Microbial utilization of residue carbon depends on placement and differs in humid and semi-arid climates

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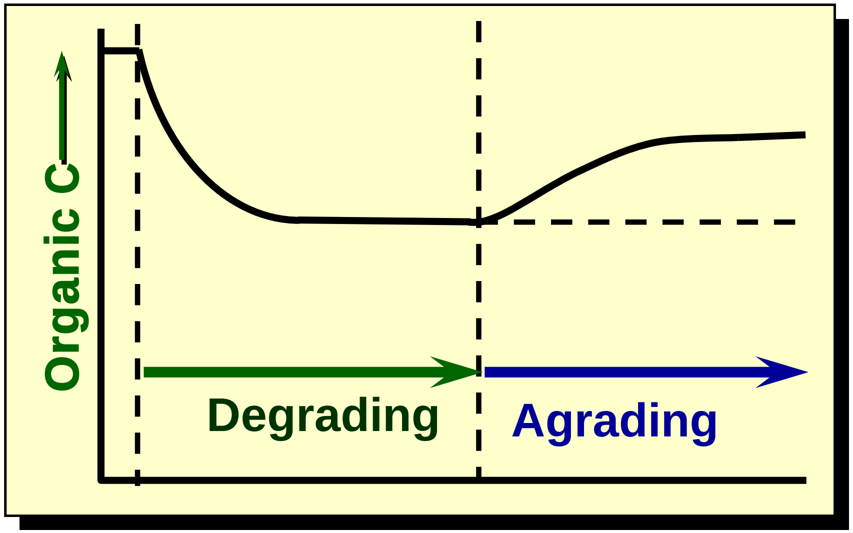
Introduction

- Producing harvestable C is the main goal of agriculture
- Crop residues are the major source of new C in agricultural soils

Sustain long-term soil productivity

- rates and mechanisms of residue C decomposition
- microbial regulation

Introduction



H. Janzen

C storage = C input – decomposition

- By manipulating residue placement we can alter the rate and perhaps pathway of C decomposition

Introduction

Microbes are primary regulators of litter decay, but pathways of decomposition are only vaguely understood and poorly quantified

Breton: triticale

Swift Current: lentil

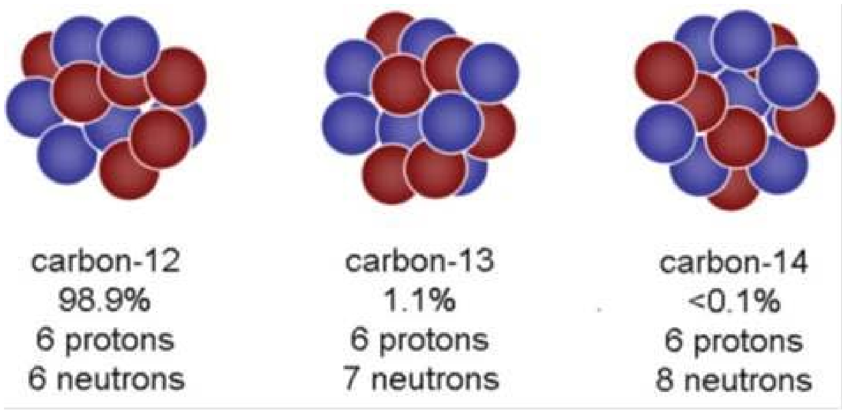
Use of ^{13}*C enriched plant* material allows us to track fate of C in various physical, chemical and biological pools

"stable isotope probing"

Background: Stable Isotope Probing

- What is a stable isotope?
  Common carbon isotopes: ^{12}C, ^{13}C, ^{14}C
  6 protons (6, 7 and 8 neutrons)

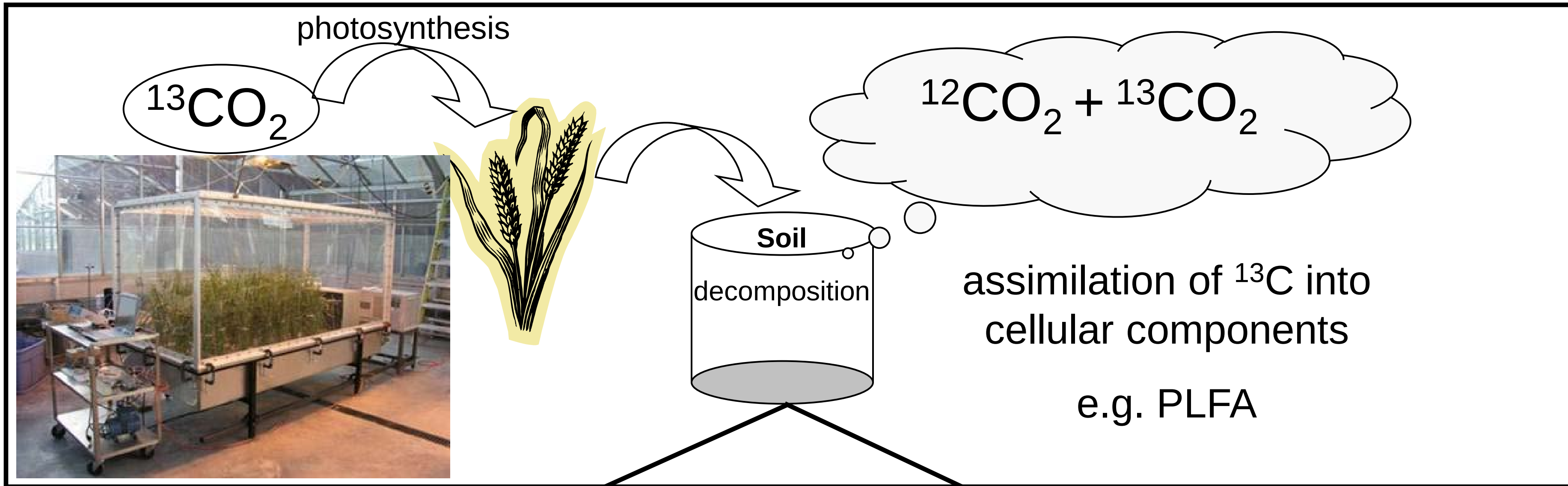
- ^{12}C and ^{13}C are stable (non-radioactive) and occur naturally at a ratio of ca. 99:1



