Postdoc and PhD Positions are available in the

ERC Consolidator Grant Project

SomSOM

Self-organization of microbial soil organic matter turnover

Christina Kaiser, University of Vienna

Project summary

Microbial turnover of soil organic matter (SOM) is key for the terrestrial carbon (C) cycle. Its underlying mechanisms, however, are not fully understood. The role of soil microbes for organic matter turnover has so far been studied mainly from the point of view of microbial physiology, stoichiometry or community composition. In this project, we aim to shed new light on it from the perspective of complex systems science.

Microbial decomposition of organic matter requires the concerted action of functionally different microbes interacting with each other in a spatially structured environment. From complex systems theory, it is known that interactions among individuals at the microscale can lead to an 'emergent' system behavior, or 'self-organisation', at the macroscale, which adds a new quality to the system that cannot be derived from the traits of the interacting agents. Importantly, if microbial decomposer systems are self-organised, they may behave in a different way as currently assumed, especially under changing environmental conditions.

The aim of this project is to investigate i) if microbial decomposition of organic matter is driven by emergent behaviour, and ii) what consequences this has for soil C and nitrogen cycling. Combining state-of-the-art methods from soil biogeochemistry, microbial ecology, and complex systems science we will

- Investigate mechanisms of spatial self-organization of microbial decomposer communities by linking microscale observations from experimental microcosms to mathematical, individual-based modelling,
- Elucidate microbial interaction networks across the soil's microarchitecture by linking microbial community composition, process rates and chemical composition of spatially explicit soil micro-units at an unprecedented small and pertinent scale.
- Explore fundamental patterns of self-organisation by applying the framework of complex systems science to high-resolution spatial and temporal data of soil microstructure and process rates.

I am looking for enthusiastic PhD students and postdoctoral researchers interested in carrying out research at the interface between Soil Microbial Ecology, Soil Biogeochemistry and Complex Systems Science in a creative, interdisciplinary team.

I am offering fully funded PhD (4 years) or PostDoc (2.5 years) positions at the Division for Terrestrial Ecosystem Research at the Centre for Microbiology and Environmental Systems Science of the University of Vienna. Our Division and Centre offers excellent opportunities for scientific interactions and

collaborations and a vivid, cooperative and friendly working environment, in a city with one of the best living conditions in the world.

More about
Christina Kaiser's team and research: http://ter.csb.univie.ac.at/people/christina-kaiser
Division for Terrestrial Ecosystem Research: http://ter.csb.univie.ac.at/
Centre for Microbiology and Environmental Systems Science: http://cmess.csb.univie.ac.at/

Open positions are available in the different project parts as described below. Applicants must have good communication skills and should be highly motivated and committed to pursuing interdisciplinary research in an international team. Excellent English in speaking and writing is mandatory. The University of Vienna values equal opportunities, as well as diversity (http://diversity.univie.ac.at/), and lays special emphasis on increasing the number of women in senior and in academic positions. Women are encouraged to apply.

Please send your application including

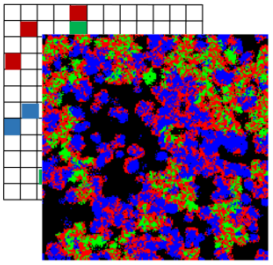
- a motivation letter (1-2 pages max; please clearly specifiy the project part/position you are applying for – see below)
- CV (including scientific publication and presentation activities, if any)
- Contact details of two possible references

to christina.kaiser@univie.ac.at. Positions will be filled as soon as possible and remain open until filled. Evaluation of applications starts in May 2019.

For questions please contact christina.kaiser@univie.ac.at.

An updated version of this document is available at http://ter.csb.univie.ac.at/open-positions

Postdoc and PhD position: Spatial self-organisation of microbial consortia decomposing soil organic matter



Interactions among decomposer microorganisms in natural soil communities are shaped by their necessity to perform "leaky" functions, for example the release of extracellular enzymes that cleave complex organic molecules into smaller units before they can be taken up into microbial cells. As small molecules are readily diffusible in a liquid environment, this allows other nearby microbes to exploit these enzymatic products ('public goods'), leading to a spectrum of social behaviours within microbial communities such as cooperation, communication, 'division of labour', synchronization and pattern formation.

The aim of this project part is to design and set up experimental microcosms (based on microfluidics), in which microbial decomposer communities can grow under controlled and observable conditions, and to link microscale observations from this experimental setup to mathematical, individual-based modelling (based on Kaiser *et al.*, 2014, 2015; Evans *et al.*, 2016).

I am looking for persons interested in microbial community ecology, in particular spatial self-organization of microbial communities. The team of this project part will be composed of an experimental scientist and a modeler working closely together. Applicants who have a background in both experimental work and modelling are most welcome, and encouraged to apply.

