Developments at the Soil and Water Management and Crop Nutrition Laboratory

Sediment Origin Determination in the Sub-Catchment of Mistelbach (Austria) using Fatty Acids Biomarkers and Compound-Specific Stable Isotope Techniques

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Compound-specific stable isotope (CSSI) signatures of inherent soil organic biomarkers allow discriminating and apportioning the source of soil contribution from different land uses. Plant communities label the soil where they grow by exuding organic biomarkers. Although all plants produce the same biomarkers, the stable isotopic signature of those biomarkers is different for each plant species.

For agri-environmental investigations, the CSSI technique is based on the measurement of carbon-13 (^{13}C) natural abundance signatures of specific organic compounds such as natural fatty acids (FAs) in the soil. By linking fingerprints of land use to the sediment in deposition zones, this approach has been shown to be a useful technique for determining the source of eroded soil and thereby identifying areas prone to soil degradation.

The authors have used this innovative technique to investigate a 3 hectares sub-catchment of Mistelbach situated 60 km north of Vienna. Using the ^{137}Cs technique, Mabit et al. (2009) reported a local maximum sedimentation rate reaching 20 to 50 t ha^{-1} yr^{-1} in the lowest part of this Austrian catchment. To test the ability of the CSSI technique to discriminate different sediment sources of these deposited sediments, representative soil samples from four main agricultural fields of the site were analyzed (see Figure 1).
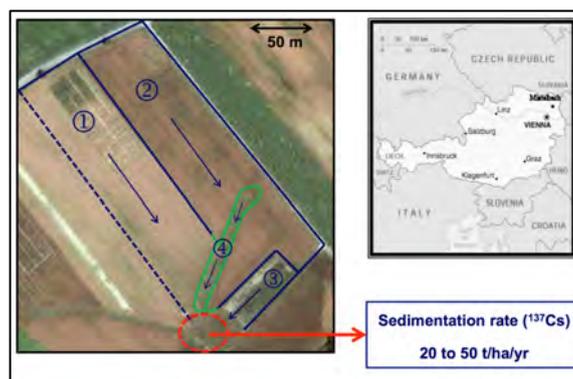

Figure 1. Location of the sub-catchment of Mistelbach
(4 agricultural fields [sources: 1, 2, 3 and 4], sedimentation area [mixture] in red)

TABLE 1. ^{13}C Signatures of the FAs Present in the Four Soil Sources and the Sediment Mixture

Sample - ID	Organic C	Bulk C	Myristic Acid (C14:0)	Palmitic Acid (C16:0)	Palmitoleic Acid (C16:1)
	(%C)	(δ^{13}C‰)	(δ^{13}C ‰)	(δ^{13}C ‰)	(δ^{13}C ‰)
Source 1	1.36	-25.05	Not measurable	-21.84	Not measurable
Source 2	1.70	-24.16	Not measurable	-26.26	Not measurable
Source 3	2.53	-14.89	-26.33	-22.85	Not measurable
Source 4	3.82	-18.65	Not measurable	-26.88	-27.72
Mixture	3.19	-17.32	-37.37	-27.70	-29.26

Sample - ID	Stearic Acid (C18:0)	Oleic Acid (C18:1)	Linoleic Acid (C18:2)	Arachidic Acid (C20:0)	Behenic Acid (C22:0)	Lignoceric Acid (C24:0)
	(δ^{13}CC‰)	(δ^{13}C ‰)	(δ^{13}C ‰)	(δ^{13}C ‰)	(δ^{13}C ‰)	(δ^{13}C ‰)
Source 1	-24.36	-26.02	-23.52	Not measurable	-32.44	-30.09
Source 2	-27.80	Not measurable	-26.29	Not measurable	-33.39	-31.44
Source 3	-22.92	-22.66	-22.49	-27.74	-30.73	-28.89
Source 4	-25.73	-30.23	-38.96	-32.70	-32.53	-32.24
Mixture	-29.75	-29.78	-26.67	-34.54	-33.23	-32.99

Using the results presented in Table 1, a biplot approach was used to select the best FAs to identify the sediment origin. In complement to the information provided by the bulk delta ^{13}C of the samples, both long-chain FAs C22:0 (i.e. Behenic Acid) and C24:0 (i.e. Lignoceric Acid) allowed the best statistical discrimination.