http://wordpress.mrreid.org/2011/03/23/

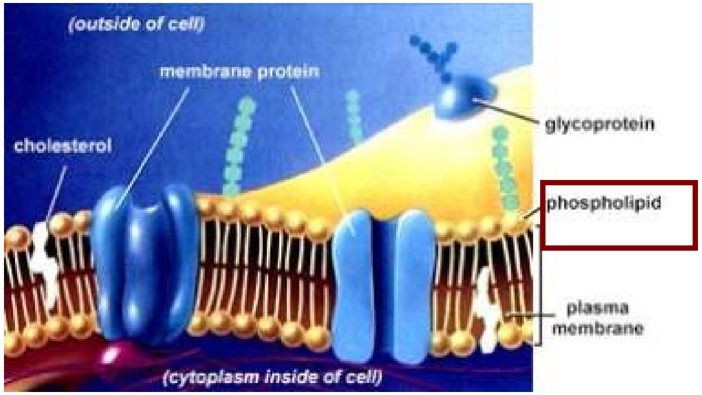
- For our purposes ^{13}C acts as a *tracer*.

Background: Stable Isotope Probing



- Whole soil $^{13}C/^{12}C$ analysis
  - Physical fractionation
  - Chemical fractionation
- Extraction of PLFAs
  - Quantification by GC-FID
    $^{13}C/^{12}C$ ratios by GC-IRMS

SIP/Phospholipid fatty acid analysis



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

Active populations:

1. abundance
2. microbial community structure

Microorganisms metabolize C obtained from their environment (^{12}C + ^{13}C)

Coupled with ^{13}C-SIP, PLFA indicates *functionally active* components of the soil microbial community

Microbial utilization of residue carbon depends on placement and differs in humid and semi-arid climates

Objective:

to determine the effect of residue placement on retention of ^{13}C in the microbial biomass in humid and semi-arid climates

Experimental Design

Fall 2007, microcosms set up in transects

Each transect (n=4) has 10 microcosms

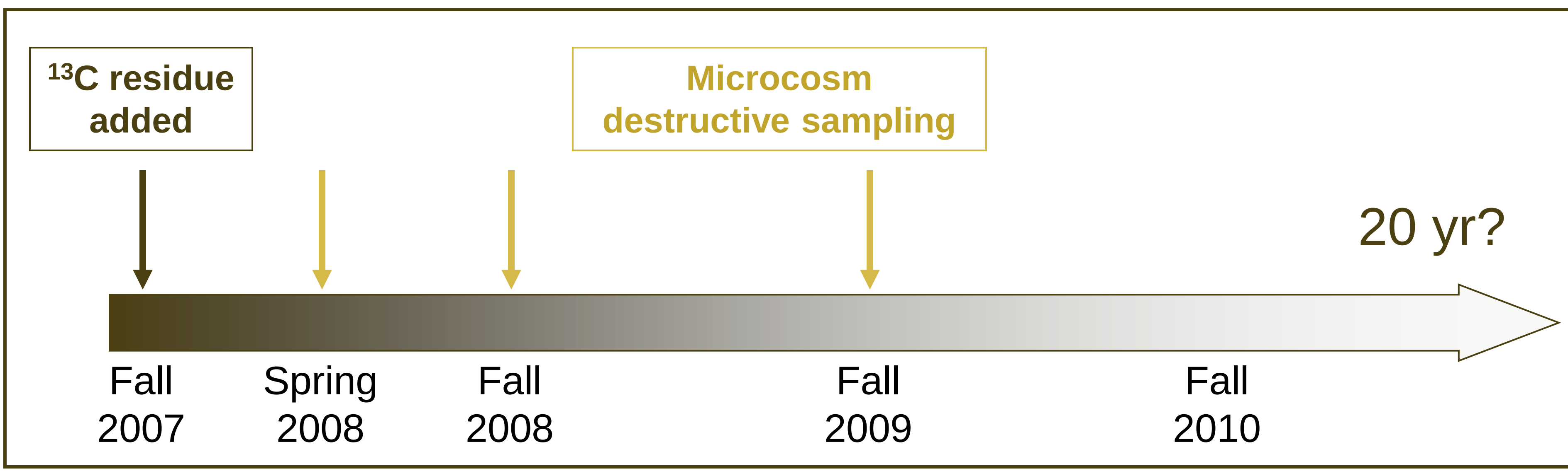
Barley residue (^{13}C at ca. 10 atom %) added at a rate of 2 Mg C ha^{-1}, either:

a. incorporated (0-10cm)

b. surface applied

Experimental design

**Microcosms are amended annually in fall with *non-labeled* barley residue



Microcosm sampling

- Microcosms (n=4) destructively sampled:

  6 mo (spring 2008)
  12 mo (fall 2008)
  24 mo (fall 2009)

- Cores divided into 2 depths:

  0-5cm
  5-10cm

- PLFA analysis:

  GC-FID, MIDI (quantitative)
  GC-IRMS ($^{13}C/^{12}C$ of 26 individual PLFAs)

Experimental design:

Basic Site characteristics:

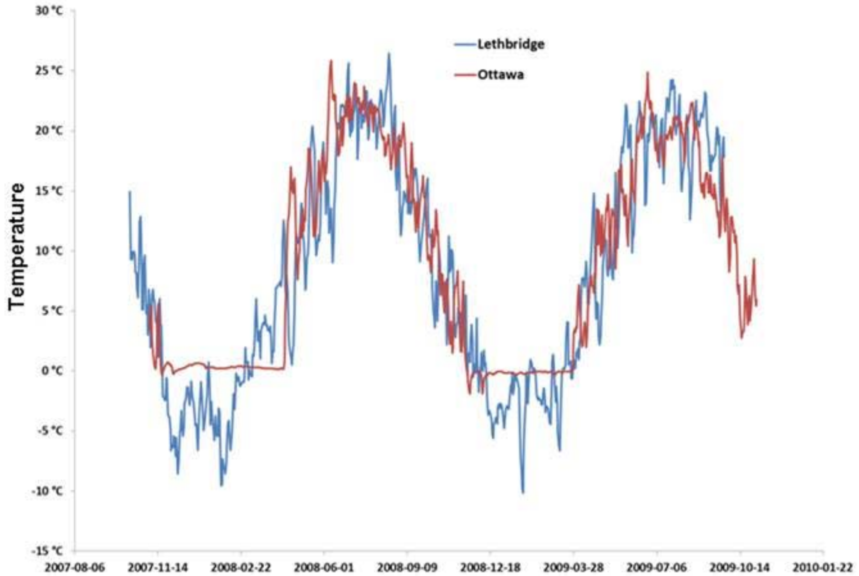
Ottawa: humid
fine sandy loam
MAP: 882mm; MAT: 5.8ºC

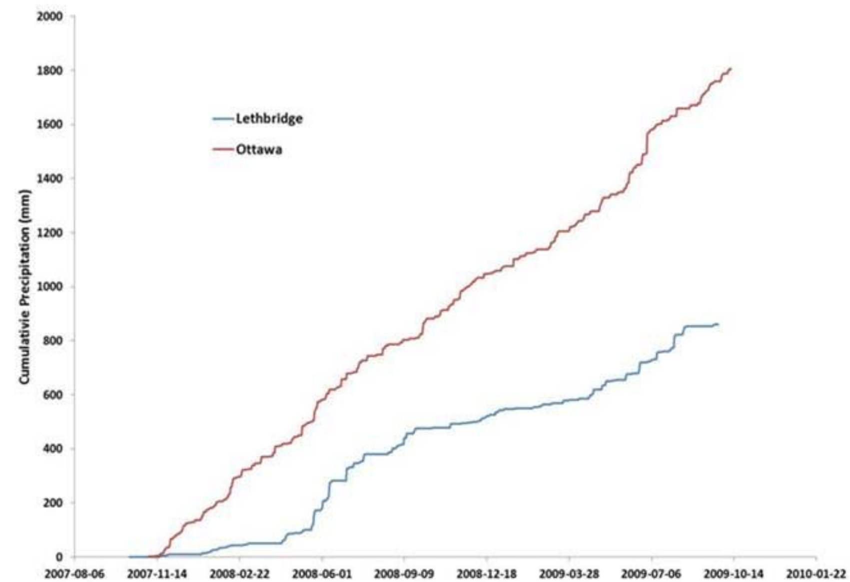
Lethbridge: semi-arid
sandy clay loam
MAP: 386mm; MAT: 5.7ºC

