Scientific report

Summer School: Molecular and structural complexity of soil organic matter formation and turnover

Dates: 25 - 30 March, 2012
Location: Kardinal-Döpfner-Haus, Freising, Germany

Summary (up to one page)

Soil organic matter (SOM) is involved in major soil functions and represents one of the largest reservoirs of organic C on the global scale. Fundamental knowledge on SOM fate and effect is thus mandatory in preserving, remediating and maintaining soil based ecosystem services under the conditions of global change.

The school aimed at bringing together young and established scientists of different disciplines in soil science (biology, chemistry, physics, modeling) to interact in an interdisciplinary course related to studying SOM its formation, properties and function. To allow intensive communications between national and international experts and young scientists, the number of participants was limited to 33 participants selected from 78 applicants. The course was organized by Technische Universität München and was sponsored by MOLTER (www.molter.no). Ten international experts provided insights into different disciplines in soil science as well as into modern analytical techniques that improved the understanding of processes in soil organic matter stabilization and turnover in recent years (see annexes: programme of the meeting and full list of speakers and participants). The special documents of the speakers (suggested papers and their lecture as well as special exercises) were provided to the participants via a password restricted download area on the webpage of the summer school (link: http://www.soil-science.com/index.php?id=239).

Program overview

- **Soil system processes:** SOM formation processes, microbial ecology, dissolved organic matter, nitrogen stabilization and turnover, vegetation fires, black carbon formation, SOM turnover in subsoils
- **Soil organic matter formation and properties at different scales:** Aggregate formation, nanoscale characteristics, interfaces - surface charge - nanoscale
- **Modelling of SOM turnover**

Description of the scientific content and discussions at the event (up to four pages)

Soils store at least three times as much carbon in soil organic matter (SOM) as is found in either the atmosphere or in living plants. The amount of C stored in a soil is determined by a dynamic equilibrium between C inputs from primary biomass production and C outputs by mineralization. Mineralization of organic C is inhibited by different stabilization processes. The interplay between theses processes is very complex, requiring an understanding of chemical, physical and biological interactions within the soils matrix.

The aim of the summer school was to promote intensive communications between national and international experts and young scientists and to interact in an interdisciplinary course related to studying formation, stabilization and decomposition of organic matter in soils and to link processes operative on the molecular and organism scale to processes at and within biogeochemical interfaces in soils and to understand their functions across different scales.

A research strategy for a better understanding of SOM stabilization processes must combine research on the molecular composition of SOM in specific soil fractions with the different methods that are now available for detailed describing SOM structure (e.g. ^{13}C and ^{15}N NMR, pyrolysis, X-ray spectrometry, SEM, Fourier-Transform Infrared Analysis, secondary ion-mass spectrometry (SIMS), scanning electron microscopy with energy-dispersive X-ray analysis) and for quantifying pool sizes and turnover rates of SOM (^{14}C dating, ^{13}C and ^{15}N natural abundances, compound-specific isotope data) to provide a measure for SOM stability, such as turnover times or the age of SOM. Improved knowledge of the size and fluxes of C from differently stabilized SOM pools is indispensable to predict C turnover in soils as a function of environmental changes.

To bring together young and established scientists of different disciplines in soil science (biology, chemistry, physics, modeling) the number of participants was limited to 33 and a participants. A rigorous selection procedure was applied to select 33 participants. Evaluated was the letter of application, the knowledge in special topics, the home country and the institution of interested students. We had to disclaim 45 interested applicants.

The poster sessions allowed the students to introduce them each other and to gain insight into their interest, competences and into the current theme of their work.

The **first group of topics** was related to **'Soil system processes'.** On Monday, March 26, 2012 the lecture **'SOM molecular structure and formation processes'** of **Prof. Ingrid Kögel-Knabner** from Germany started with a detailed description of the molecular composition of organic material in soils including input material and cell wall components of plants and microorganisms as well as specific components of fungi and bacteria. She explained different degradation pathways and stabilization mechanisms of organic materials

