Monitoring C storage and loss through isotope technology

Chen Janet, **Dercon G., Heiling J., Resch C., *et al.***
FAO/IAEA Soil & Water Management & Crop Nutrition Laboratory

THEME 1

INTRODUCTION

What are the benefits of using stable isotope technology in SOC studies?

SOC studies are often labor-intensive, time-consuming and limited to assessing total organic C stocks. The role of various carbon compounds and crops in SOC storage and loss can be identified with stable isotope technology.

What does stable isotope technology measure?

Stable isotope technology differentiates sources of SOC storage and loss by measuring differences in the natural abundance of carbon-12 (12C) carbon-13 (13C) in plant and soil carbon pools and using artificially labelled 13C tracers. Accurate estimations of plant C contributions to soils are only possible with homogenous ^{13}C-labelling of plant material. Labelled plants are increasingly used to trace the fate of plant-derived C in soils. Classic laboratory instrumentation measures amounts of carbon and the proportion of ^{12}C and ^{13}C isotopes in a sample. Laser stable isotope spectroscopy is an emerging technology that will provide more robust data on sources of CO_2 lost from soils. The instrumentation can be transported to a desired location to take *in situ* measurements and can take continuous, real-time measurements without delays in sample collection and processing.

Fig. 1: Gas mixing line linked to a vacuum pump, pressure gauge, CO_2 and synthetic air gas tanks to make reference gases for laser stable isotope analyzers

OBJECTIVES

What work is being conducted in the SWMCNL?

The Soil and Water Management & Crop Nutrition Laboratory is:

- Developing methods of calibration and data correction for laser stable isotope spectroscopy for accurate and precise data;
- Testing analysis of sources of soil C loss with laser stable isotope spectroscopy in a soil mulch-application study;
- Increasing resolution of soil C storage and loss analysis in the mulch-application study using classic methods of SOC analysis;
- Producing homogenously ^{13}C-labelled plant material as well as pulse ^{13}C-labelled plant material to trace storage and loss of plant-derived C in soils.

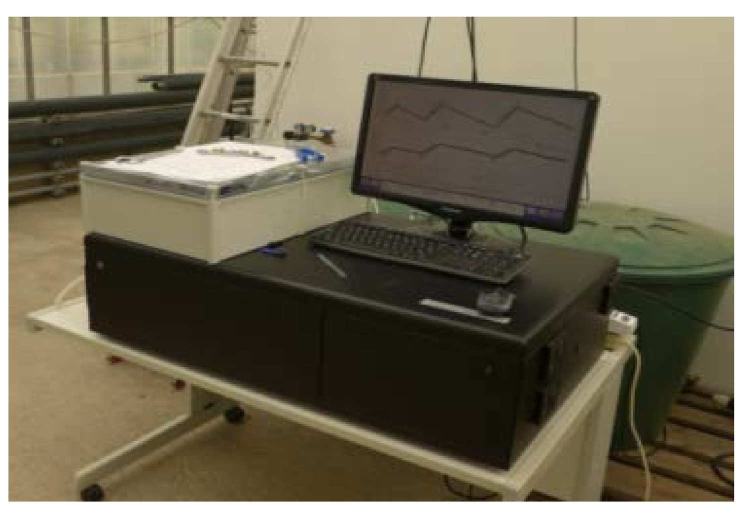

Fig. 2: ^{13}C-CO_2 laser stable isotope analyzer for measuring CO_2 emissions and $\delta^{13}C$ of CO_2 from soils

MAIN RESULTS

Progress to date?

- Reference gases mixed with synthetic air (Fig. 1) were determined to be appropriate for ^{13}C-CO_2laser stable isotope spectroscopy (Fig. 2).
  Instrumentation calibration and data correction to be validated;
- Measurements of fluxes of ^{13}C-CO_2 from soils has been achieved (Fig. 3).
  Processing and evaluating methods for large amounts of CO_2 and $\delta^{13}C$ data have been established;
- Effects of superficial mulch-application on soil C and N analyzed 4 yr after experimental setup (Table 1). Mulch effects mostly observed in top soil. Microbial C slightly responsive to mulch, SOC content is not. SOC $\delta^{13}C$ suggest a shift in C contributing processes. More mulch effects in high OM soils;
- High throughput homogenous ^{13}C-labelling of maize has been achieved (Fig. 4 & Table 2).
  Additional ^{15}N-labelling of soybean has also been achieved. Dual-labelled plants will be produced this year.

