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The use of ^{13}C & ^{14}C to quantify the amount of C sequestered below-ground in agricultural systems

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- *presented by Mark Peoples*

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Department of Agriculture, Fisheries and Forestry

The use of the stable isotope ^{13}C & the radio-isotope ^{14}C to examine sequestration of C in soils under perennial C4-grass based pastures in Australia

Application of ^{13}C methodologies

- **The natural differences in discrimination of ^{13}C that occurs during photosynthesis in C4 plants ($\delta^{13}C$ ~ -13 ‰) compared to C3 plants ($\delta^{13}C$ ~ -27 ‰) can be exploited to attribute soil C to either C4 or C3 plant systems.**

Use of ^{13}C in the current study:

C3 to C4 transition study *– ^{13}C was used to quantify the contribution of perennial C4 grasses to soil C sequestration utilising existing pasture systems where the perennial grasses had been grown for periods of up to 45 yrs in soils which had previously only grown annual C3 species*

C3/C4 transition study: Methods

Site selection & soil sampling protocols

At each of 3-4 farms in 3 different regions of Australia

- Paired C4 perennial & C3 annual pastures were identified based on soil type & management history (established between 3-45 years previously)

Within each of a total of 41 pasture comparisons

- 8 randomly located cores were collected in 10 cm increments to 30 cm using a volumetric corer

Fractionation of soil organic matter

Roots > 2 mm recovered using sieve

Particulate organic matter <2 mm >50 µm

A vibrating wet sieve method used to separate Particulate Organic Matter (POM) from humus (< 50µm)

Humus in solution was recovered by precipitation

Both soil fractions *analyzed for total organic C (by dry combustion) & $\delta^{13}C$ (IRMS)*

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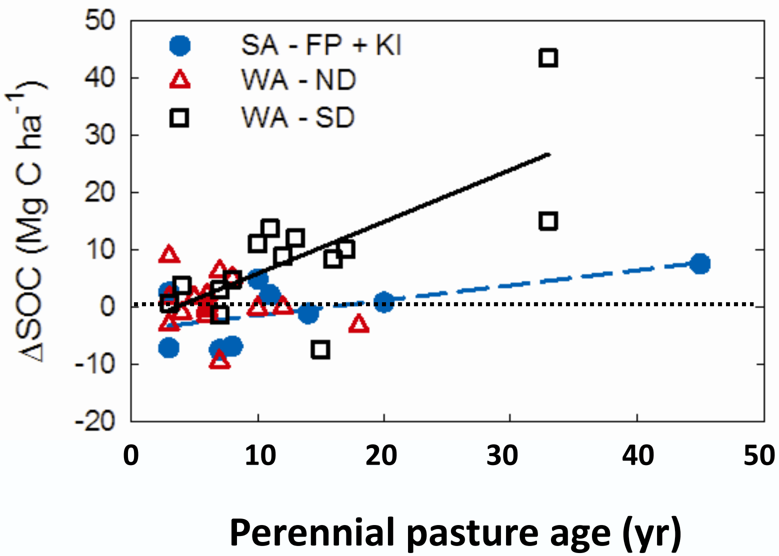
C3/C4 transition results: Overall trends



Regional SOC sequestration rates

- ➢0.9 ± 0.3 MgC ha^{-1} yr^{-1} for Kikuyu in WA (SD)
- ➢0.3 ± 0.1 MgC ha^{-1} yr^{-1} for Kikuyu in SA (FP + KI)
- ➢No trend for Rhodes/Panic grass in WA (ND)

- Kikuyu more responsive than pastures with a mix of Panic/Rhodes grasses
- Greater response on the low fertility sandy soils of WA than higher fertility loamy soils of SA

SA - FP +KI is Fleurieu Peninsula + Kangaroo Is, SA, kikuyu pasture (n=11)

WA - ND is northern district WA –Rhodes-Panic grasses (n=16)

WA - SD is southern district WA – kikuyu pasture (n=14)

