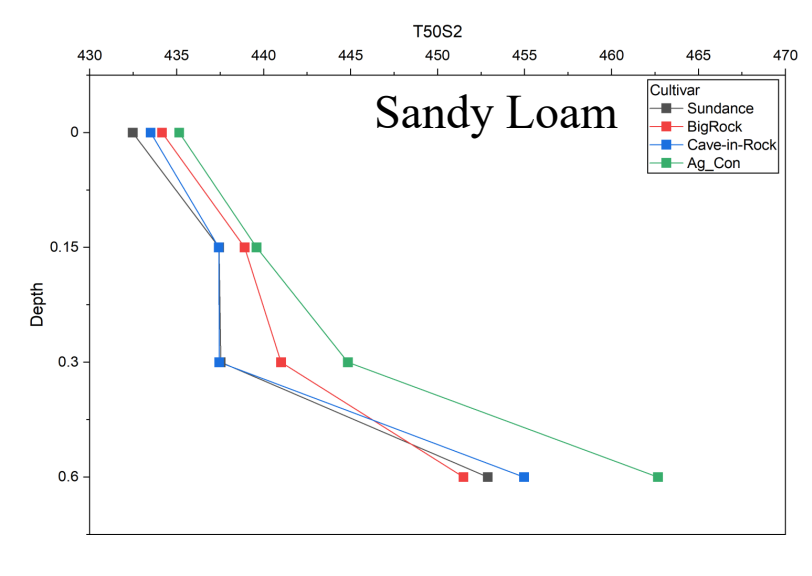
3) **Quantify thermal stability** under different switchgrass cultivars across varying soil textures and depths.

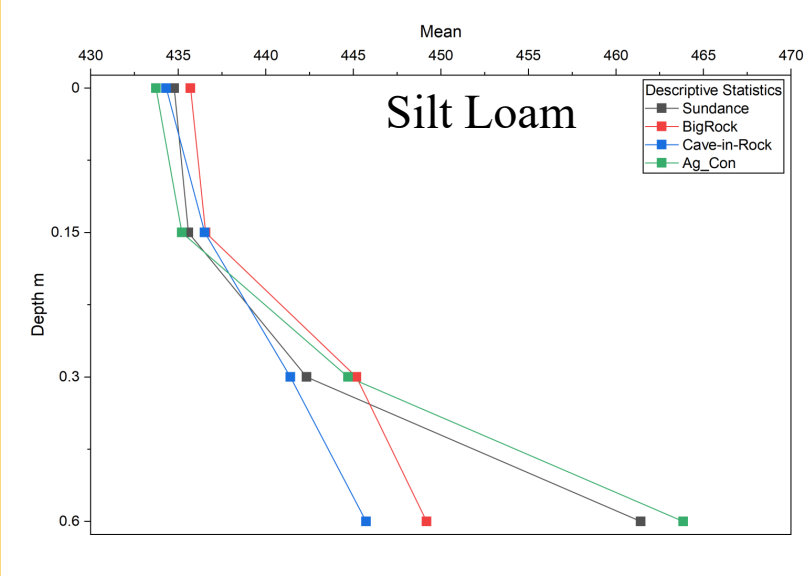
Sandy Loam and Clay showed small difference at surface

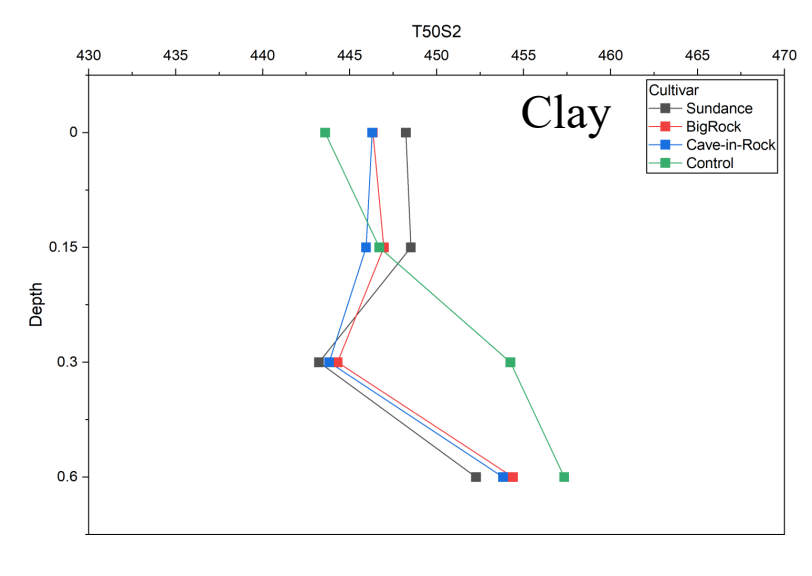
Main differences at depth – 30 cm or 60 cm

More ‘thermally labile’ C at depth

Indicates root contributions







Preliminary results:

4) Assess the contribution of switchgrass-derived carbon to bulk soil using natural abundance $\delta^{13}C$ isotopic signatures.