in soils and showed results revealed by advanced techniques in soil fractionation and identification and origin tracing of functional groups and individual molecules. She concluded that soil organic matter stabilization is a multi-factor interplay of processes that are controlled by the complex parent material, texture, mineralogy, and pH and that are specific for different pedogenetic soil types and horizons. The second lesson was hold by **Prof. Andreas Richter** from Austria on **'Soil microbial ecology - A primer in soil microbial ecology'**. Prof. Richter introduced different methods to measure single microbial cells (e.g. FISH, rRNA, PCR), microbial communities (e.g. PLFAs, Meta genomics) and microbial diversity (e.g. (DGGE, Meta genomics). He summarized, that theories and methods to link community composition to processes and functions are still missing and that microbial functional types still await definition. In his outlook he drew the attention to a combination of life form concepts (domains, phyla) and the r/K selection theory that could be used as a step forward. In the afternoons **Prof. Karsten Kalbitz** form Netherlands presented the lecture **'Cycling downwards – Dissolved organic matter in soils'**. He demonstrated that dissolved organic matter (DOM) is a substrate and product of microbial activity and that it reflects the interaction of biotic and abiotic processes. To verify effects of changes in temperature and DOM retention (i.e. DOM input into the mineral soil, adsorption, (co-)precipitation) he prepared for the students an exercise based on an Excel file 'Carbon stabilization by DOM an exercise.xls' containing 4 different worksheets: Two worksheets explicitly highlight different stabilization processes (sorption, precipitation) and the other two worksheets demonstrated ways to describe/illustrate the relationships between temperature, DOC retention and carbon stabilization (temperature or DOC retention as the independent variable on the x-axis). The students had all data necessary for the calculations and an example/suggestion how to structure their calculations.

On Tuesday, March 27, 2012, **Prof. Pascale Boeckx** from Belgium summarized in his lecture **'Nitrogen stabilization and turnover'** the state of the art in tools, especially stable isotope natural abundance vs. tracer studies, to quantify in situ simultaneously occurring (internal) terrestrial N cycling processes and their future role in view of net primary production and climate change. Session 5 **'All you ever wanted to know about fire-derived, pyrogenic organic matter (including biochar) - but were afraid to ask'** was hold by **Prof. Michael Schmidt** from Switzerland. He started with an input-talk of 30 minutes including time for questions. His major statements were: I. Fire derived organic matter is (almost) everywhere but not all char is created equal. II. Black carbon is a soil forming factor and a sink for carbon and nitrogen in ecosystems. III. Until now it is not clear if and how soil fertility benefits from biochar inputs. During the next hour the students had time to develop a research proposal. To prepare a case study already in February 2012 a handout 'Shoot-out for a research fund – The most pressing question on fire-derived organic matter in the

environment' was sent to the students. The handout described the procedure how students should develop a research proposal in individual groups and provided a list of relevant literature. The discussion happened in individual groups. After dinner each group of students had 4 minutes time to present their projects to a panel of senior scientists. The panel (Denis Anger, Daniel Rasse, Margit v. Lützow and Carolin Bimüller) selected the successful project(s), and the 'research fund' was given on site in 'Swiss gold' (Toblerone chocolate).

The lecture **'SOM turnover in subsoils'** by Prof. **Cornelia Rumpel** from France particularly highlight that subsoil SOM may participate in C and N cycles provided that fresh litter is available for microbial activity and microbial biomass has access to SOM.

The **second group of topics** was related to **'soil organic matter formation and properties at different scales'**. On Wednesday, March 28, 2012 **Prof. Kai-Uwe Totsche** form Germany focused in his lecture to **'Soil nano-architecture'.** He particularly highlighted that soils are dynamic and hierarchically organized systems of various organic and anorganic constituents and organisms and their spatial structure defines a large complex and heterogeneous interface. He concluded that biogeochemical processes at soil interfaces are fundamental for the overall soil development and that they are the primary driving force for key ecosystem functions such as plant productivity and water quality. The lecture **'The Link between soil organic matter stabilization and aggregate formation: Theory and application'** by **Prof. Johan Six** from USA comprised the three issues: I. Theory of aggregate dynamics. II. Applications e.g. aggregates as a tool to quantify effects of cultivation and III. incorporating aggregation into modeling.

The **third group of topics** was related to **'Modeling and SOM turnover'** and started on Thursday, March 29, 2012 with the lecture **'Modeling Soil Organic Matter Turnover'** by **Prof. Daniel Rasse** from Norway who introduced different one pool models and multi-pool models in particular Rothamsted and Century type models and a lignin turnover model that allow to compute fluxes, quantities or specific parameters in soil, to explore concepts and to simulate future outcomes of interests e.g. modelling of climate change. The final lecture was hold by **Dr. Denis Angers** from Canada on **'Soil organic matter dynamics and sequestration in managed ecosystems'.** Denis Angers showed by examples with case studies and meta-analyses how management factors can affect C sequestration. His lecture addressed the issues: Aggregate disruption, altered input conditions (quantity and quality) and altered depth distribution of soil organic matter and modelling of SOM turnover.