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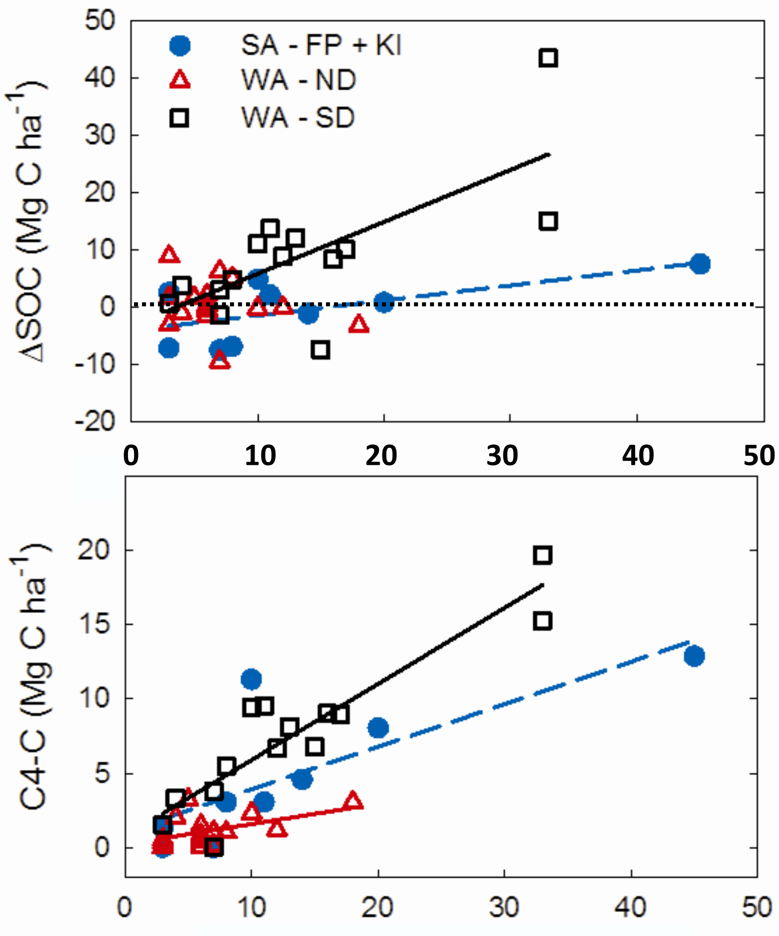

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- Greater response on the low fertility sandy soils of WA than higher fertility loamy soils of SA

- The increase in new C4-derived SOC (*bottom panel*) closely follows pattern of total SOC (*top panel*) indicating that the new C4 grasses were largely driving the observed changes in SOC