Natural abundance stable C isotopes

C4 plants (switchgrass) exhibit a distinct carbon isotopic signature ($\delta^{13}C$) ranging from -16‰ to -10‰

This differs from C3 plants which have values between -33‰ and -24‰

Preliminary results: **4) Assess the contribution of switchgrass-derived carbon** to bulk soil using natural abundance $\delta^{13}C$ isotopic signatures.

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Contributions of switchgrass-derived carbon can be quantified by comparing the isotopic signature ($\delta^{13}C$) of a control soil (tree line, no C4 plants present) to those under switchgrass cultivation using a mixing model:

To calculate the amount of root-derived C present in bulk soil and each soil fraction, the following mass balance was used (Cheng, 1996; Nottingham et al., 2009):

$$Q_p = Q_t * \left(\delta^{13}C_t - \delta^{13}C_s\right) / \left(\delta^{13}C_p - \delta^{13}C_s\right) \quad (2)$$

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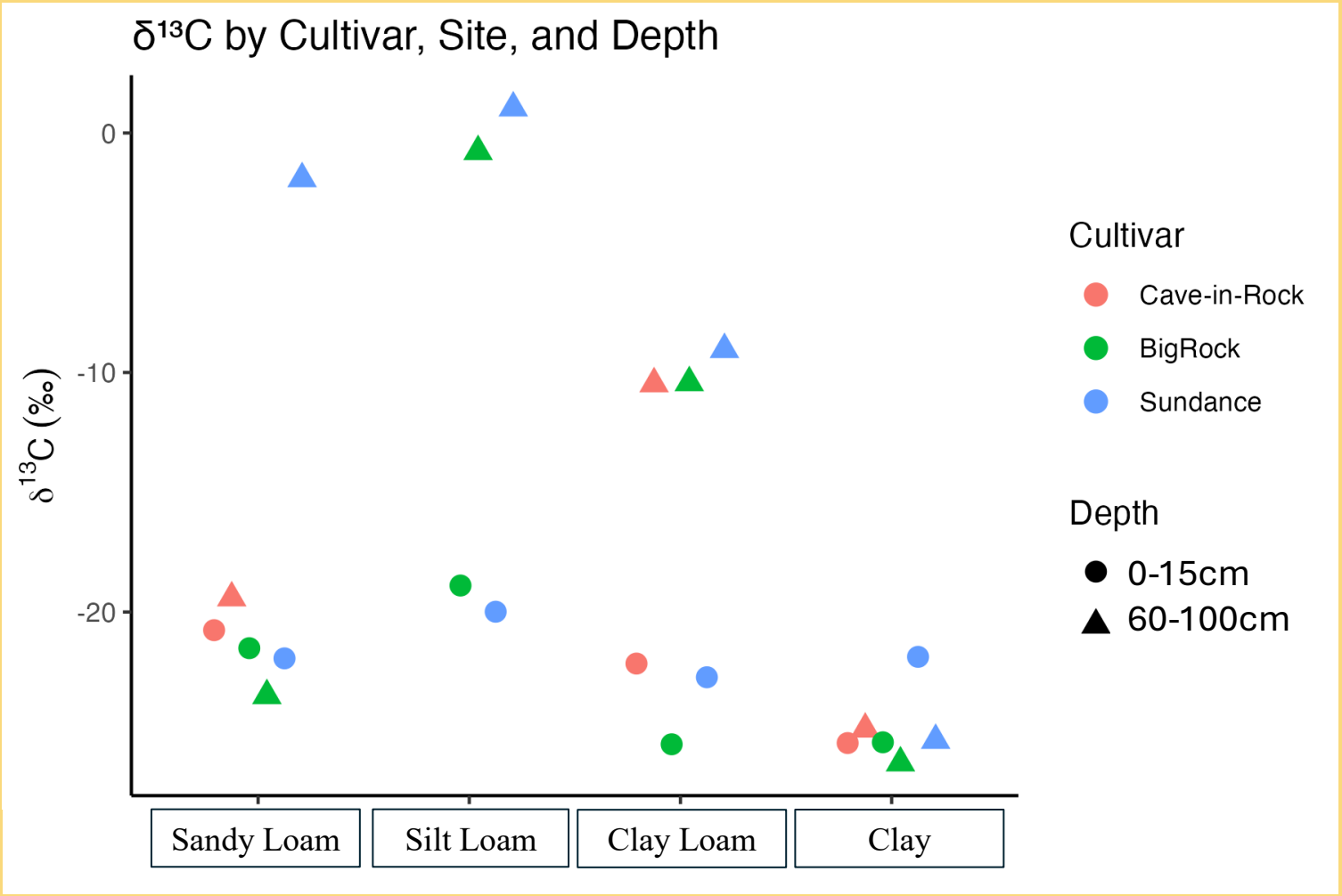

Spot the problem!