Tab. 2: $\delta^{13}C$ of stabile components (lignin and cellulose) and labile components (proteins, carbohydrates and organic acids) of plant material collected along the length of maize

Leaf	Intra-leaf	$\delta^{13}C$ stabile	$\delta^{13}C$ labile
top	stem	399	404
top	tip	398	403
middle	stem	398	407
middle	tip	378	395
bottom	stem	396	406
bottom	tip	282	305

Tab. 1: C and N analysis of soil organic C and N as well as microbial C and N of meso-cosm soils (Fig. 1) with low (L) or high (H) organic matter without mulch (OM) and with mulch (M). Each value represents the mean of 3 replicates and standard errors. Significant differences in values due to organic matter and mulch are shown for $P < 0.05$

0-5 cm	LOM	LM	HOM	HM
SOC $\delta^{13}C$	-26.24 ± 0.03^{ac}	-25.69 ± 0.23^{bd}	-26.27 ± 0.06^{ab}	-25.76 ± 0.06^{cd}
Soil mg organic C g^{-1} soil	10.82 ± 0.11^{a}	12.56 ± 0.58^{a}	24.66 ± 1.55^{b}	26.39 ± 0.54^{b}
Microbial mg C g^{-1} soil	0.011 ± 0.006^{abc}	0.063 ± 0.004^{abc}	0.054 ± 0.031^{b}	0.154 ± 0.023^{c}
$\delta^{15}N$	7.54 ± 0.22^{a}	8.00 ± 0.16^{a}	8.38 ± 0.29^{b}	8.60 ± 0.30^{b}
mg N g^{-1} soil	1.38 ± 0.04^{abc}	1.43 ± 0.05^{abc}	2.26 ± 0.04^{b}	2.55 ± 0.09^{c}
Microbial mg N g^{-1} soil	0.015 ± 0.005^{a}	0.015 ± 0.002^{a}	0.028 ± 0.002^{b}	0.026 ± 0.005^{b}

5-15 cm	LOM	LM	HOM	HM
SOC $\delta^{13}C$	-26.53 ± 0.04^{abc}	-26.42 ± 0.05^{abc}	-26.28 ± 0.09^{b}	-26.11 ± 0.05^{c}
Soil mg organic C g^{-1} soil	10.66 ± 0.39^{a}	10.34 ± 0.05^{a}	23.89 ± 0.50^{b}	24.00 ± 0.52^{b}
Microbial mg C g^{-1} soil	0.041 ± 0.011^{a}	0.040 ± 0.004^{a}	0.177 ± 0.028^{b}	0.147 ± 0.022^{b}
$\delta^{15}N$	7.07 ± 0.14^{a}	7.25 ± 0.12^{a}	8.25 ± 0.10^{b}	7.99 ± 0.21^{b}
mg N g^{-1} soil	1.27 ± 0.02^{a}	1.23 ± 0.02^{a}	2.29 ± 0.05^{b}	2.29 ± 0.05^{b}
Microbial mg N g^{-1} soil	0.016 ± 0.0003^{a}	0.018 ± 0.008^{a}	0.021 ± 0.004^{a}	0.022 ± 0.004^{a}

Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

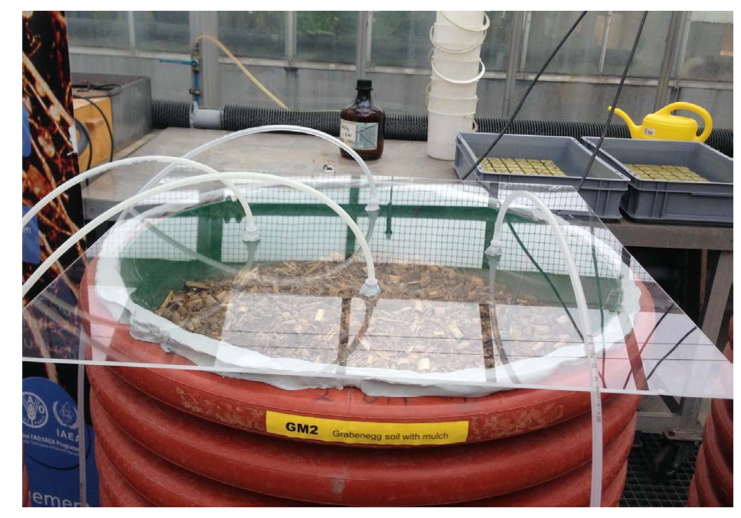

Fig. 3: Experimental meso-cosms. Agricultural soil being sampled for CO_2. For 4 ys, maize and soybean have been grown in rotation and no mulch/ mulch has been applied as an experimental treatment. Water has been maintained constant in treatments

Fig. 4: Maize plants grown in growth chamber with $^{13}CO_2$ labelling. Scrubbers are suspended to reduce ethylene levels and a desiccant rests on the floor to reduce humidity. Fans promote structural stability of maize

CONCLUSION

Stable isotope techniques for climate-smart agriculture

At the joint FAO/IAEA SWMCN laboratory isotope techniques are being established and combined to evaluate practices for climate-smart agriculture. Specifically, mulch applications are being evaluated for the capacity to:

- Reduce soil CO_2 emissions due to the large potential for soils to emit this greenhouse gas to the atmosphere;
- Store SOC belowground to improve soil quality and reduce atmospheric levels of CO_2.

Mulch applications are also being evaluated for…

- Managing fertilizer application to improve plant yield and reduce pollution;
- Reducing soil N_2O emissions due to the large potential for fertilizers to release this greenhouse gas.

Stable isotope techniques will be combined into guidelines for Member States to use for climate-smart agriculture.