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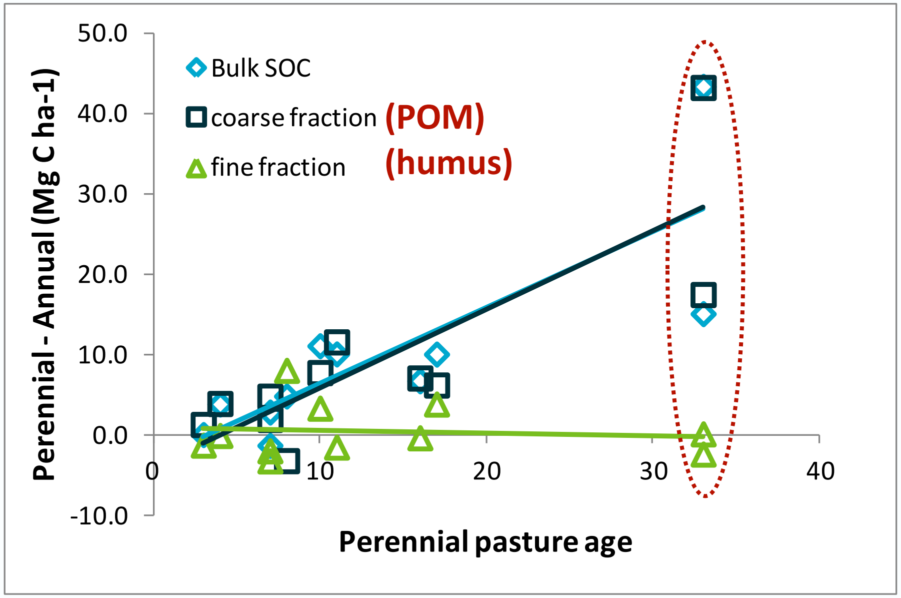
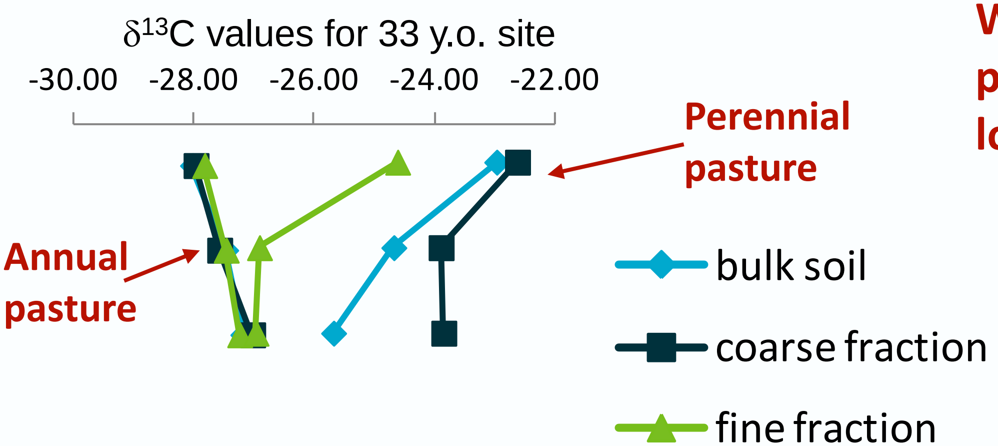
C3/C4 transition results: Fractionation

WA - SD





Nearly all SOC gained in the sandy soils of WA was in the POM (*coarse*) fraction

Isotope shift also dominated by POM

This contrasted to the loamy soils of SA, where 30-40% of the increase in SOC was in the humus (*fine*) fraction.

SOC is accumulating at a greater rate in WA, but it is associated with a more labile pool so is more vulnerable to short-term losses than the SOC accumulating in SA

Application of radioisotope ^{14}C

- **Has a very small natural abundance:**

  - Enables daily inputs of C to be traced within a large soil C pool

  - Can establish above & below-ground allocation of photosynthate

Use of ^{14}C in current study:

- Quantify the distribution of C between root material, POM & humus.

- Follow the change in distribution over time following $^{14}CO_2$ feeding.

- Time-course of information useful for validating models predicting changes in soil C with transition between production systems.

