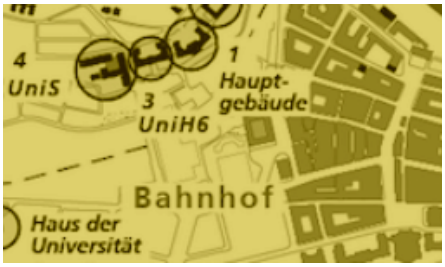
BGS JAHRESTAGUNG – 9./10. FEBRUAR 2017 – UNIVERSITÄT BERN

# BODENWISSENSCHAFT UND BODENSCHUTZ: EINE GRENZÜBERSCHREITENDE HERAUSFORDERUNG

SSP CONGRÈS ANNUEL – LES 9/10 FÉVRIER 2017 – UNIVERSITÉ DE BERNE

# LA SCIENCE ET LA PROTECTION DU SOL: UN DÉFI À TRAVERS LES FRONTIÈRES




SSP CONGRESSO ANNUALE – 9/10 FEBBRAIO 2017 – UNIVERSITÀ DI BERNA

# SCIENZA E PROTEZIONE DEL SUOLO: UNA SFIDA SENZA CONFINI

SSSS ANNUAL MEETING – FEBRUARY 9th/10th 2017 – UNIVERSITY OF BERN

# SOIL SCIENCE AND SOIL PROTECTION: A CHALLENGE ACROSS BOUNDARIES

BODENKUNDLICHE GESELLSCHAFT DER SCHWEIZ
SOCIÉTÉ SUISSE DE PÉDOLOGIE
SOCIETÀ SVIZZERA DI PEDOLOGIA
SOIL SCIENCE SOCIETY OF SWITZERLAND

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3012 Bern

## Tagungsband | Volume des résumés


Ausgabe | Édition 1 / 2017
Auflage | Tirage 200
Druck | Imprimé ZHAW, 8820 Wädenswil


## Herausgeber | Éditeur


Bodenkundliche Gesellschaft der Schweiz BGS
Société Suisse de Pédologie SSP


## Redaktion | Rédaction


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# PROGRAM | PROGRAMM | PROGRAMME | PROGRAMMA

## Thursday, 9th February | Donnerstag, 9. Februar | Jeudi, le 9 février

08.45 **Registration, coffee and croissants** / Anmeldung, Kaffee und Gipfeli / Inscription, café et croissants

09.45 **Welcome** / Begrüssung / Bienvenue

**Matias Laustela**, President Soil Science Society of Switzerland

09:55 **Introduction** / Einführung / Introduction

**Sandra Spielvogel**, Head Soil Science Unit, University of Bern

### Session 1: Frank Hagedorn (F 021)

Formation, composition and properties of soil organic matter

Bildung, Zusammensetzung und Eigenschaften der organischen Bodensubstanz

Développement, composition et propriétés de la matière organique du sol

10.10 **KEYNOTE: Soil minerals and organic matter sequestration**
Ingrid Kögel-Knabner, Technische Universität München

10.35 **Carbon and nitrogen in managed organic soils in Switzerland - indications for soil degradation and implications for $N_2O$ emissions at national scale**
Jens Leifeld, Agroscope

10.55 **What factors predominantly influence soil organic matter (SOM) stability in alpine ecosystems?**
Matteodo Magalì, Université de Lausanne

**Special Session Swiss SOM**

11.15 **KEYNOTE: The Swiss soil organic matter put to the acid test: results from the SwissSOM cluster, national research programme "Soil as a recource"**
Samuel Abiven, Universität Zürich

11.40 **The vulnerability of organic matter in Swiss forest soils**
Beatriz González Domínguez, Universität Zürich

12.00 **Insights into soil carbon dynamics across climatic and geologic gradients from time-series radiocarbon measurements on Swiss soils**
Tessa Sophia Van der Voort, ETH Zürich

12.20 **Controlling factors of soil organic carbon storage (SOC) in Swiss forest soils - the impact of land-use history, climate and soil chemistry**
Sia Gosheva, WSL

### Session 2: Stéphane Burgos (F 022)

Sustainable use of soil as a resource

Nachhaltige Bewirtschaftung der Ressource Boden

La gestion durable de la ressource sol

10.20 **Connecting biodiversity monitoring and soil inventory - A Swiss case study**
Reto Giulio Meuli, NABO

10.40 **Organic matter and porosity values as criteria for soil structure quality evaluation**
Pascal Boivin, HES-SO Genève

11.00 **Assessing the impact of agricultural management practices on soil quality - insights from the EU iSQAPER project**
Abdallah Alaoui, CDE

11.20 **Bewertung von Ökosystemleistungen: Was ist der Beitrag unserer Böden? - EU-Projekt RECARE und Fallbeispiel Region Frienisberg**
Gudrun Schwilch, CDE

11.40 **Les lignoformes, des formes d'humus encore peu étudiées**
Dylan Tatti, HAFL

12.00 **Erfassen von Bodenerosion nach starken Niederschlagsereignissen und Abklärung der Effizienz von Bodenschutzmassnahmen aufgrund von Drohnenbildern, Feldmethoden und Befragungen**
Laura Ebneter, CDE

12.20 **Long-term monitoring of organic pollutants in soil: a conceptual approach to select pesticides potentially accumulating in soil**
Daniel Wächter, NABO

13:00 **Lunch** / Mittagessen / Dîner

### Session 3: Klaus Jarosch (F 021)

Soil organisms: Diversity, function and soil fertility

Bodenorganismen: Diversität, Funktion und Bodenfruchtbarkeit

Organismes du sol: Diversité, fonction et fertilité du sol

14.00 **KEYNOTE: Understanding the functional significance of microbial communities in soil C dynamics**
Naoise Nunan, IEES Paris