Alex Colville, *To Prince Edward Island*, 1965
Acrylic emulsion on Masonite, 61.9 x 92.5 cm
National Gallery of Canada, Ottawa

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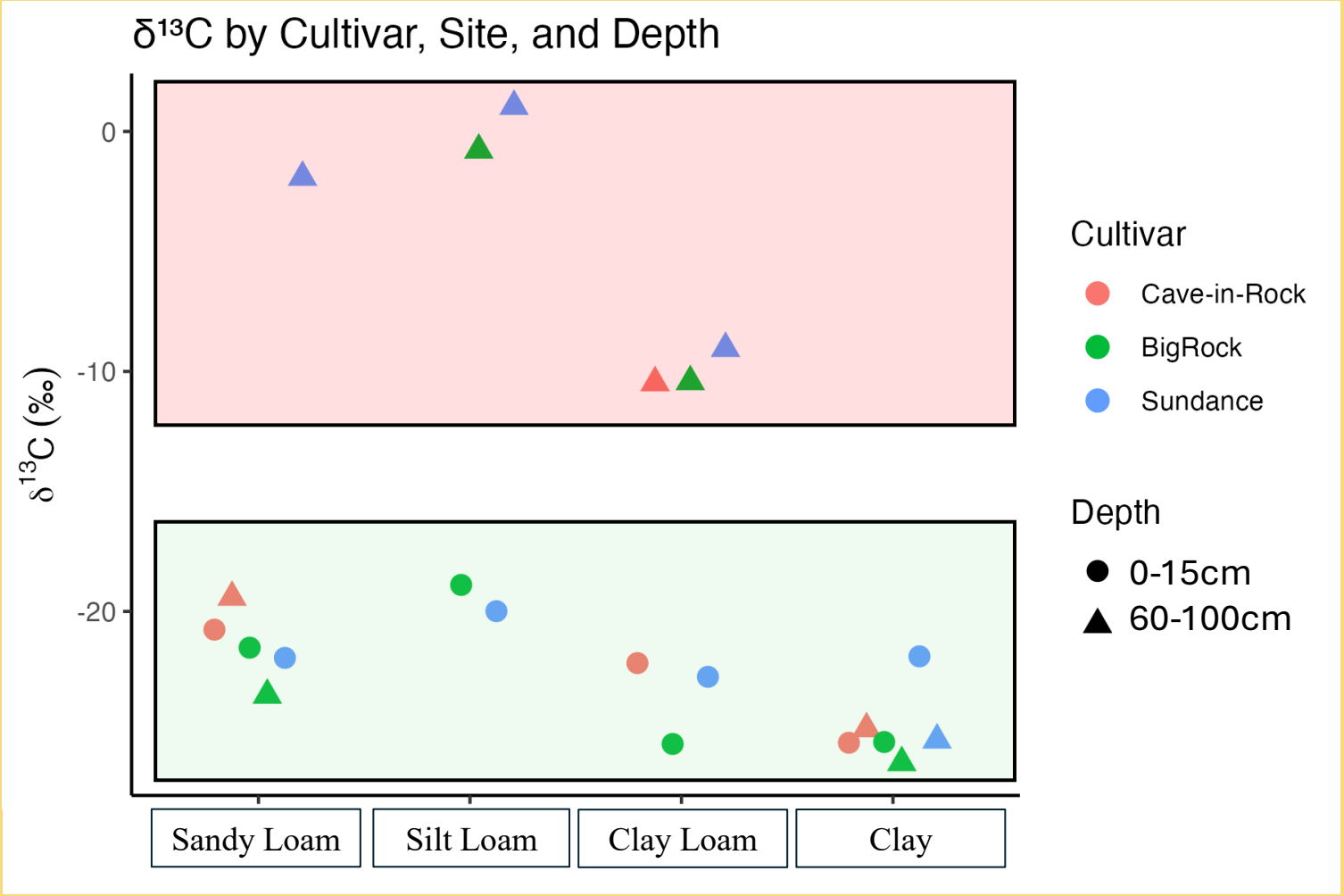