Experimental design

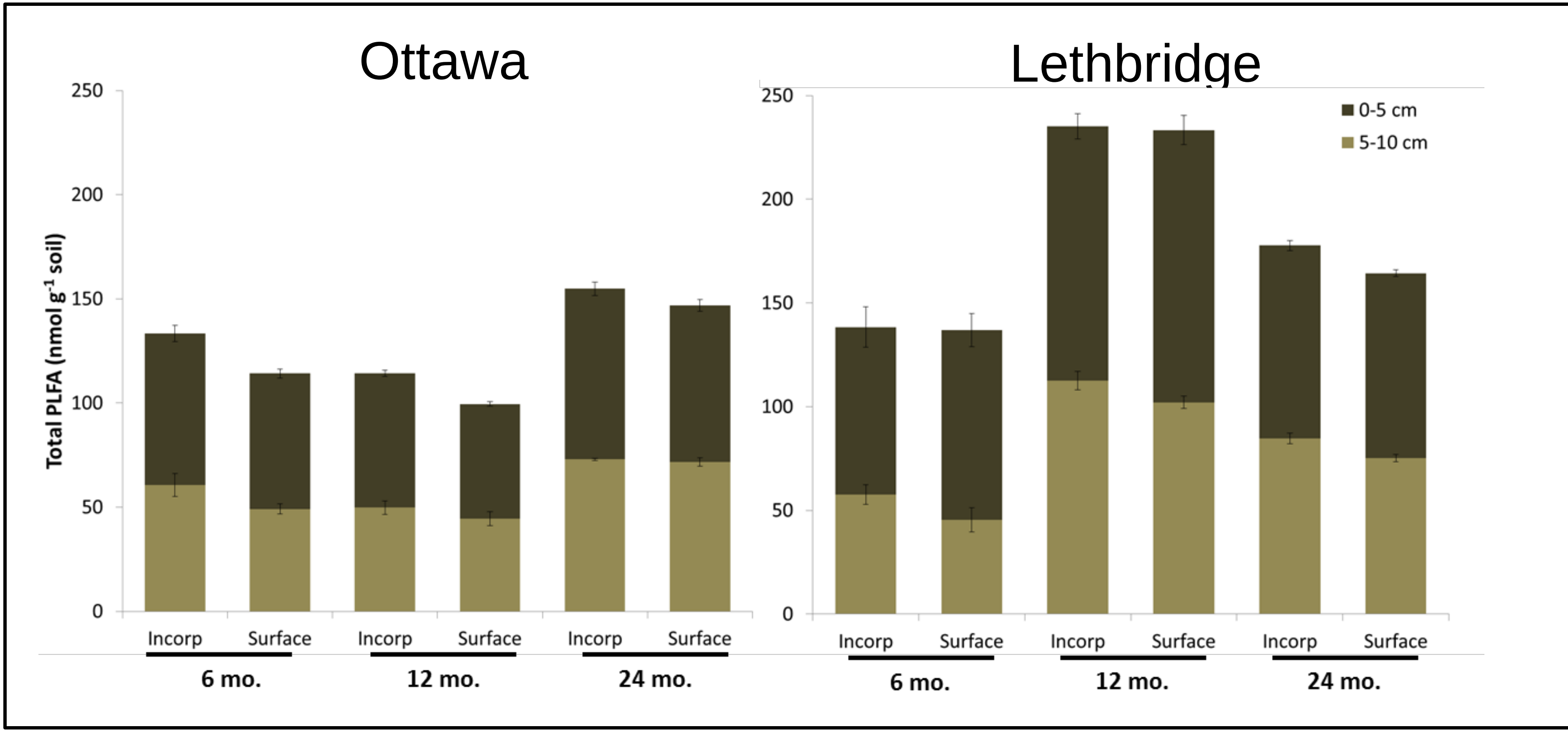
Basic Site characteristics:

- similar mean annual temperature
- very different temporal patterns of soil temperature
- very different precipitation patterns