14.25 **Hotsphere illumination**
Bahar Razavi, Universität Göttingen

14.45 **Composition and functions of microbial communities in top- and subsoils of degraded pasture ecosystems on the Tibetan Plateau**
Andreas Breidenbach, Universität Göttingen

15.05 **Metabarcoding of Soil Microbial Communities for Soil Quality Monitoring**
Florian Gschwend, Agroscope

### Session 4: Markus Steffens (F 022)

Soil physics, soil structure and soil hydrology

Bodenphysik, Bodenstruktur und Bodenhydrologie

La physique, la structure et l'hydrologie du sol

14.00 **KEYNOTE: We can compact a soil within seconds, but how long does it take a soil to recover from compaction damage?**
Thomas Keller, Agroscope

14.25 **Utilisation des images aériennes à haute résolution pour documenter et mesurer de l'érosion en agriculture suite à des pluies intenses**
Dorothea Noll, CHANGINS

14.45 **Identification of spatiotemporal patterns of rainfall erosivity as decision support to erosion control in Switzerland**
Simon Schmidt, Universität Basel

15.05 **Analyse des risques d'érosion sur une exploitation agricole**
Stéphane Burgos, HAFL

15.25 **Posters and Coffee** / Postersession und Kaffeepause / Session des posters et pause-café

16.00 - 18.15 **General assembly** / Generalversammlung / Assemblée générale (F 021)

18.30 **Dinner** / Abendessen / Souper

## Friday, 10th February | Freitag, 10. Februar | Vendredi, le 10 février

09.00 **Arrival and Registration** / Ankunft und Anmeldung / Arrivée et inscription

| | Session 5: Moritz Bigalke (F 021) | Session 6: Beatrice Kulli (F 022) |
|---|---|---|
| | Organic and inorganic pollutants in soil: Biogeochemistry, cycling, relevance for ecosystem services and soil protection<br>Organische und anorganische Schadstoffe in Böden: Biogeochemische Kreisläufe, ökosystemare Bedeutung und Bodenschutzmassnahmen<br>Les polluants organiques et inorganiques dans les sols: cycles biogéochimiques, importance écosystémique et mesures de protection des sols | Soil and plant nutrition: Nutrient cycling as a function of site conditions, management and nutrient availability<br>Boden und Pflanzenernährung: Nährstoffkreisläufe in Abhängigkeit von Standort, Bewirtschaftung und Nährstoffverfügbarkeit<br>Le sol et les plantes: les cycles des éléments nutritifs en fonction des conditions du site, de la gestion et de la disponibilité des nutriments |
| 09.25 | **KEYNOTE: Release, biomethylation and biovolatilisation of metals and metalloids in soils. Relevance for biogeochemical cycles and future implications**<br>Adrien Mestrot, Universität Bern | **KEYNOTE: Interaktionen zwischen Mikroorganismen, Bodenstruktur und Phosphatverfügbarkeit**<br>Else Bünemann-König, FiBL |
| 09.50 | **Land-atmosphere exchange of Hg - from industrially contaminated sites to remote boreal peatlands and forest ecosystems**<br>Jen-How Huang, Univeristät Basel | **Phosphorus (P) balances and P availability in a field trial comparing organic and conventional farming systems**<br>Klaus Jarosch, Universität Bern |
| 10.10 | **Green manure and long-term fertilization effects on soil zinc and cadmium availability and uptake by wheat (Triticum aestivum L.) in a Swiss field trial**<br>Roman Grüter, ETH Zürich | **Nitrogen balances in organic and conventional farming systems: The efficiency-sustainablity dilemma**<br>Jochen Mayer, Agroscope |
| 10.30 | **Field scale Boscalid residues, degradation and half-life estimation in a sandy soil**<br>Anneli Karlsson, Universität Bern | **The C:N:P:S stoichiometry of soil organic matter**<br>Jörg Luster, WSL |

10.50 **Posters and Coffee** / Postersession und Kaffeepause / Session des posters et pause-café

**Plenary session / Plenarsitzung / Assemblée plénière: Sandra Spielvogel (F 021)**

Soil science and soil protection: A challenge across boundaries

Bodenwissenschaft und Bodenschutz: Eine grenzüberschreitende Herausforderung

La science et la protection du sol: un défi à travers les frontières

11.10 **KEYNOTE: Bodenschutz in den Alpen – Verbesserungspotenziale des Bodenschutzprotokolls der Alpenkonvention**
Georg Guggenberger, Leibniz Universität Hannover

11.40 **KEYNOTE: Bodenwissenschaft und Bodenschutz: Wie gelingt der Austausch zwischen Forschung und Praxis?**
Thomas Mosimann, Lauwil

12.10 **KEYNOTE: Bodenfruchtbarkeit erhalten - Erträge steigern - eine Quadratur des Zirkels?**
Paul Mäder, FiBL

12.40 **Lunch** / Mittagessen / Dîner

| | Session 3: Adrien Mestrot (F 021) | Session 4: Else Bünemann-König (F 022) |
|---|---|---|
| 13.50 | **Combining position-specific $^{13}$C labeling with $^{13}$C-PLFA analysis to assess microbial utilization of free versus sorbed Alanine**<br>Jennifer Herschbach, Universität Bern | **KEYNOTE: Few recurring types of microdomains define smallest units of soil functioning**<br>Markus Steffens, Technische Universität München |
| 14.10 | **Seasonal dynamics of soil microeukaryote communities along a gradient of disturbance in a restored floodplain (Thur River, Switzerland)**<br>Thierry Heger, CHANGINS | **Rainfall-induced aggregate breakdown as a determinant of size-selective sediment transport in soil erosion**<br>Pu Shi, ETH Zürich |
| 14.30 | **Long- and short-term effects of mercury contamination on the soil microbiome**<br>Aline Frossard, WSL | **Dimensions of preferential flow**<br>Peter German, Universität Bern |
| | **Session 5: Adrien Mestrot (F 021)** | **Session 6: Else Bünemann-König (F 022)** |
| 14.50 | **Uranium in soils, ground- and spring waters in the canton of Berne**<br>Moritz Bigalke, Universität Bern | **The impact of soil biota on nitrogen losses and nutrient use efficiency - a multidisciplinary approach**<br>Chantal Herzog, Agroscope |
| 15.10 | **Cadmium fluxes in Swiss arable farming systems**<br>Matthias Wiggenhauser, ETH Zürich | **Root growth and plant zinc uptake in response to heterogeneous soil moisture, phosphorus and zinc distribution**<br>Huifang Ma, ETH Zürich |