Methods

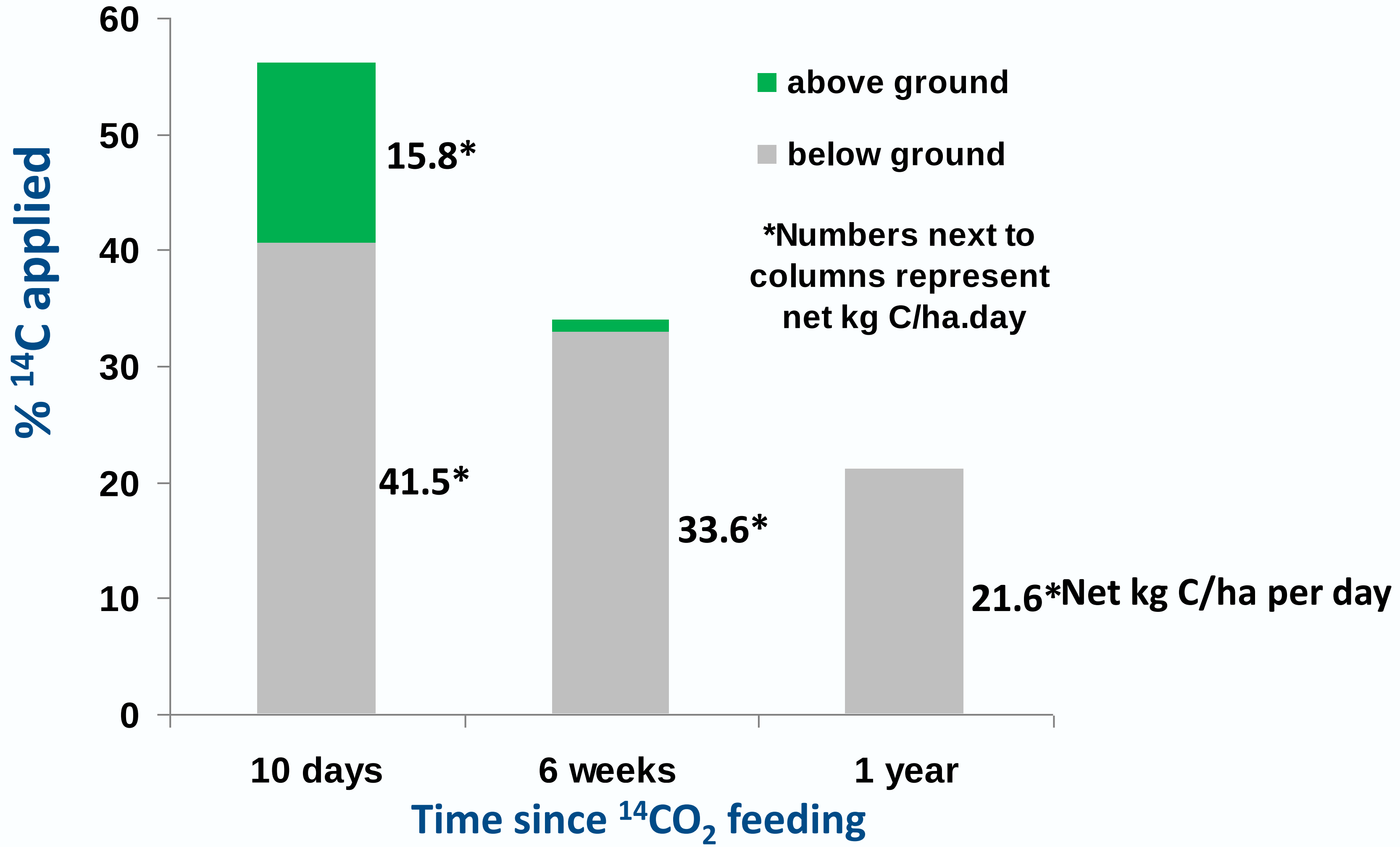
- 70 cm long metal cylinders driven into soil in either a kikuyu pasture (30 cm diameter), or Rhodes/Panic pasture (70 cm diameter)

- $^{14}CO_2$ (130 MBq ^{14}C) was pulse-fed to pastures on each of 3 occasions over ~3 wk growth period using enclosures shown

- Shoot material, root & soil (5 layers to 70 cm) sampled after 7-10 days, 6 & 52 weeks

$^{14}CO_2$ pulse-labelling technique applied
Method adapted from Bhupinderpal-Singh et al. (2005)

Allocation of ^{14}C above and below ground 10 days, 6 weeks and 1 year after last $^{14}CO_2$ feed to 'Spring' kikuyu pasture



Shoot & root was dried, finely ground, combusted to generate CO_2 for total C analysis & scintillation counting