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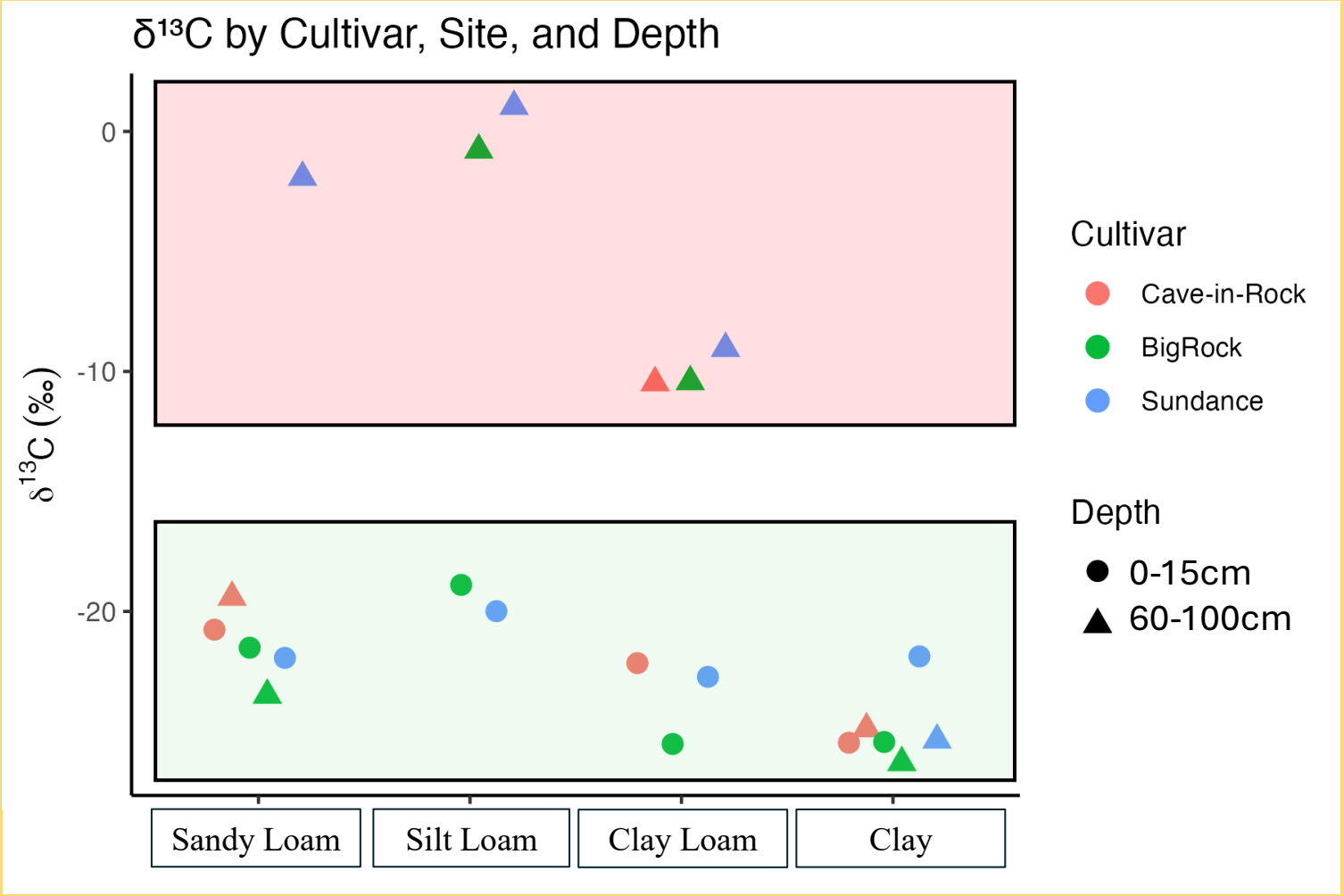

Spot the problem!