15.30 **Coffee** / Kaffepause / Pause-café

15.50 **Summary and outlook** / Zusammenfassung und Ausblick / Résumé et perspectives

16.00 **Awards** / Prämierung / Remise des prix

**Plenary Session: Soil science and soil protection: A challenge across boundaries**
How can we use soil and at the same time protected soil, so that its functions can be maintained for the future or even just be promoted? This is a central question that can only be answered in cross-border collaboration between science and practice, cantons and neighbouring countries within Europe. The aim of the annual meeting of the Soil Science Society of Switzerland in 2017 is to discuss key challenges of soil science and soil protection in 6 thematic sessions and one plenary session from the viewpoint of soil research and practice.

**Session 1: Formation, composition and properties of soil organic matter**
Soil organic matter (SOM), as largest terrestrial carbon pool, plays a decisive role in the global carbon cycle. At the same time, SOC plays a key role for many soil functions, e.g. for nutrient storage, pollutant retention, aggregate stability and habitat function. We welcome contributions focusing on the chemical structure, stabilization mechanisms and functioning of SOM. Vulnerability of SOM to climate change and management practices will be discussed. We furthermore welcome presentations dealing with cutting-edge methods that allow for analyzing chemical composition, cycling and three-dimensional heterogeneity of SOM (spectroscopic techniques, isotope methods, molecular marker analyses).

**Session 2: Sustainable use of soil as a resource**
Productive soils are the central resource for the production of food. Consequently, long-term economic productivity of land that is used for agriculture must be safeguarded and even enhanced. This is the only way to ensure security of supply for all the uses of vegetable biomass. Besides production of marketable biomass, agricultural soils provide ecosystem services (e.g. the capacity to store water and the function of soils as carbon stores) that need to be permanently protected. Hence, this session calls for presentations dealing with agricultural management practices and their effects on soil quality and soil functioning. We furthermore encourage contributions focusing on predictive mapping of soil properties for the evaluation of soil functions, regional soil monitoring systems and decision-making tools for sustainable soil use.

**Session 3: Soil organisms: Diversity, function and soil fertility**
The soil is a heterogeneous habitat for a wide range of soil organisms, which are crucial for various soil functions, such as soil fertility or climate regulation. Hence, soil biota delivers a substantial contribution to the ecosystem performance of soil. This session welcomes contributions on living communities and their biodiversity, biotic soil processes, and inter-dependencies between organisms, habitat properties and environmental factors in complex soil ecosystems. Basic knowledge about biodiversity strategies will be put into practice and linked to key soil functions.

**Session 4: Soil physics, soil structure and soil hydrology**
This session investigates the three-dimensional structure of soils – pore networks, aggregates and the soil profile. This structure affects all the physical and biological processes and is itself a product of these processes. On the landscape scale, the interaction between the geographical distribution of functionally different soils, the flow of water and associated transport of substances between neighbouring ecosystem compartments shall be discussed. We invite contributions that include the following topics: Novel methods to characterize soil structure and soil void space, biophysicochemical aspects of soil structure formation and self-organization in soils, resistance and resilience of soil structure to mechanical stresses, and the restoration of post compacted soils.

**Session 5: Organic and inorganic pollutants in soil: Biogeochemistry, cycling, relevance for ecosystem services and soil protection**
Pollutants from natural sources, factories, farming, transportation, and households are ubiquitous in soil. Downwards transport into the groundwater or plant uptake can pose severe risk to human and environmental health. We welcome contributions about reactions, transformation and bioavailability of pollutants in soil. We will furthermore discuss the (re-) mobilization of pollutants and their discharge into ground- and surface waters.

**Session 6: Soil and plant nutrition: Nutrient cycling as a function of site conditions, management and nutrient availability**
Nutrition strategies of soil organisms and plants are a function of site conditions, management and nutrient supply. Recent findings indicate that adaption mechanisms to sites with poor nutrient supply are not only a result of the adaptation of single organisms but of ecological interactions, which enable ecosystem nutrient (re-) mobilisation, uptake, usage and storage. In this session we will discuss adaption strategies of soil organisms and plants to soil chemical and biological conditions in near-natural and agricultural ecosystems, but also how soil biogeochemical processes and characteristics are influenced by these adaption strategies.

**Plenarsitzung: Bodenwissenschaft und Bodenschutz: Eine grenzüberschreitende Herausforderung**
Wie kann Boden genutzt und gleichzeitig geschützt werden, damit seine Funktionen für die Zukunft erhalten bleiben oder gar noch gefördert werden? Dies ist die zentrale Frage, die nur grenzüberschreitend im Austausch zwischen Forschung und Praxis, zwischen den Kantonen und im Austausch mit unseren Nachbarländern in Europa beantwortet werden kann. Ziel der Jahrestagung der Bodenkundlichen Gesellschaft der Schweiz 2017 ist es, zentrale Herausforderungen der Bodenforschung und des Bodenschutzes in 6 thematischen Sessions und einer Plenarsitzung aus Sicht der Wissenschaft und Praxis zu diskutieren.