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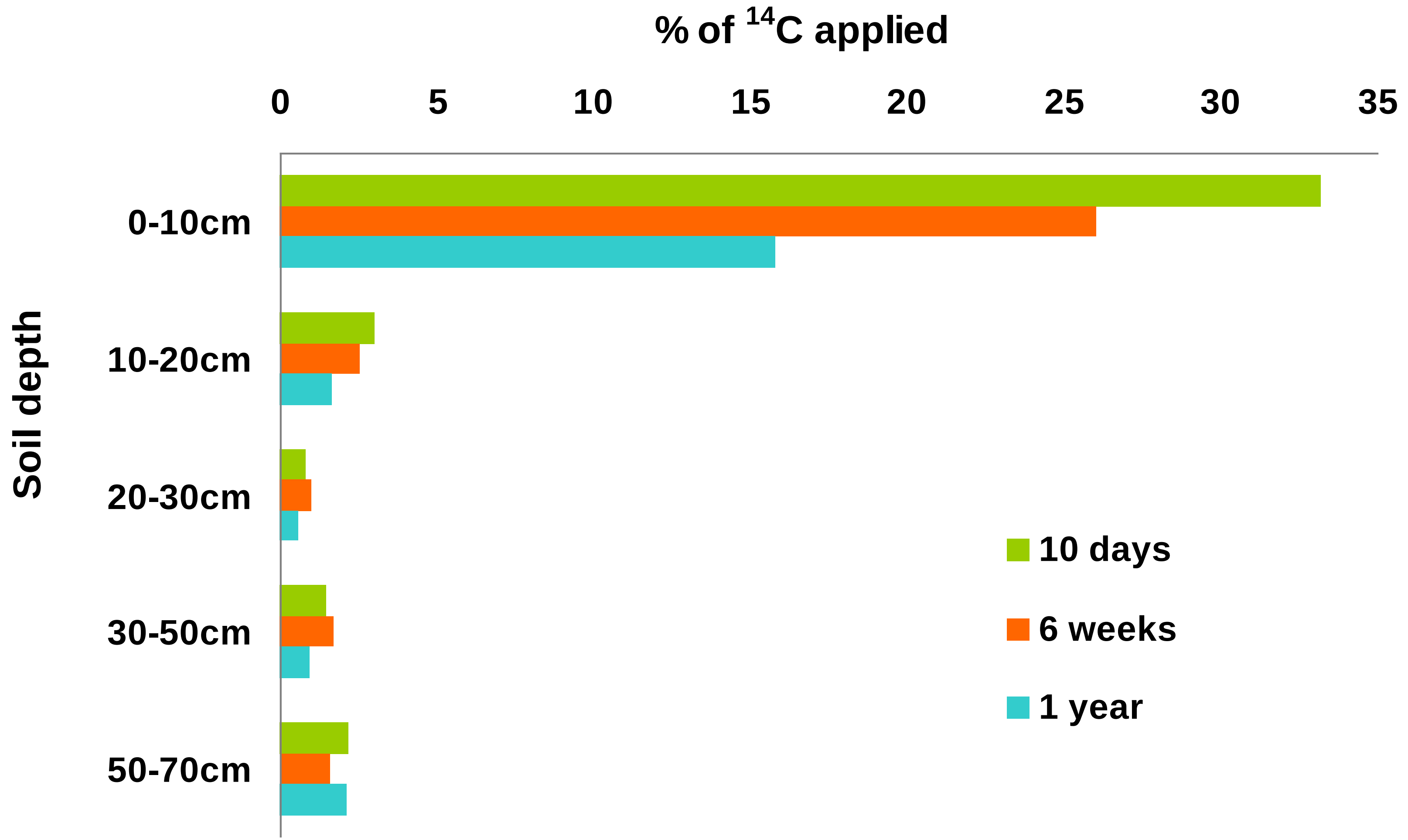
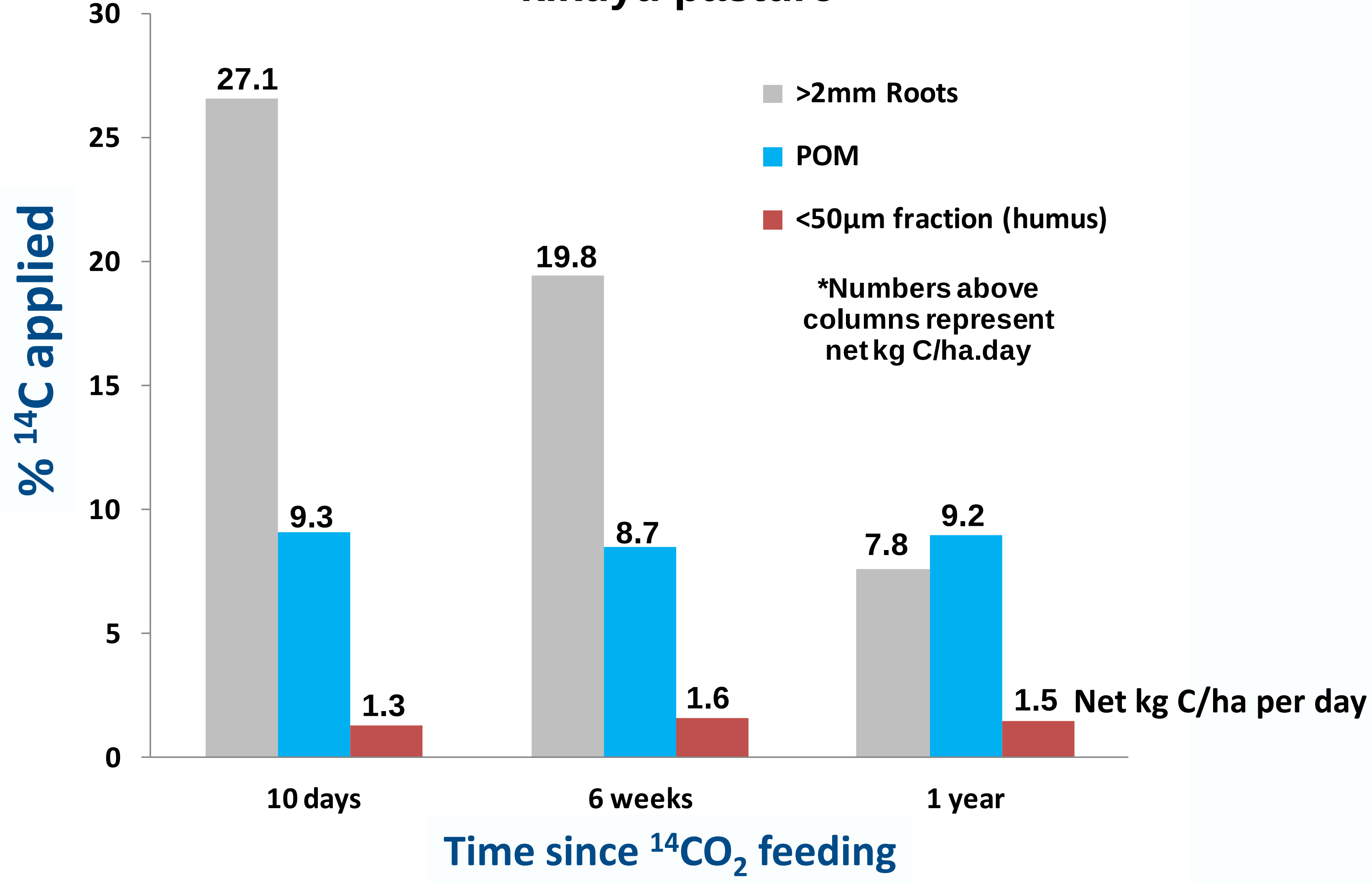
Distribution of ^{14}C below-ground by depth, 10 days, 6 weeks & 1 year after last CO_2 feed to 'Spring' kikuyu pasture



%^{14}C allocated to OM fractions in 0-30cm soil depth for 'Spring' kikuyu pasture



Soil was fractionated as described earlier; POM & humus material finely ground & combusted to generate CO_2 for total C analysis & scintillation counting

Summary

- **Use of differences in $\delta^{13}C$ signature between species & application of ^{14}C has provided new insights on C sequestering capacity of C4 perennial grasses in farming systems dominated by annual C3 species.**

- **Fractionation of soil organic matter into particulate organic matter (*coarse fraction*) & humus (*fine fraction*), for the perennial grasses under study, showed that the accumulation of soil C in WA was mainly in the POM, not the stable humus fraction which is more resistant to decomposition.**

- **Numerous production systems exist globally where these techniques could be applied to determine rates of C sequestration.**