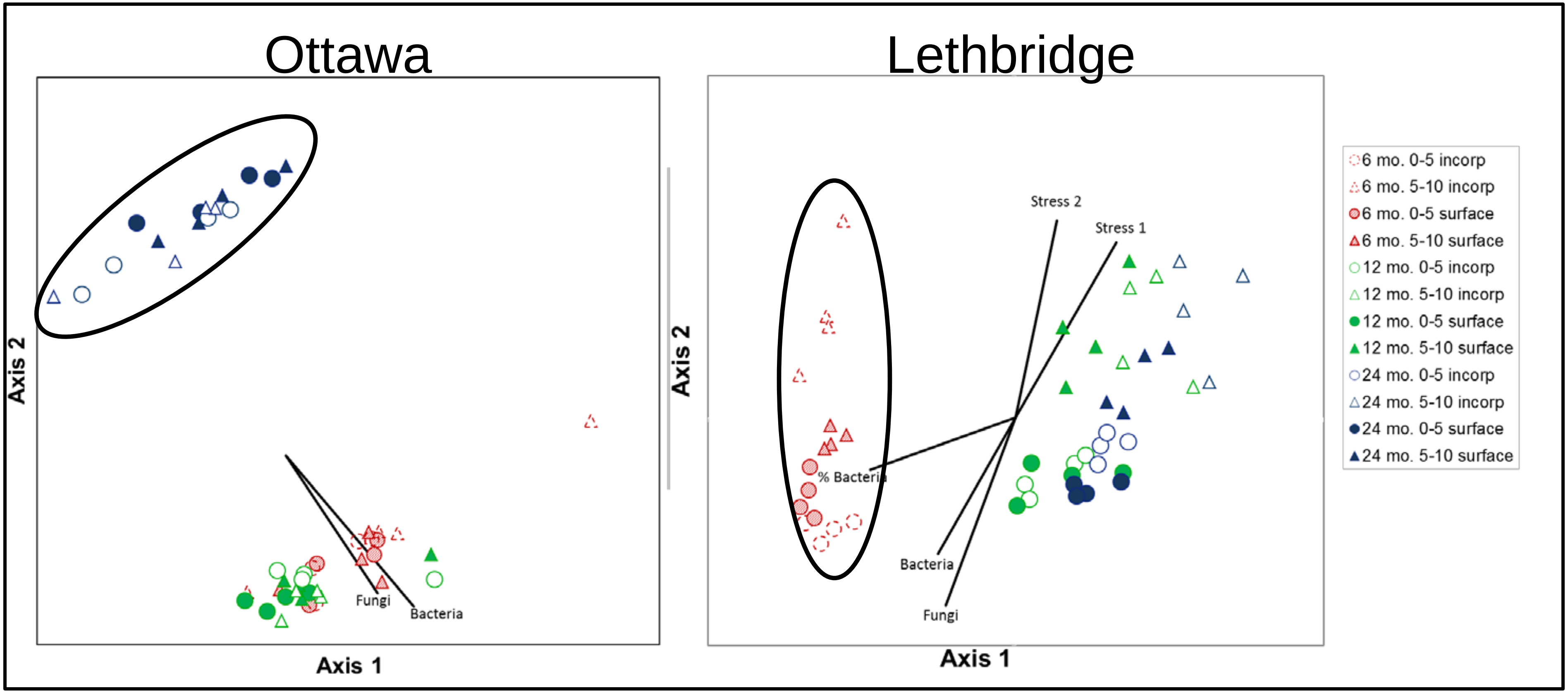


Microbial abundance – $^{12}C + ^{13}C$ PLFA



- Higher fall biomass at Lethbridge than Ottawa
- Significant biomass at 0-5 and 5-10 cm depths

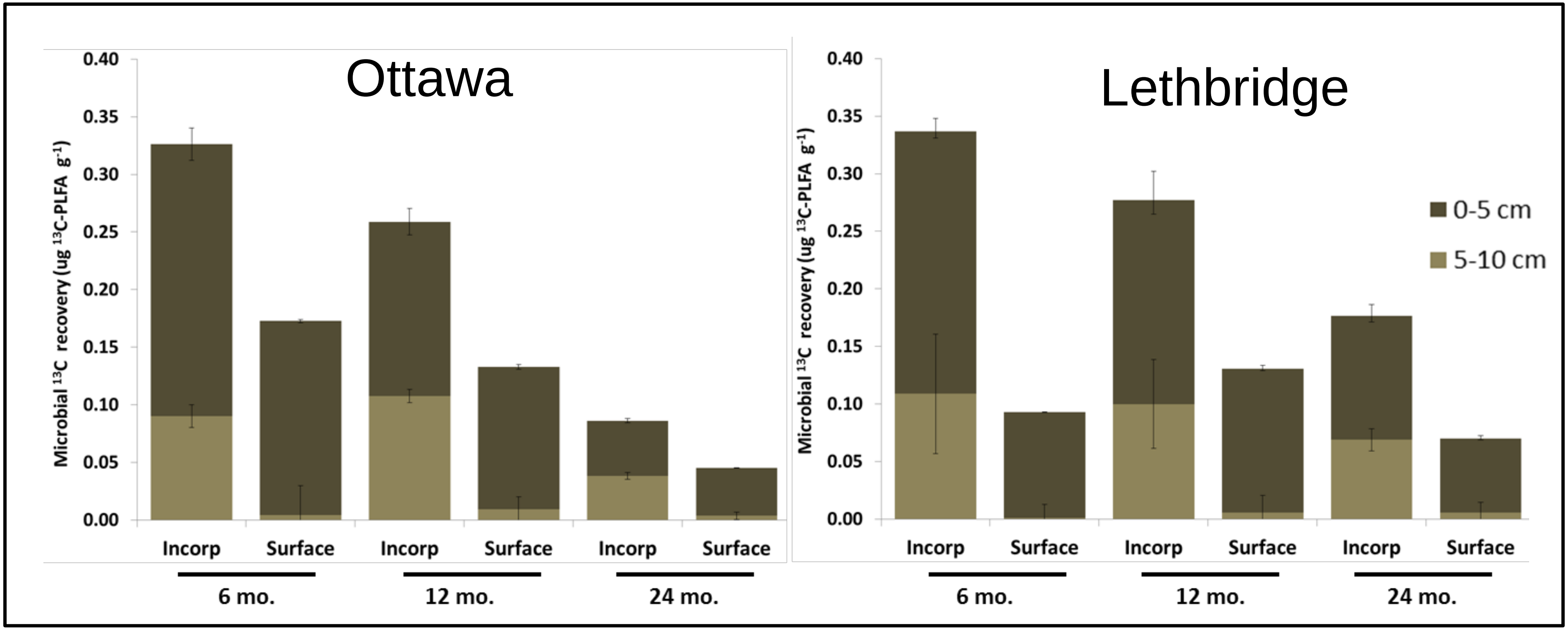
Community structure – $^{12}C + ^{13}C$ PLFA



Ottawa: communities similar in season 1, major shift by 24 mo.