**Session 1: Bildung, Zusammensetzung und Eigenschaften der organischen Bodensubstanz**
Die organische Bodensubstanz (OBS), als grösster terrestrischer Kohlenstoffspeicher ist eine entscheidende Grösse im globalen Kohlenstoffkreislauf. Gleichzeitig spielt die OBS eine Schlüsselrolle für viele Bodenfunktionen, wie z.B. für die Nährstoffspeicherung, die Schadstoffretention, die Aggregatstabilität und die Habitatfunktion. Diese Session richtet sich an Beiträge, die sich mit der chemischen Struktur, Stabilisierungsmechanismen und den Funktionen der OBS beschäftigen. Auswirkungen von Klimawandel und Bewirtschaftungsmassnahmen auf die OBS sollen diskutiert werden. Ebenfalls willkommen sind Beiträge zu innovativen Methoden, mit deren Hilfe sich Zusammensetzung, Umsatzprozesse und dreidimensionale Heterogenität der OBS untersuchen lassen (spektroskopische Techniken, Isotopenmethoden, molekulare Marker).

**Session 2: Nachhaltige Bewirtschaftung der Ressource Boden**
Die zentrale Ressource für die Erzeugung von Nahrungsmitteln sind produktive Böden. Da die landwirtschaftlichen Flächenanteile an der Landfläche nur sehr begrenzt erweiterbar sind, ist eine zukünftige Erhöhung der Flächenproduktivität zur Sicherung der Ernährung unabdingbar. Hinzu kommt eine steigende Konkurrenz zwischen unterschiedlichen Nutzungsformen (Anbau von Nahrung vs. Futter, Rohstoffen, Energie). Eine nachhaltige Versorgungssicherheit kann daher nur gewährleistet werden, wenn die Leistungsfähigkeit agrarisch genutzter Böden dauerhaft erhalten wird. Gleichzeitig ist es notwendig die vielfältigen weiteren Ökosystemdienstleistungen von Böden (Speichervermögen für Wasser, Kohlenstoffspeicherung) erhalten bleiben. In dieser Session sind Beiträge willkommen, die sich mit standortsangepasster, nachhaltiger Bodenbewirtschaftung und der Validierung von Bewirtschaftungsmassnahmen beschäftigen. Darüber hinaus sind Beiträge willkommen, die sich mit Systemen zum Monitoring, der Digitalisierung und der Regionalisierung von Bodenzustandsdaten befassen (Bodenfunktionsbeurteilung, Bodenmonitoring, Entscheidungsplattformen).

**Session 3: Bodenorganismen: Diversität, Funktion und Bodenfruchtbarkeit**
Der Boden ist heterogenes Habitat einer grossen Vielfalt von Bodenorganismen. Sie beeinflussen Funktionen wie Bodenfruchtbarkeit oder Regulation des Klimas und liefern damit einen erheblichen Beitrag zu den ökosystemaren Leistungen des Bodens. Diese Session bietet Beiträgen eine Plattform, die Lebensgemeinschaften und deren Diversität, sowie biotische Bodenprozesse und deren Abhängigkeiten von Umweltfaktoren und Habitateigenschaften untersuchen. Grundlegende Erkenntnisse zur Bedeutung der Bodenbiodiversität sollen so in die Praxis umgesetzt und mit zentralen Bodenfunktionen verknüpft werden.

**Session 4: Bodenphysik, Bodenstruktur und Bodenhydrologie**
Der Schwerpunkt dieser Session liegt auf der dreidimensionalen Struktur von Böden, vom Porennetzwerk über Aggregate bis zum Bodenprofil sowie auf Methoden zur Strukturanalyse. Die Bodenstruktur beeinflusst alle physikalischen und biologischen Prozesse und ist dabei selbst Produkt dieser Prozesse. Auf der Skala von Landschaften soll die Wechselwirkung zwischen der räumlichen Verteilung funktional verschiedener Böden, den Fließwegen von Wasser und dem damit verbundenen Stofftransport zwischen benachbarten Ökosystemkompartimenten betrachtet werden. Wir freuen uns über Beiträge zu neuen Methoden der Bodenstrukturanalyse, zur Selbstorganisation und Bodenstrukturbildung, zur Widerstandskraft gegen mechanische Belastung aber auch zur Erholung und Wiederherstellung der Bodenstruktur nach schadhafter Bodenverdichtung.

**Session 5: Organische und anorganische Schadstoffe in Böden: Biogeo-chemische Kreisläufe, ökosystemare Bedeutung und Bodenschutzmassnahmen**
Schadstoffe sind in Böden allgegenwärtig. Sie stammen aus natürlichen Quellen, aus Industrie, Landwirtschaft, Verkehr und privaten Haushalten. Wenn sie sich im Boden anreichern und von dort ins Grundwasser gelangen oder von Pflanzen aufgenommen werden, können sie zum Risiko für Mensch und Umwelt werden. Wir freuen uns über alle Beiträge, die sich mit dem Verhalten, der Transformation und der Bioverfügbarkeit von Schadstoffen in Böden beschäftigen. Ebenfalls diskutiert wird die (Re-)-mobilisierung von Schadstoffen und der Austrag in Grund- und Oberflächengewässer.

**Session 6: Boden und Pflanzenernährung: Nährstoffkreisläufe in Abhängigkeit von Standort, Bewirtschaftung und Nährstoffverfügbarkeit**
Die Ernährungsstrategien von Bodenorganismen und Pflanzen hängt vom Standort, seiner Bewirtschaftung und vom Nährstoffangebot ab. Dabei wird zunehmend deutlich, dass es Anpassungsmechanismen an die Nährstoffverfügbarkeit von Standorten gibt, die nicht auf der Anpassung einzelner Individuen beruhen sondern auf sehr gut abgestimmter Zirkulation von Nährstoffen im System. Im Zentrum dieser Session stehen Beiträge, die sich mit angepassten Ernährungsstrategien von Bodenlebewesen und Pflanzen an bodenchemische und bodenbiologische Eigenschaften in naturnahen und Agrarökosystemen beschäftigen aber auch wie bodenbiogeochemische Prozesse und Eigenschaften durch diese Anpassungsstrategien verändert werden.