Assessment of the results and impact of the event on the future directions of the field (up to two pages)

The poster sessions were not only ideal for the students to introduce them each other and to gain insight into their current theme of their work, moreover they were ideal to present and discuss their research with the speakers. Also the evening sessions were used as informal discussions with the students and experts in the Kardinal-Döpfner-Haus bar and had the motto ‘meet the experts’.

The lectures were followed with very great interest. The students had the opportunity to ask numerous questions, to participate in active and dynamic discussions, to do exercises and to present their ideas.

Furthermore the students had the possibility to visit in small groups the NanoSIMS 50L facility at the chair of soil science in Freising that was guided by Dr. Carsten Müller.

Like our last summer school this summer school was a great experience for the students.

The summer school ‘Molecular and structural complexity of soil organic matter formation and turnover’ was the second training event in the complex topic ‘organic matter in soil’. The first summer school ‘Soil organic matter- composition and turnover’ took place from March 16 – 20, 2009 at the Kardinal-Döpfner-Haus in Freising, Germany and was organized by the Technische Universität München and sponsored by the DFG (German Research Foundation).

Annexes: programme of the meeting and full list of speakers and participants

Schedule: SOM Summer School, Freising, Germany, March 25-30, 2012

	8.15-10.00		10.30 – 12.15		13.30-14.30	14.30-15.00	15.00-17.15	18.00	19.30-22.00
Sunday							Arrival		Welcome/ get-together
Monday	Session 1	Coffee	Session 2	Lunch	Student posters	Coffee	Session 3	dinner	Evening session
Tuesday	Session 4	Coffee	Session 5	Lunch	Guided tour*	Coffee	Student posters	dinner	Evening session
Wednesday	Session 6	Coffee	Session 7	Lunch	Tour**				
Thursday	Session 8	Coffee	Session 9	Lunch	Student poster	Coffee		dinner	Evening session
Friday	Session 10	Coffee	Final session	Lunch	Departure				

Session		**Speaker**
Soil system processes		
1	SOM molecular structure and formation processes	Ingrid Kögel-Knabner, Germany
2	Microbial ecology	Andreas Richter, Austria
3	Dissolved organic matter	Karsten Kalbitz, Netherlands
4	Nitrogen stabilization and turnover	Pascal Boeckx, Belgium
5	Vegetation fires, black carbon formation	Michael Schmidt, Switzerland
6	SOM turnover in subsoils	Cornelia Rumpel, France
SOM formation and properties at different scales		
7	Soil nanoarchitecture	Kai Uwe Totsche, Germany
8	The role of aggregation	Johan Six, USA
Bringing it all together: modelling and managing SOM		
9	Modelling of SOM turnover	Daniel Rasse, Norway
10	SOM dynamics and sequestration in managed ecosystems	Denis Angers, Canada
Final session		
	(wrap up, take home messages; what did you learn?)	Ingrid-Kögel-Knabner Kai UweTotsche Daniel Rasse

*Guided tour to historical surroundings (Mariendom), extra costs not covered by MOLTER

**Tour to Munich (optional), costs at participants own expense

List of speakers

1 **Dr. Denis Angers**
Agriculture et Agroalimentaire Canada | Agriculture and Agri-Food Canada
2560 Hochelaga
Québec, Québec
G1V 2J3
Canada
denis.angers@agr.gc.ca
Phone: 418-210-5022
Cell. 418-561-2811

2 **Dr. Pascal Boeckx**
Laboratory of Applied Physical Chemistry - ISOFYS,
Faculty of Bioscience Engineering
Ghent University, Belgium
Pascal.Boeckx@UGent.be
Phone: +32 9 264 60 00

3 **Prof. Dr. Karsten Kalbitz**
University of Amsterdam
Instituut voor Biodiversiteit en Ecosysteem Dynamica
Nieuwe Achtergracht 166 (Room B 3.32)
NL-1018 WV Amsterdam
Netherlands
Phone 0205257457
k.kalbitz@uva.nl

4 **Prof. Dr. Ingrid Kögel-Knabner**
Lehrstuhl für Bodenkunde
Technische Universität München
85350 Freising-Weihenstephan
Phone: 08161-713677
koegel@wzw.tum.de

5 **Dr. Daniel Rasse**
Department for Soil Quality and Climate
Bioforsk - Norwegian Institute for Agricultural and Environmental Research
Saghellinga A,
Frederik A. Dahls vei, 20
1432 Ås
Norway
Phone: (+47) 92 26 36 08
Fax: (+47) 63 00 94 10
e-mail : daniel.rasse@bioforsk.no