Lethbridge: strongest effects of season and depth

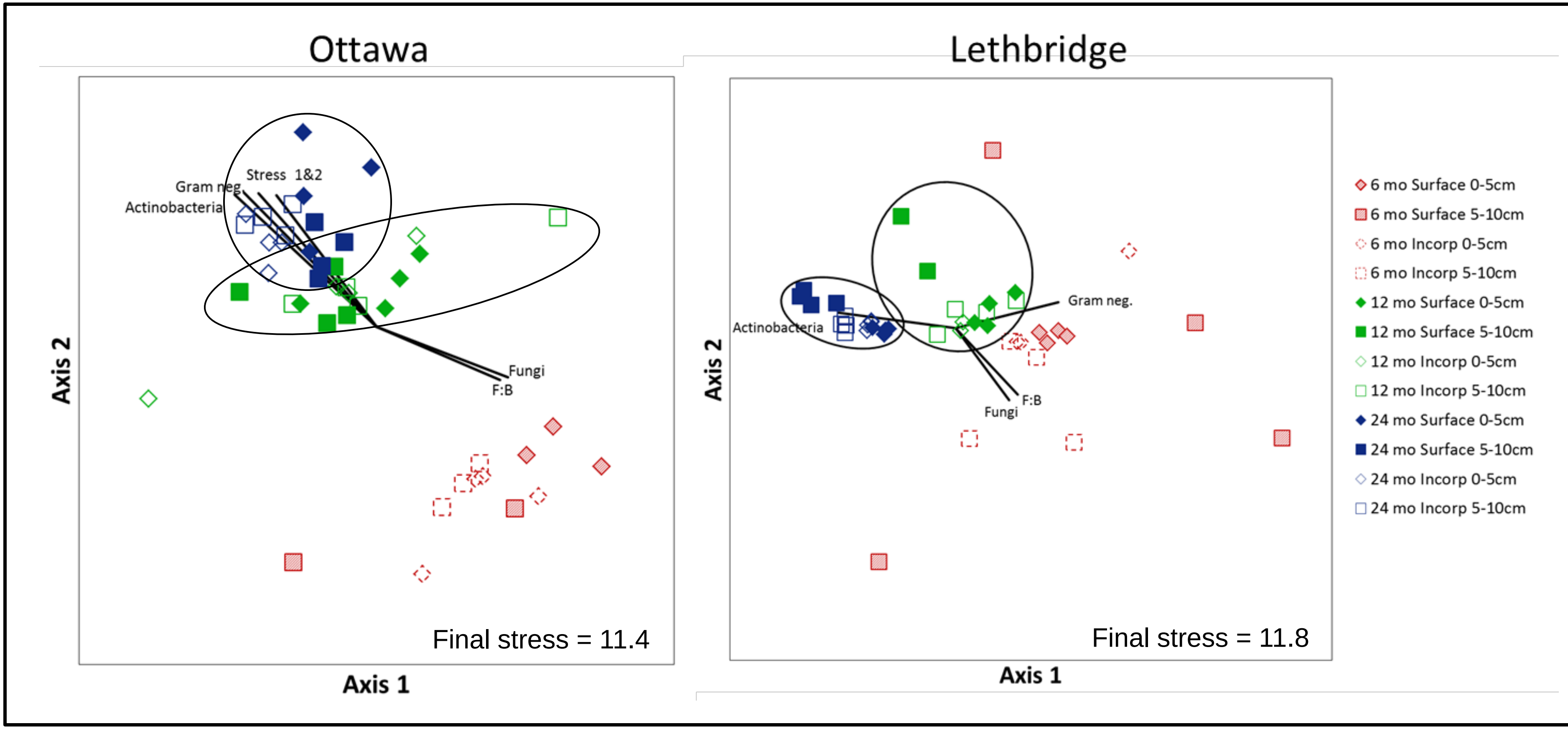
^{13}C recovery in the microbial biomass



Incorporated: Highest recovery at 6 mo.
Little difference between sites

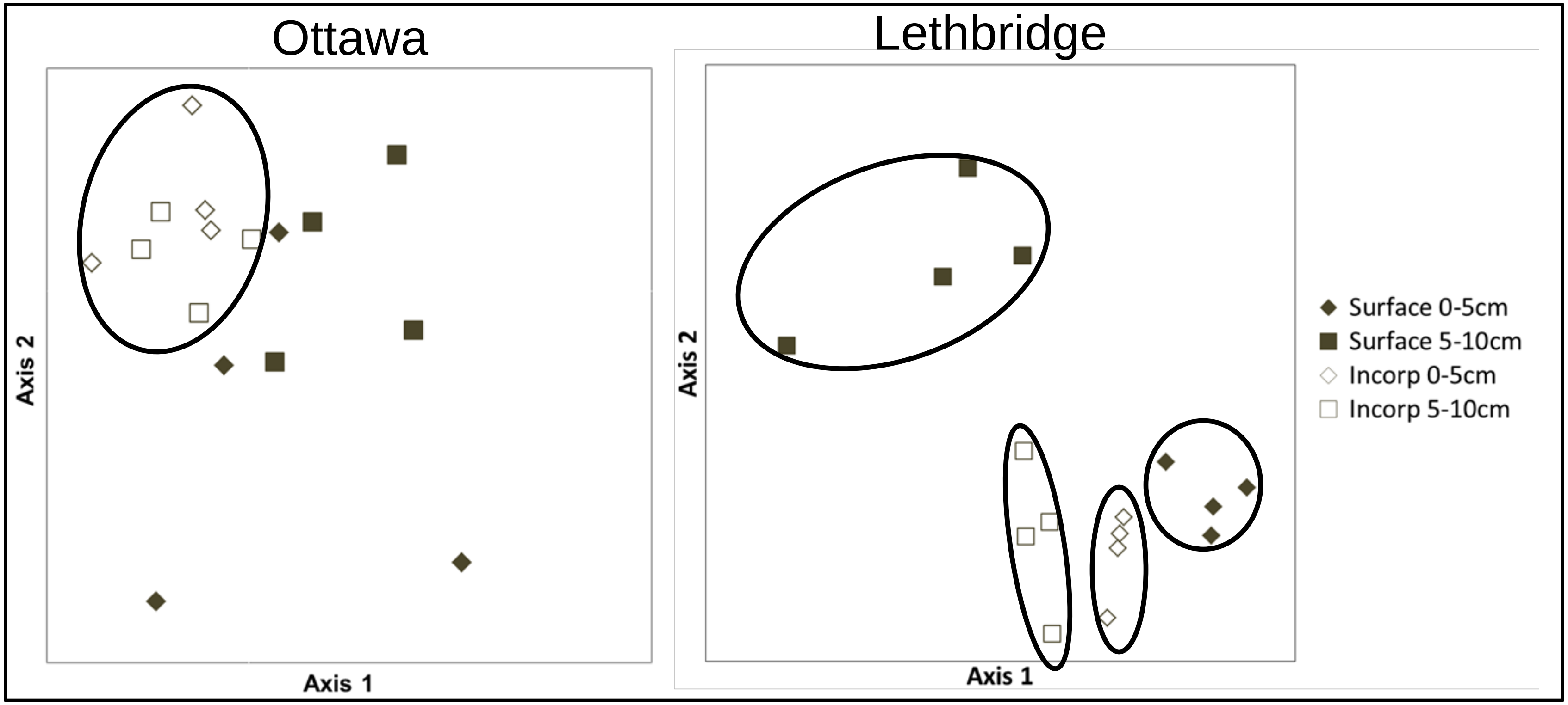
Surface applied: Only 50% as much ^{13}C recovered
Negligible ^{13}C recovery below 5 cm after 2 yr