**Assemblée plénière : La science et la protection du sol : un défi à travers les frontières**
Comment pouvons-nous utiliser et en même temps protéger le sol, de sorte que ses fonctions restent préservées, voire même augmentées dans le futur ? C'est une question centrale à laquelle on ne peut répondre sans une collaboration étroite entre la recherche et la pratique, avec les cantons et les utilisateurs du sol, et par des échanges avec nos pays voisins européens. Le but de la réunion annuelle de la Société Suisse de Pédologie en 2017 est de discuter des défis centraux pour la recherche et la protection du sol en 6 sessions thématiques et une session plénière du point de vue de la recherche et de la pratique.

**Session 1: Développement, composition et propriétés de la matière organique du sol**
La matière organique du sol (MO) en tant que plus important réservoir de carbone terrestre de la planète, joue un rôle déterminant dans le cycle global du carbone. La MO est également un facteur important pour des nombreuses fonctions du sol telles que : le stockage des éléments nutritifs, la rétention des polluants, la stabilité de la structure, ou encore la biodiversité des organismes du sol. Cette session regroupe des contributions concernant la structure chimique, les mécanismes de stabilisation et les fonctions de la MO. L'impact du changement climatique et des pratiques culturales sur la MO seront discutés. Les contributions sur des méthodes innovantes, permettant l'étude de la composition, des processus de recyclage et de l'hétérogénéité en trois dimensions de la MO (techniques spectroscopiques, méthodes isotopiques, marqueurs moléculaires) sont également bienvenues.

**Session 2: La gestion durable de la ressource sol**
Des sols productifs sont une ressource centrale pour la production des denrées alimentaires. Comme les surfaces agricoles ne sont pas extensibles la productivité économique des sols agricoles doit impérativement être préservée et même renforcée à l'avenir. . À cela s'ajoute parfois un conflit d'intérêt entre les diverses formes d'utilisation des sols (cultures destinées à l'alimentation *vs* production fourragères, production de biomasse ou d'énergie). La sécurité d'approvisionnement durable pour toutes les formes de production passe donc par une préservation du potentiel de production des sols. Outre la production de biomasse commercialisable, les sols agricoles fournissent des services écosystémiques (par exemple la capacité de retenir et tamponner l'eau de surface ou de stocker le carbone) qui doivent être protégés en permanence. Dans cette session nous invitons des contributions qui traitent des pratiques agronomiques durables et adaptées aux conditions locales et la validation de leurs effets sur la qualité et le fonctionnement du sol. En outre, nous invitons des contributions qui traitent des systèmes de suivi, de la numérisation et de la régionalisation des données sur l'état du sol (appréciation du fonctionnement du sol, monitoring des sols, plates-formes de décision).

**Session 3: Pédofaune : diversité, fonction et fertilité des sols**
Le sol est un habitat hétérogène pour une grande variété d'organismes. Ils sont cruciaux pour diverses fonctions du sol, telles que la fertilité des sols ou la régulation du climat. Par conséquent, la biologie du sol offre une contribution considérable à la performance de l'écosystème du sol. Cette session accueille des contributions sur les communautés vivantes et leur biodiversité, les processus biotiques du sol et sur leur dépendance aux caractéristiques de l'habitat et aux facteurs environnementaux. Des connaissances de base sur l'importance de la biodiversité des sols seront mises en pratique et liées aux fonctions clés du sol.

**Session 4: La physique, la structure et l'hydrologie du sol**
Cette session examine la structure tridimensionnelle des sols - à l'échelle des réseaux de pores, de la structure et du profil du sol - ainsi que des méthodes pour l'analyse structurelle. La structure du sol affecte tous les processus physiques et biologiques et est elle-même une issue de ces processus. A l'échelle du paysage, l'interaction entre la distribution spatiale des sols de différentes fonctionnalités, les voies d'écoulement d'eau associé aux transports des substances entre les compartiments adjacents de l'écosystème seront discutés. Nous invitons les contributions concernant non seulement les nouvelles méthodes d'analyse et de caractérisation de la structure du sol, de son'auto-organisation, de la formation de structures pédologiques, et dela résistance au stress mécanique, mais aussi la restauration de la structure des sols compactés.

**Session 5: Les polluants organiques et inorganiques dans les sols : cycles biogéochimiques, importance écosystémique et mesures de protection des sols**
Les polluants sont omniprésents dans les sols. Ils proviennent de sources naturelles, de l'industrie, de l'agriculture, des transports et des ménages. L'accumulation dans le sol peut entrainer l'absorption des polluants par les plantes ou le transport en direction des eaux souterraines et occasionner un risque grave pour la santé humaine et l'environnement. Nous accueillons toutes les contributions qui traitent des réactions, de la transformation et de la biodisponibilité des polluants dans le sol aussi bien que de la (re-)mobilisation de polluants et des rejets dans les eaux souterraines et les eaux de surface.

**Session 6: Le sol et les plantes : les cycles des éléments nutritifs en fonction des conditions du site, de la gestion et de la disponibilité des nutriments**
Les stratégies alimentaires des organismes et des plantes du sol dépendent des conditions du site, de la gestion et de la fourniture de nutriments. Il devient de plus en plus évident qu'il existe des mécanismes d'ajustement à la disponibilité des éléments nutritifs des sites qui ne sont pas basées sur l'adaptation des individus, mais sur la circulation très bien coordonnée des éléments nutritifs dans le système. L'objectif de cette session est de discuter des stratégies d'adaptation des plantes et des organismes du sol aux conditions chimiques et biologiques dans les écosystèmes semi-naturels et agricoles, ainsi que l'influence de ces stratégies d'adaptation sur les caractéristiques et les processus biogéochimiques.