To apply for the 'experimental' position, you should have a scientific background (Msc or PhD) in Ecology, Microbial ecology or a related field, while for the 'modelling' position a Science degree (Biology, Physics, Mathematics, or similar) combined with proven abilities of mathematical modelling and computer programming is desired. Knowledge of chemical pathways during the degradation of complex organic compounds and of microbial physiology, metabolism and interactions is of advantage, as is knowledge in soil biogeochemistry and complex systems science. Profiles:

<u>Experimentalist:</u>

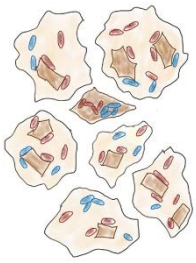
- Practical experience in molecular microbial ecology
- experience/interest to work with strain databases and/or metagenomics data to extract and characterize microbial functional groups (with respect to degradation of complex C compounds) (KEGG, Pathfinder…) (this can also be on the side of the modeler)
- experience with microfluidic approaches in microbial ecology is an advantage
- experience in cultivation of soil microbes is an advantage
- microscopy (e.g. CLSM), FISH, Stable isotope tracing, NanoSIMS, HPLC is an advantage

<u>Modeler:</u>

- Mathematical modelling, ecological modelling, Individual-based modelling
- background in ecology, microbial ecology or microbial metabolic pathways is an advantage
- Interest /Knowledge in complex system science
- Programming (JAVA, or an alternative programming language like C++ allowing you to learn and build on JAVA-based programs)

Each position can be carried out either as a PhD (4 years) or a postdoctoral project (2.5 years) – depending on the suitability and complementarity of the candidates.

Postdoc and PhD position: Fine-scale organization of the soil microbiome across the soil's physical micro-architecture



The aim of this project part is to better understand soil organic matter turnover by understanding the fine-scale organization of the soil microbiome. This will be done by combining methods from soil microbiology and complex systems sciences.

From a microbial perspective, soil is one of the most complex and heterogenous environments on earth. It is organized in spatial micro-units (macro- and microaggregates) in a hierarchical way. Formation and turnover of these aggregates, which are usually from 20 – 5000 µm in diameter, is driven by interactions between physicochemical processes and microbial activity. As soil microbes interact with each other only over very small 'calling' distances of a few tens of µm, it is likely that the soil's microarchitecture shapes the fine-scale organization of the soil microbiome.

In this project part we aim to identify microbial interaction networks across the soil's microarchitecture and link it to measured parameters of soil organic matter turnover. Towards this goal, we will refine and develop techniques to measure community composition and decomposer functions at the scale of individual aggregates. This project part will combine methods from soil biogeochemical research (i.e. Pyrolysis-GC-MS, stable isotopes, process rates measurements,..), soil microbial ecology (16S rRNA gene amplicon sequencing, metagenomics), with mathematical approaches, theoretical ecology and complex system science to get a better understanding of the intrinsic and extrinsic factors driving the organization of the soil microbiome across scales, and its consequences for soil organic matter turnover.

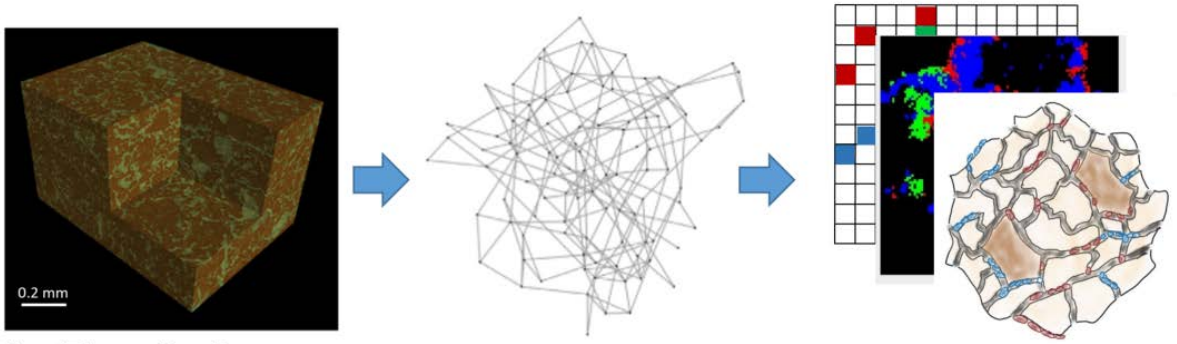
I am looking for interdisciplinary-thinking scientists interested in combining knowledge of different fields to develop new approaches and ideas to better understand the soil from a soil 'systems' perspective. You should have a background in soil microbial ecology, soil biogeochemistry, and/or mathematics, physics or complex systems science, and need to have good communication skills to favor cross-discipline discussions.