6 **Associate Prof. Andreas Richter**
University of Vienna
Department of Chemical Ecology and Ecosystem Research
Althanstrasse 14, 1090 Vienna, Austria

Phone +43 1 4277 54252
andreas.richter@univie.ac.at

7 **PD. Dr. C. Rumpel**
Chargée de Recherche CNRS
Laboratoire de Biogéochimie des Milieux Continentaux
Centre INRA de Versailles-Grignon
Bâtiment EGER, Aile B
F-78850 Thiverval-Grignon
FRANCE
Phone +33-130-8154-79
Cornelia.Rumpel@grignon.inra.fr

8 **Prof. Dr. Michael W. I. Schmidt**
Associat Prof., Physical Geography, Soil Science & Biogeography
Winterthurerstr. 190
CH 8057 Zürich
SWITZERLAND
Phone +41-1-6355140
michael.schmidt@geo.unizh.ch

9 **Prof. Dr. Johan Six**
Agroecology Lab
One Shields Avenue
Davis CA 95616
USA
Phone (530) 752-1212
jwsix@ucdavis.edu

10 **Prof. Dr. Kai U. Totsche**
Lehrstuhl für Hydrogeologie
Institut für Geowissenschaften
Friedrich-Schiller-Universität Jena
Burgweg 11
07749 Jena
Phone +49 (0) 3641 948650
kai.totsche@uni-jena.de

List of participants

1 Achtenhagen, Jan
Helmholtz-Zentrum für Umweltforschung GmbH – UFZ
Department Environmental Biotechnology
Permoserstraße 15
04318 Leipzig Germany
jan.achtenhagen@ufz.de

2 Andruschkewitsch, Rouven
University of Kassel
Department of Environmental Chemistry
Nordbahnhofstraße 1a
37213 Witzenhausen
Germany
andruschkewitsch@uni-kassel.de

3 Black, Jasmine
University, Newcastle upon Tyne
Drummond Building, School of Civil Engineering and Geosciences
NE1 7RU
Newcastle
United Kingdom
jasmine.black@newcastle.ac.uk

4 Boschi, Vanessa
University of Pennsylvania
Department of Earth & Environmental Science
240 S. 33rd Street - Hayden Hall
PA 19104-6316 Philadelphia
USA
vaboschi@sas.upenn.edu

5 Budai, Alice
Bioforsk - Soil and Environment Norwegian Institute for Agricultural and Environmental Research
Frederik A. Dahl vei 20
1432 Ås
Norway
Alice.Budai@bioforsk.no

6 Doetterl Sebastian
Université de Louvain
ELI - Earth and Life Institute
TECLIM - Center for Earth and Climate Research
3, Place Louis Pasteur
Bureau b.336, Bâtiment Mercator
B-1348 Louvain-la-Neuve

Belgium
sebastian.doetterl@uclouvain.be

7 Ellström, Magnus
Lund University
Microbial Ecology, Department of Biology
Sölvegatan 37
22362 Lund
Sweden
Magnus.Ellstrom@mbioekol.lu.se

8 Erens, Hans
Ghent University
Department of Geology and Soil Science
Krijgslaan 281/S8
9000 Ghent
Belgium
hans.erens@ugent.be

9 Guidi, Claudia
IASMA, Research and Innovation Centre
Forest and Biogeochemical Cycles
Via E.Mach, 1
38010 SAN MICHELE ALL'ADIGE (TRENTO)
Italy
c.guidi@yahoo.it

10 Das Gupta, Sanatan
University of Alberta
Department of Renewable Resources
4-42 Earth Sciences Building
T6G 2E3 Edmonton
Canada
sanatan@ualberta.ca

11 Armas Herrera , Cecilia
Centre INRA Versailles-Grignon
Bioemco Laboratory, Bâtiment Eger
78850 Thiverval-Grignon
France
cmarmas@ull.es

12 Kvitkina, Anna
Russian Academy of Sciences (RAS)
Institute of Physicochemical and Biological Problems in Soil Science of the RAS
Institutskaya 2
142290 Pushchino (Moscow Region)
Russia
aqvia@mail.ru

13 Lattanzi, Fernando
Technische Universitaet Muenchen
Lehrstuhl für Grünlandlehre
Alte Akademie 12
85350 Freising
Germany
lattanzi@wzw.tum.de

14 Lehtinen, Taru
University of Natural Resources and Life Sciences (BOKU)
Institute of Soil Research
Höhnegasse 18/23
1180 Wien
Austria
mk2@hi.is