**Sessione plenaria: Scienza e protezione del suolo, una sfida senza confini.**
Come possiamo gestire e nel contempo salvaguardare la risorsa suolo affinché anche in futuro si possa mantenere o addirittura migliorare le sue funzioni? Si tratta di una questione fondamentale che può essere affrontata solo istituendo scambi tra scienza e pratica, tra Cantoni nonché collaborando con gli Stati a noi più vicini in Europa, al di là degli steccati di qualsiasi tipo. Il convegno annuale 2017 della Società svizzera di pedologia si propone di condurre un dibattito sulle principali sfide per la ricerca pedologica e la protezione del suolo. Nell'arco di 6 sessioni tematiche ed una sessione plenaria si confronteranno i punti di vista dei ricercatori e di coloro attivi nella pratica.

**Sessione 1: Formazione, composizione e proprietà della sostanza organica nel terreno.**
La sostanza organica nel terreno (SOT) rappresenta la più grande riserva terrestre di carbonio, tale da svolgere un ruolo fondamentale nel ciclo globale del carbonio. Nel contempo la SOT è essenziale per molte funzioni del suolo, quali ad esempio lo stoccaggio degli elementi nutritivi, la ritenzione delle sostanze nocive, la stabilità degli aggregati e come habitat. È possibile sottoporre contributi inerenti struttura chimica, meccanismi di stabilizzazione e funzionalità della SOT. Si discuterà anche dell'impatto dei cambiamenti climatici e delle pratiche di gestione sulla SOT. Sono inoltre benvenuti contributi che trattano l'impiego di metodologie innovative che permettono di studiare la composizione, i processi di trasformazione e l'eterogeneità tridimensionale della SOT (tecniche spettroscopiche, metodi isotopici, analisi mediante marcatori molecolari).

**Sessione 2: Gestione sostenibile della risorsa suolo.**
I terreni produttivi sono la risorsa fondamentale per produrre alimenti. La quota di superficie terrestre che può essere utilizzata ai fini agricoli può essere aumentata solo in modo limitato. L'aumento della produttività è pertanto essenziale per garantire la sicurezza alimentare a lungo termine. A ciò si aggiunge la crescente concorrenza tra diverse forme di utilizzo del suolo (coltivazione di alimenti vs. foraggi, materie prime, energia). Per garantire una sicurezza alimentare sostenibile è necessario conservare in modo duraturo le potenzialità dei suoli utilizzati a scopo agricolo. Nel contempo occorre preservare i molteplici servizi ecosistemici forniti dai suoli (capacita di accumulo idrico, ritenzione del carbonio). Sono quindi ben accetti contributi inerenti l'utilizzazione del suolo adattata alla situazione locale e le presentazioni che trattano la convalida delle misure di gestione. Si incoraggia anche la presentazione di contributi riguardanti i sistemi di monitoraggio nonché la digitalizzazione e regionalizzazione dei dati raccolti sullo stato del suolo (valutazione delle funzioni del suolo, monitoraggio del suolo, piattaforme decisionali).

**Sessione 3: Organismi del suolo: diversità, funzione e fertilità del suolo**
Il suolo è un habitat eterogeneo per una moltitudine di organismi terricoli. Questi ultimi influenzano funzioni quali fertilità del terreno o regolazione del clima e forniscono un notevole contributo ai servizi eco-sistemici del suolo. In questa sessione si intende dare spazio a contributi che esplorino le biocenosi in tutte le loro diversità, i processi biotici che avvengono nel suolo e le interdipendenze tra organismi, caratteristiche dell'habitat e fattori ambientali. Le conoscenze di base sull'importanza della biodiversità devono essere tradotte in pratica e venir connesse alle funzioni chiave del suolo.

**Sessione 4: Fisica del suolo, struttura del suolo e idrologia del suolo.**
Questa sessione si concentra sulla struttura tridimensionale dei suoli (reticolo porale aggregati e profilo del suolo) nonché sui metodi di analisi strutturale. La struttura del suolo influisce sui processi chimici e biologici e costituisce essa medesima un prodotto di questi processi. A scala di paesaggio verranno discusse le interazioni tra la distribuzione geografica di suoli funzionalmente diversi ed i flussi idrici che guidano il trasporto di sostanze fra compartimenti contigui dell'ecosistema. Saranno benvenuti contributi volti a presentare nuovi metodi per caratterizzare la struttura del suolo, l'autorganizzazione e la formazione dello stato strutturale del suolo, la capacità di resistenza alle sollecitazioni meccaniche e non da ultimo nuovi metodi per ripristinare la struttura del suolo a seguito di costipamenti dannosi per il terreno.

**Sessione 5: Sostanze nocive organiche ed inorganiche nel suolo: cicli biogeochimici, rilevanza ecosistemica e misure di protezione del suolo.**
La presenza di sostanze nocive nel suolo è onnipresente. Le fonti di tali sostanze nocive sono molteplici: industria, agricoltura, traffico, attività domestiche. Quando si accumulano nel terreno e raggiungono la falda o vengono assorbiti dai vegetali queste sostanze possono costituire un rischio per la salute umana ed ambientale. Accogliamo volentieri contributi relativi al comportamento, trasformazione e biodisponibilità delle sostanze nocive nel suolo. Discuteremo anche della (ri-) mobilizzazione delle sostanze nocive ed il loro convogliamento nelle acque freatiche e di superficie.

**Sessione 6: Suolo e nutrizione delle piante: cicli dei nutrienti in funzione del sito, sistema colturale e disponibilità di nutrienti.**
Le strategie nutrizionali attuate dagli organismi del suolo e dai vegetali dipendono dal luogo in cui si trovano, dal sistema colturale e dall'approvvigionamento di elementi nutritivi. A questo proposito appare sempre più evidente che esistono meccanismi di adattamento alla ridotta disponibilità di nutrienti in determinati siti che non si basano sull'adattamento di singoli organismi ma che invece fanno capo ad una circolazione di nutrienti ben dosata nel sistema. In questa sessione si vuole riflettere sulle strategie nutrizionali adattive perseguite da organismi terricoli e piante in determinate condizioni chimiche e biologiche riscontrabili in ecosistemi rimasti quasi allo stato naturale e negli agroecosistemi. La sessione si chinerà anche sull'influenza di queste strategie adattive sui processi e caratteristiche di natura biogeochimica che riguardano il suolo.