Values of ^{13}C signatures of these two specific FAs and the bulk ^{13}C of the sediment mixture and potential source soils were analyzed with the Phillips and Gregg (2003) mixing model IsoSource (see Figure 2).
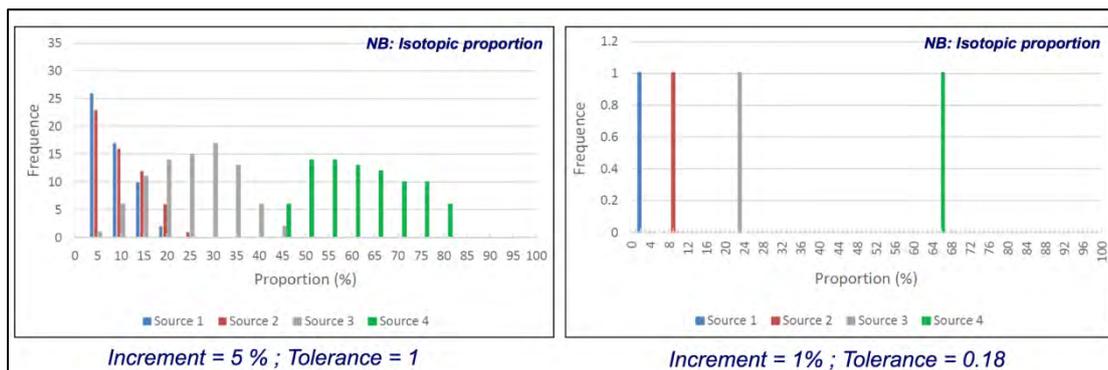

*Figure 2. Isotopic proportion of the sources obtained with the IsoSource model
(Raw data on the left side and computed data on the right side)*

Using the isotopic proportion determined by the IsoSource model and the organic carbon content of each source allowed quantification of the different soil sources (see Gibbs, 2008). As recently suggested by Alewell et al. (2015), when available, it is recommended to use the abundance of the respective FAs for conversion into soil proportion.

Our preliminary results suggest that the agricultural fields i.e. sources 1, 2, 3 and 4 (i.e. the main grassed waterway of the sub-catchment) contributed to 4, 15, 26 and 55% to the sediment deposited at the catchment outlet, respectively.

This study, that will require further refinement and discussion, highlights that CSSI techniques and FRNs are complementary as fingerprints and tracers of land sediment redistribution. While in our study the ^{137}Cs technique provided information on the sedimentation magnitude at the outlet of the sub-catchment, CSSI techniques applied for FAs provided information about the origin of those sediments.

As climate change is expected to further accelerate soil erosion, a better understanding for reducing soil erosion and sedimentation-related agri-environmental problems represents a key requirement for mitigating the expected impact of climate change. Jointly applied, these isotopic techniques (i.e. CSSIs and FRNs) can provide key information for optimized decision-making to land managers to ensure the sustainability of agro-ecosystem management.

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Laser Carbon-13 and Nitrogen-15 Isotope Analysis for Greenhouse Gases now available at the SWMCNL

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Agriculture, forestry, and other land use (AFOLU), contribute 20-24% to the total anthropogenic emission of greenhouse gases (GHG) such as nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4). This contribution makes the AFOLU globally the largest emitting sector after energy, and even more important in developing countries (IPCC Fifth Assessment Report 2013-2014).

IPCC estimates annual GHG emissions (mainly CH_4 and N_2O) from agricultural production in 2000─2010 at 10─12% (5.0─5.8 $GtCO_2eq/yr$), and annual GHG flux from land use and land use change activities at 9─11% of global emissions (4.3─5.5 $GtCO_2eq/yr$). The same IPCC report indicates that a combination of supply-side and demand side options can reduce up to 80% the emissions from the sector by 2030.

To develop technologies for greenhouse gas emission reduction in agriculture, it is imperative to have the expertise and capability of measuring and tracing GHG to get further insights about their sources in soil. For this purpose, in 2015, the SWMCN Laboratory purchased two laser isotope analysers to measure the Carbon-13 and the Nitrogen-15 signatures of CO_2 and N_2O. The two new analysers are now being tested and calibrated under field and laboratory conditions, to offer training and analytical services to our Member States.

These activities are also linked to CRP D1.50.16 on "Minimizing farming impacts on climate change by enhancing carbon and nitrogen capture and storage in Agro-Ecosystems". The SWMCNL in Seibersdorf will play a key role in providing technical support in using stable isotopic technique of ^{15}N and ^{13}C at natural abundance to unveil the C-N interaction to optimise both C and N capture as well as to reduce GHG.

First specific protocols, using the ^{15}N-N_2O laser isotope analyser, are now being developed to assess the efficiency of the use of N process inhibitors mixed with urea fertilizer to reduce the emission of N_2O. N_2O fluxes are measured through the ^{15}N isotopic signature of the N_2O. In addition, first tests have been made to use the ^{13}C-CO_2 analyser in carbon dynamics studies (Figure 1). Besides these tests the ^{13}C-CO_2 analyser is also being used in the optimization of walk-in growth chamber based ^{13}C labelling of plant materials (Maize) (Figure 2). This analyser helps to stabilize the ^{13}C enrichment of the CO_2 in the growth chamber to ensure the homogeneity of the plant labelling. The ^{13}C-labelled material is then used in organic carbon decomposition studies to trace the source of CO_2.

Figure 1. a. Nitrogen-15 N_2O laser isotope analyser for screening the efficiency of N process inhibitors in reducing N_2O emission from urea-fertilized applied to lysimeters in growth chamber (left); b. Controlling Carbon-13 enrichment of CO_2 in the growth chamber during Carbon-13 labelling of maize (right)

Figure 2. Carbon-13 labelling of maize in ^{13}C-CO_2 analyser controlled walk-in growth chamber at the SWMCN Laboratory