15 Mastrolonardo Giovanni
University of Florence
Department of Plant, Soil and Environmental Science, (DIPSA)"
Piazzale delle Cascine 28
50144 Firenze
Italy
giovanni.mastrolonardo@unifi.it

16 Mordhorst, Anneka
Christian-Albrechts-Universität zu Kiel
Institut für Pflanzenernährung und Bodenkunde
Hermann-Rodewald-Str. 2
24118 Kiel
Germany
a.mordhorst@soils.uni-kiel.de

17 Olshansky, Yaniv
The Hebrew University of Jerusalem
Department of Soil and Water Science
The Robert H. Smith Faculty of Agricultural, Food and Environmental
P.O. Box 12
76100 Rehovot
Israel
yaniv.olshansky@mail.huji.ac.il

18 Pagel, Holger
Universität Hohenheim
Emil-Wolff-Str. 27
70599 Stuttgart
Germany
holger_pagel@uni-hohenheim.de

19 Poirier, Vincent
Université Laval
Department of Wood and Forest Sciences
2405, Rue de la Terrasse Bur. Abp - 2130
G1V OA6 Québec, QC
Canada
vincent.poirier.1@ulaval.ca

20 Puissant, Jérémy
UR Ecosystèmes Montagnards
Irstea Groupement de Grenoble, Domaine Universitaire
2, rue de la Papeterie - BP 76
38402 Saint-Martin-d'Hères Cedex
France
eremy.puissant@cemagref.fr

21 Recio Vazquez, Lorena
Consejo Superior de Investigaciones Científicas (CSIC)
C/Serrano 115 - bis
28006 Madrid
Spain
lorena.recio@ccma.csic.es

22 Riggs, Charlotte
University of Minnesota
Dept. of Ecology, Evolution & Behavior; 100 Ecology Bldg.
1987 Upper Buford Circle
55108 Saint Paul, MN
USA
criggs@umn.edu

23 Rodríguez Eugenio, Natalia
University of La Laguna, Tenerife
Department of Soil Science and Geology
38206 La Laguna
Av. Astrofisico Fco. Sanchez, S/N
Spain - Canary Islands
nrodeug@ull.es

24 Sabine Schäfer
Friedrich-Schiller-Universität Jena
Lehrstuhl für Hydrogeologie
Institut für Geowissenschaften
Burgweg 11
07749 Jena
Germany
Sabine.Schaefer@uni-jena.de

25 Michael Scheifele
Soil Sciences Division
Forschungsinstitut für biologischen Landbau (FiBL)
Research Institute of Organic Agriculture
Ackerstrasse, Postfach
CH-5070 Frick
Switzerland
michsche@student.ethz.ch

26 Schellekens, Judith
University of Santiago de Compostela
Fac. de Bioloxía- Campus Universitario Sur
Departamento de Edafoloxía e Química Agrícola
15782 Santiago de Compostela (La Coruña)
Spain
schellekens.j@hetnet.nl

27 Schnecker, Jörg
University of Vienna
Faculty of Life Sciences, Department of Chemical Ecology& Ecosystem Research
Althanstrasse 14
A-1090 Vienna
Austria
joerg.schnecker@univie.ac.at

28 Schweigert, Michael
Helmholtz-Zentrum für Umweltforschung GmbH - UFZ
Department für Umweltmikrobiologie
Permoserstraße 15
04318 Leipzig
Germany
michael.schweigert@ufz.de

29 Schiedung, Henning
INRES - Bodenwissenschaften
Nussallee 13
53115 Bonn
Germany
henning.schiedung@uni-bonn.de

30 Studer, Mirjam
University of Zurich
Soil Science and BiogeographyDepartment of Geography
Winterthurerstr. 190
CH-8057 Zurich
Switzerland
mirjam.studer@geo.uzh.ch

31 Tischer, Alexander
Dresden University of Technology
Institute of Soil Science and Site Ecology
Pienner Str. 19 / Beamtenhaus E.09
1737 Tharandt
Germany
Alexander.Tischer@tu-dresden.de

32 Walter, Katja
Johann Heinrich von Thünen Institut (vTi)
Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei
Bundesallee 50
38116 Braunschweig
Germany
katja.walter@vti.bund.de

33 Wang, Xiang
University of Amsterdam
Earth Surface Science - Institute for Biodiversity and Ecosystem Dynamics
P.O. Box 94240 1
090 GE Amsterdam
Netherlands X.Wang@uva.nl