## Soil minerals and organic matter sequestration

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Observations of matured soils and the study of chronosequences in the field provide many valuable insights into soil formation and development over long time scales. However, these studies are limited by the availability of suitable field sites, natural heterogeneity in e.g. parent material and environmental conditions and uncertainties in the development history. A novel approach is therefore to perform carefully designed laboratory studies with the goal of understanding a specific process under simplified conditions (Pronk et al., 2012, 2013, 2017). We designed an artificial soil incubation experiment, and used extensive interdisciplinary characterization covering both soil physical and chemical properties, and the establishment and functionality of a microbial community to elucidate the effect of mineral composition and charcoal presence on the formation of a soil-like system.

The experiment showed that the essential ingredients to produce an emergent aggregated soil material are a parent mineral material composed of phyllosilicates and/or iron oxides, an organic substrate and a heterotrophic microbial community. A series of artificial soils of eight different compositions was produced in this simple system that excluded the influences of environmental conditions, soil fauna, or roots on aggregate formation, nor did it take place in situ, but never-the-less intensive aggregate formation took place. The type of clay mineral was decisive for microbial community composition and macroaggregation, but the amount and quality of the OM bound to the minerals was similar. The effect of phyllosilicate minerals seemed to become evident only in developed soil-like systems. After several OM additions, clay minerals seem to be important for the differentiation of newly formed biogeochemical interfaces, whereas charcoal and iron oxides had no effect.

The results found in early artificial soil experiments compared to the differences in more mature artificial soils indicated that freshly added pure minerals react differently compared to minerals already incorporated in a soil-like structure. Overall, the results suggest that the initial soil composition may determine specific chemical structures and microbial community composition, but soils seem to develop comparable functions largely independent of the initial composition. The comparison of the artificial soils with the natural soil showed that the produced soil-like systems have OM dynamics comparable to natural soils and thus offer a valuable experimental system for further studies with defined mineral materials. Such experiments provide a new means to understand soil formation under controlled conditions and with controlled parent materials.

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## Carbon and nitrogen in managed organic soils in Switzerland - indications for soil degradation and implications for $N_2O$ emissions at national scale

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Organic soils in Switzerland cover ca. 28'000 ha, and most of them are managed as agricultural land or forest, whereas a smaller share is either extensively used or unmanaged. As a result, the majority of peat formerly stocked in organic soils is already gone, mostly by peat extraction and peat oxidation[1]. Yet, the remaining areas emit substantial amounts of $CO_2$ and $N_2O$ and are considered hot spots for management induced greenhouse gas (GHG) emissions in the land use sector.

The $N_2O$ release from organic soils is tightly coupled to their C/N ratio [2, 3]. We applied these published relationships between the C/N ratios and annual $N_2O$ emission to infer a consolidated estimate of $N_2O$ emissions, and their uncertainties, from organic soils in Switzerland. 48 sites in Switzerland (cropland CL n = 10, grassland GL n = 11, forest FL n = 26, and one natural bog NL), situated at altitudes between 414 and 1640 m asl. were investigated. In total, 1470 soils samples were analysed for their organic C (OC) and total N content, and most samples also for organically bound O and H. Samples were taken from a median depth of 0.38 m (range 0-2.0 m) and contained, on average, 41.7 ± 0.3 (1 SE) % OC and 1.79 ± 0.01 % N. OC contents, across all sampled soil layers, decreased significantly in the order NL > FL > GL > CL. Relative to the other major elements in peat (C, O, H), nitrogen was enriched during peat decomposition. This imposes a risk for substantial N loss from highly degraded organic soils as typically found under arable use. C/N ratios increased with depth and were always significantly larger in subsoils (> 0.3 m) than in topsoils (0-0.3 m). C/N ratios in topsoils increased in the order CL (17.9 ± 0.3) < GL (19.5 ± 0.4) < FL (29.1 ± 0.4) < NL (38.4 ± 1.8), indicating an influence of land use on peat composition. For estimating $N_2O$ release, only samples from 0-0.3 m depth were considered.

With the method cited above, we predict annual $N_2O$ emissions, based on C/N ratios, of 9.0 (0.5, 1 SD), 6.5 (4.5), and 1.7 (1.6) kg $N_2O$-N $ha^{-1}$, for CL, GL, and FL, respectively, whereas NL was not significant different from zero. The emission rates from agriculturally managed organic soils are higher than the average emissions from agriculturally managed mineral soils in Switzerland of 3.4 kg $N_2O$-N $ha^{-1}$ $a^{-1}$. When applied to the organic soil coverage of each of the three managed land use types of together ca. 22 kha, the resulting annual $N_2O$ emissions are 49.6, 19.2, and 3.0 kt $CO_2$-eq. for CL, GL, and FL, the sum of which is very similar to the emission reported in the national GHG inventory (71.4 kt $CO_2$-eq.). Currently, the Swiss GHG Inventory assigns 633 kt $CO_2$ emissions to carbon losses from managed organic soils. Accordingly, the calculated warming effect of managing these soils increases by 11 % when also $N_2O$ is taken into account.

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## What factors predominantly influence soil organic matter (SOM) stability in alpine ecosystems?

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There is an emerging understanding of mechanisms governing soil organic matter (SOM) stability, which is challenging the historical view of carbon persistence (Schmidt et al., 2011). According to this alternative vision, SOM stability is not directly regulated by the molecular structure of plant inputs (i.e. the historical view), but the biotic and abiotic conditions of the surrounding environment which play a major role and mediate the influence of compound chemistry. The persistence of SOM is thus influenced by ecological conditions, controlling the access and activity of decomposers enzymes and being ecosystem-dependent.