There are two positions available, which will be selected to complement each other. To join the team you should have some of the following skills:

- Background in soil microbial ecology and/or soil biogeochemistry
- Alternatively, Background in mathematics or physics
- Interest/Background in theoretical ecology and complex systems science
- Molecular microbial ecology (16S rRNA gene amplicon sequencing, metagenomics or metatranscriptomics of soil microbial communities)
- Interest in soil microscale processes and interactions
- good command of R or another programming language
- Experience in microbial interaction (co-occurrence) network analysis is an advantage
- Knowledge/interest in Graph theory
- Soil chemical analysis (Pyrolysis-GC-MS), phospholipid fatty acids
- Soil process measurements (Respiration, enzyme activities, N mineralisation)
- Experience in using stable isotopes in soil ecology

Both positions can be carried out either as a PhD (4 years) or a postdoctoral project (2.5 years) .

PhD (or PostDoc) position: Linking aggregate pore geometry to microbial interactions and functions in soil



Micro-CT image of a soil aggregate (Bacq-Labreuil et al, Geoderma, 2018)

Extracting network properties

New 3D Pore Space interaction model

Pore geometry of soil aggregates are essential for microbial dynamics as it determines i) habitability, ii) accessibility of substrates to microbes and iii) accessibility of microbes for predators. Geometric properties of the pore network, such as connectivity and fragmentation, greatly influence potential microbial interactions. At a high fragmentation (i.e. islands of reasonable habitats separated by long distance connections with limited resource access), for example, species with a small range of dispersal will have access only to a small fraction of the network while species with a long range of dispersal, such as fungi can percolate through the network.

In this project part I am looking for a motivated PhD student or a postdoctoral researcher, who is interested in soil microscale interactions, ecology, graph theory and complex systems science.

The successful candidate will extract geometric properties and pore size distribution data from 3D micro-CT images of soil aggregates. This data will be used to generate 'model pore network landscapes' reflecting characteristic geometric properties of pore networks of certain aggregate types, in a refined (i.e. 3D) version of an existing individual-based microbial community model (Kaiser *et al.*, 2014, 2015; Evans *et al.*, 2016). The resulting model will be – together with measured parameters - used to investigate how certain spatial structures and pore geometric properties affect microbial interactions and, in turn, soil organic matter decomposition. Percolation-, graph theory and other mathematical approaches will be used to analyse results.

The successful candidate should have the following skills:

- Background in soil microbial ecology or soil science
- Alternatively, a background in mathematics, physics, informatics or complex systems science
- Programming skills (ideally JAVA, other programming languages also ok)
- Good command of R
- Experience with image processing/image processing software is an advantage

He or she will work closely together with the rest of the project team.

Scientific programmer/Data scientist

In the course of the project our existing individual-based microbial community model (Kaiser *et al.*, 2014, 2015; Evans *et al.*, 2016), which is written in Java, need to be further developed and refined by different members of the team. I am looking for an enthusiastic data scientist/scientific programmer to coordinate these efforts and support the whole team with programming, data management and data visualization.

You should ideally have a background in informatics (Bsc, Msc, or HTL/HBVLA degree), or alternatively a science (i.e. physics, mathematics, biology,…) background with experience in computer programming (JAVA) and data management. Professional experience in team software development is a big plus. You should be interested in soil ecology and complex systems science, and have a communicative and open personality.

The successful candidate will be responsible for

- coordinating the programming efforts of the team members, implementing critical parts yourself and support the team with your expertise.
- efficient code and version management and deposition/maintainance of the source code in public repositories.
- assisting in creating and implementing a data management plan for depositing experimental data obtained in the project in public repositories in a reproducible way.
- exploring and implementing options for the visualization of complex datasets such as microbial interaction networks, pore networks etc. (f.e. based on Gephi or other tools).

I offer a part-time position (20 hours) for 2 years in a creative and vivid scientific team at the Terrestrial ecosystem research/Centre for Microbiology and Environmental systems science. This position will be central for the modeling part of the project, and the successful candidate will be, if interested, involved in the science as much as in the technical aspects of it.

References

Evans S, Dieckmann U, Franklin O, Kaiser C. **2016**. Synergistic effects of diffusion and microbial physiology reproduce the Birch effect in a micro- scale model. *Soil Biology & Biochemistry* **93**: 28–37.

Kaiser C, Franklin O, Dieckmann U, Richter A. **2014**. Microbial community dynamics alleviate stoichiometric constraints during litter decay. *Ecology Letters* **17**.

Kaiser C, Franklin O, Richter A, Dieckmann U. **2015**. Social dynamics within decomposer communities lead to nitrogen retention and organic matter build-up in soils. *Nature Communications* **6**.