Carbonates! Their $\delta^{13}C$ values are typically **much more positive** than organic carbon

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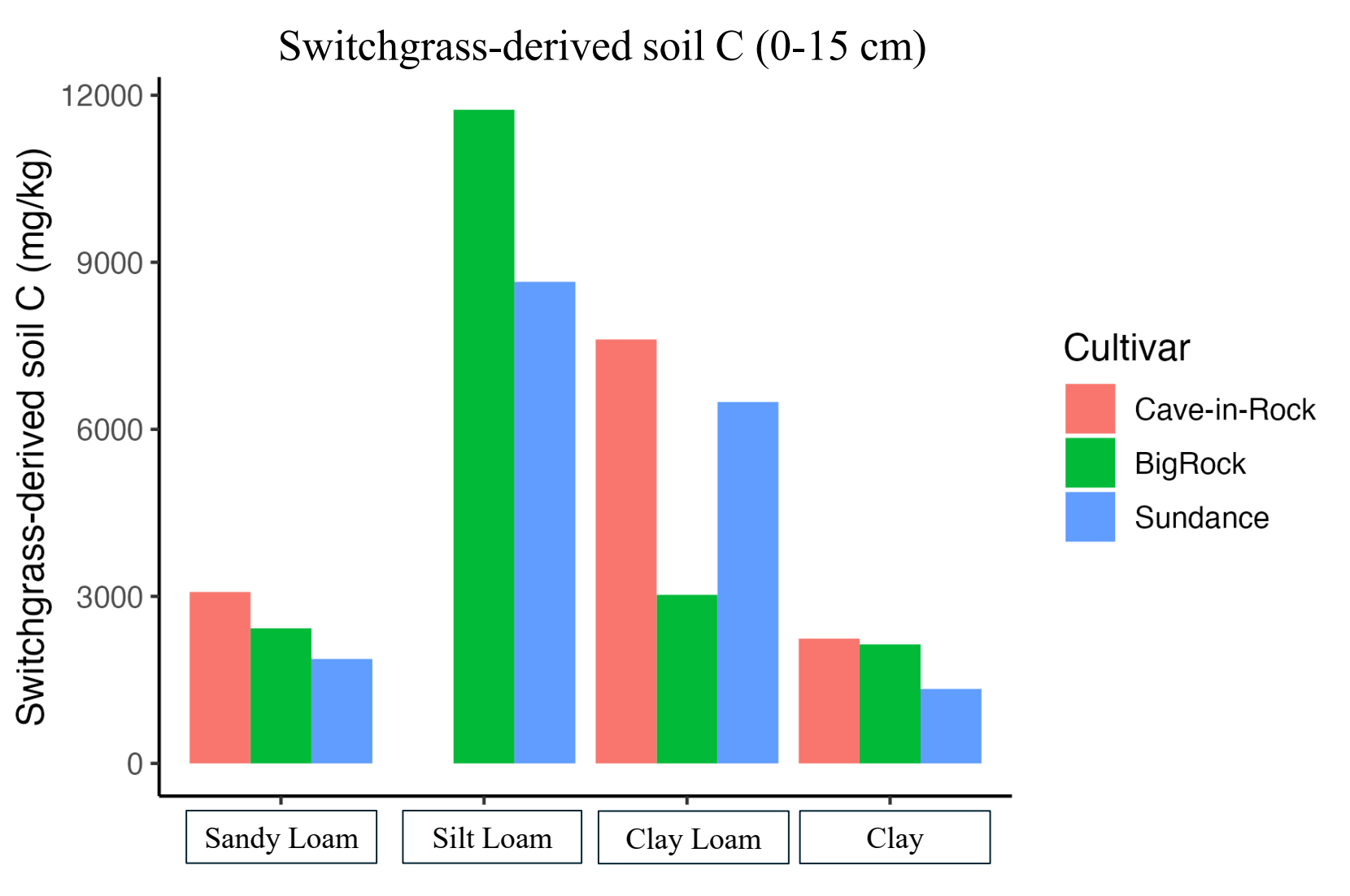

All soils have positive switchgrass-derived C contributions

Too early to statistically test cultivar or depth differences

Preliminary conclusion

1. Soil texture strongly influenced carbon storage, **most differences appearing at 30-60 and 60-100cm**

2. **Cultivar selection had little effect on carbon stocks -** suggesting that landowners and biomass producers have flexibility to select cultivars based on other management objectives or preferences without compromising soil carbon outcomes

3. Thermal stability lower under switchgrass, especially at 30-60cm – suggesting input of labile root-derived material & more nutrient cycling

4. Stay tuned for more isotope data!

Upcoming

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Impact of Switchgrass on Soil Function

- New OMAFA funded project
- New plots seeded 2025: Elora, Simcoe, Ridgetown
- Tracking soil C
- Comparing improved soil structure

The sampling was done on plots of various cultivars of switchgrass and miscanthus established in 2010 as part of the Quebec Bioindustrial Plants Network funded by the Quebec Ministry of Agriculture, Fisheries and Food.

L'échantillonnage a été réalisé sur des parcelles de différents cultivars de panic érigé et le miscanthus géant, plantés en 2010 et faisant partie du réseau des plantes bio-industrielles du Québec financé par le ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec.

In collaboration with

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