^{13}C recovery in the microbial biomass



- Initially, ^{13}C labelled community structure highly variable
- Stronger effect of depth at Lethbridge than at Ottawa

^{13}C PLFA Community structure: 24 mo.



2 years after the application of the ^{13}C label:

- distinct community structure reflected earlier residue placement
- there was a strong effect of depth at Lethbridge

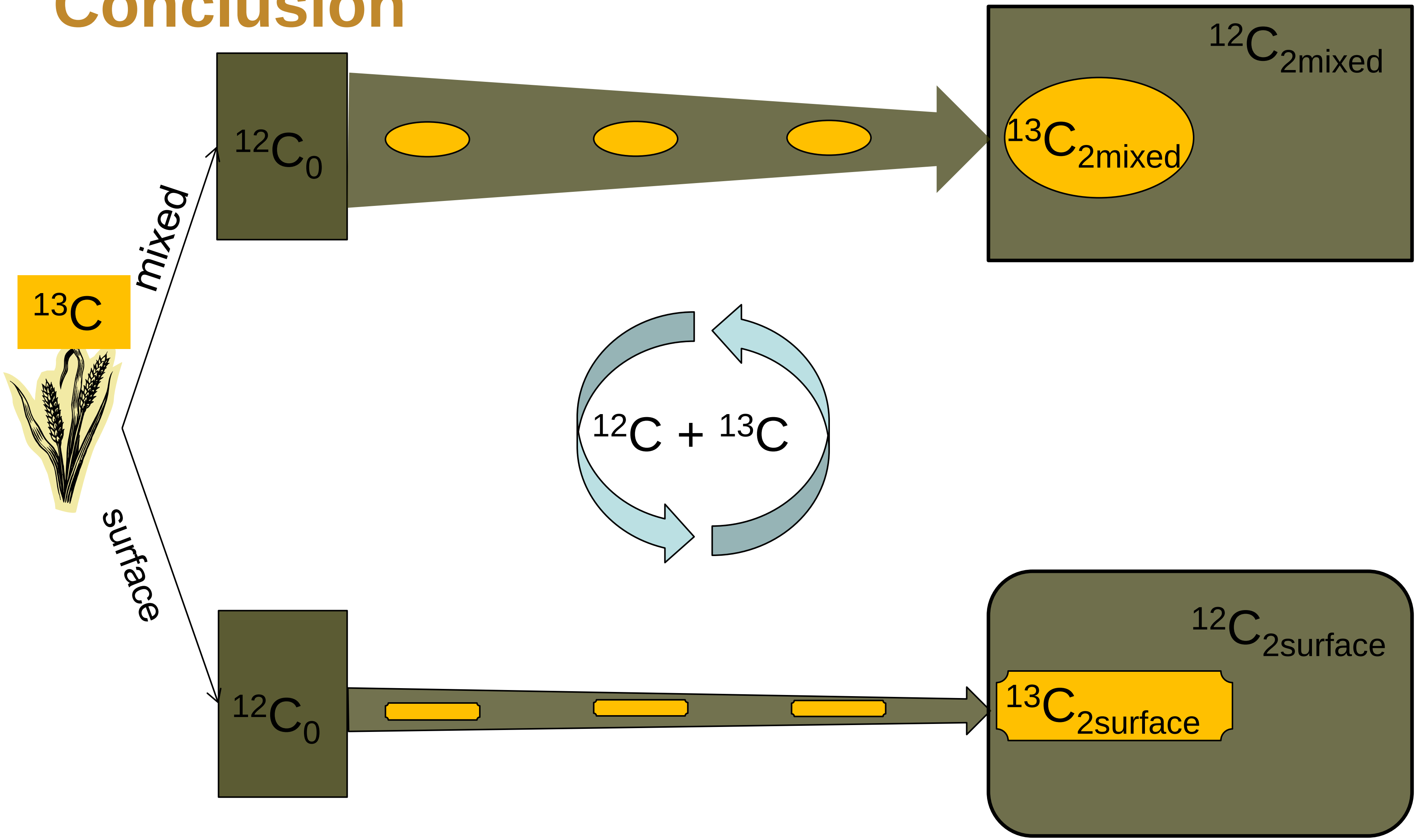
Conclusion

The effect of residue placement was:

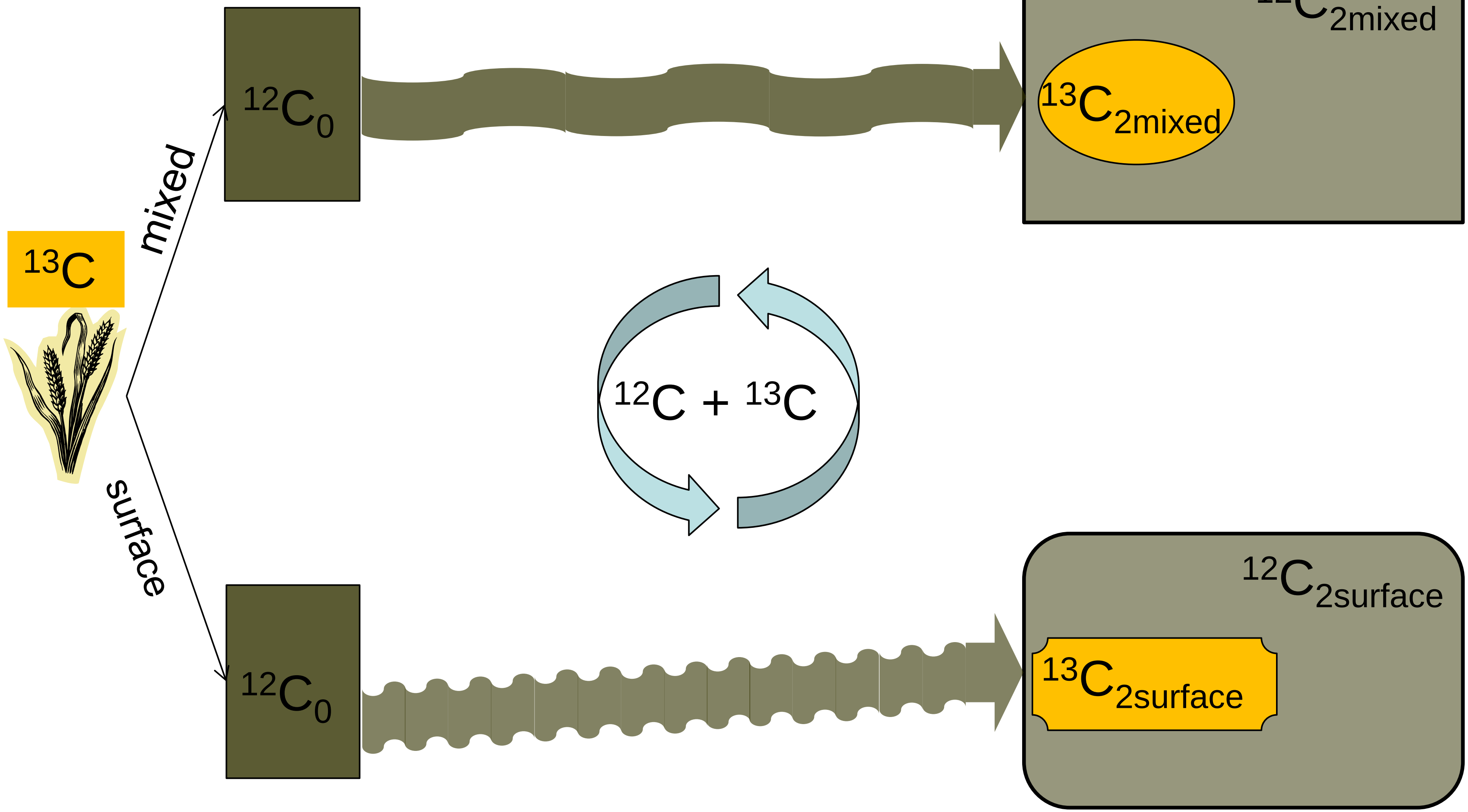
- *site-specific* with,

- a gradual shift toward a *defined community structure* of the labeled microbial biomass that reflected whether residues had been incorporated into the soil or applied to the surface *two years earlier*.

Conclusion


$^{12}C_{2mixed}$
$^{13}C_{2mixed}$
$^{12}C_0$
mixed
^{13}C
$^{12}C + {}^{13}C$
surface
$^{12}C_{2surface}$
$^{13}C_{2surface}$
$^{12}C_0$

Conclusion



^{13}C
mixed
surface
$^{12}C_0$
$^{12}C_0$
$^{12}C_{2mixed}$
$^{13}C_{2mixed}$
$^{12}C + {}^{13}C$
$^{12}C_{2surface}$
$^{13}C_{2surface}$

Implication

Climate has a greater influence on microbial utilization of residues when they are placed on the surface than when they are mixed into the soil.

- Consequently, residue C dynamics may show much higher-site-to-site variability in no-tillage systems than in conventionally tilled systems

- This may explain why NT increases soil C in some cases, but not in others

Acknowledgements

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Canada