In this study, we investigated differences of stability of organic matter in litter, organomineral and mineral layers from the most widespread plant communities at the subalpine-alpine level of the Swiss Alps. For this purpose, 230 samples from 46 soil profiles have been analysed across eight plant communities, along a subalpine-alpine elevation gradient. Both calcareous and siliceous grasslands were studied, as well as snowbed and ridge communities. Aboveground litter and soil horizons were sampled and analysed using Rock-Eval Pyrolysis, a proxy-technique commonly used for the investigation of organic matter composition and stability (Disnar et al., 2003; Sebag et al., 2006).

According to the results, the thermal stability of the litter layer is highly variable among plant communities. The litter from plant communities linked to moist soils (snowbeds) is more resistant and has lower C/N than the litter of other grasslands. In the organomineral layer, the thermal stability of the SOM is more homogeneous among plant communities and it is mainly linked to its total amount (TOC). The balance between OM inputs and outputs appears to be the main factor influencing the stability of organomineral associations. In mineral horizons, the stability of SOM is mainly driven by the soil texture, the silty soils showing the highest SOM stability.

These results show a clear disconnection between organic, organomineral, and mineral horizons in terms of factors governing soil organic matter stability. Consistent with the recent view of the carbon balance, plant input seems to influence the litter C dynamics but not the SOM stability in A and mineral horizons.

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## The Swiss soil organic matter put to the acid test: results from the SwissSOM cluster, national research programme “Soil as a resource”

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Soil organic matter plays a key role in the services provided by the soil. It is crucial for soil fertility and plays an important role in relation to climate change. However, global change (climate change and land use change) may affect this soil organic matter. New conditions, brought by factors such as rising temperatures or changes in plant growth patterns, may increase the loss of organic matter. This decreases its potential to provide ecosystem services. However, we do not know which soils will mainly be affected by these changes. Assessing this vulnerability is vital to protect these soils effectively.

In the frame of the national research programme “Soil as a resource”, four projects looked at the soil organic matter on the Swiss territory. The overarching goal of this cluster was to better understand the carbon cycle and help stakeholders to design adapted solutions to protect this resource. The objectives the projects were the following:

- to establish which characteristics of organic soils are the main causes of mineralisation and to identify policy instruments effective in promoting a more sustainable management of the remaining peat soils
- to achieve a better understanding of soil carbon stability and vulnerability in relation to climate change as well as provide tools that can be used as indicators or sentinels of soil carbon vulnerability
- to identify the main determining factors of carbon storage in Swiss forest soils, climate, historical land-use and physico-chemical soil properties
- to evaluate the soil organic matter vulnerability of Swiss forest soils and provide tools to predict it.

To achieve these objectives, we combined a series of complementary tools: compound specific analyses associated with radiocarbon measurements, statistical data series analysis, process oriented modelling, archives and fresh resampled soils, incubations, soil fractionations, $^{14}C$-$CO_2$ measurements, $^{13}C$ labelling plant-soil analysis to cite a few.

This communication will give an overview of the results from this cluster, highlighting the complementarity of these different approaches and the main messages we identified.

## The vulnerability of organic matter in Swiss forest soils

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Soils contain more carbon than atmosphere and terrestrial vegetation combined[1], and thus they become key players in the carbon cycle. With climate change, the soil organic carbon (SOC) pool is vulnerable to loss, thus amplifying warming with this carbon feedback[2]. The objective of this study was to investigate the variation of indicators of SOC vulnerability (e.g. C mineralisation, turnover time, bulk soil and mineralized $^{14}C$ signatures) and to evaluate climate (i.e. proxies to soil temperature and moisture), soil (i.e. pH and % clay) and terrain (i.e. slope gradient and orientation) as primary drivers.

To choose study locations we used a statistics-based approach to select a balanced combination of 54 forest sites with de-correlated drivers of SOC vulnerability. This approach overcame the difficulty of statistically distinguish between the effect of confounded drivers. Sites were selected from a soil database of over 1,050 profiles spread over Switzerland and managed by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). We incubated soils and repeatedly measured cumulative SOC mineralisation on days 4, 13, 30, 63, 121 and 181 with sodium hydroxide traps[3].

We found that despite the well-studied relationship between climate and SOC dynamics[4], temperature did not emerge as a predictor of SOC vulnerability. Moreover, moisture only had a secondary role. Drier sites showed higher vulnerabilities. This indicates a possible limitation of heterotrophic activity due water shortage, at least during part of the hydrological cycle. The strongest driver controlling SOC vulnerability was soil pH. Soils with higher pH also showed higher vulnerabilities. This could be explained by lower pH values favouring stronger bond types[5]. We conclude that in temperate forests, the control that soil properties exert on SOC dynamics might overcome the influence of climate. Under these circumstances, the role of soil properties should be appropriately represented in Earth system models to obtain more realistic projections under different climate scenarios.

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## Insights into soil carbon dynamics across climatic and geologic gradients from time-series radiocarbon measurements on Swiss soils

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Soil organic carbon constitutes the largest terrestrial reservoir of organic carbon and in the framework of ongoing climate and land use change, a better understanding of the potential vulnerability of this pool is essential. However, the effects of climate and land use change on soil carbon dynamics are poorly understood. Radiocarbon constitutes a uniquely powerful tool to unravel soil carbon dynamics. In this study, radiocarbon time-series and single time-point measurements combined with a numerical model are used to determine the turnover time of decadal ("bomb-aged") soil carbon as well as centennial to millennial ("pre-bomb") carbon turnover times. This project encompasses a series of soil profiles spanning a large climatic climatic (MAT 1.3-9.2°C, MAP ~600 to 2100 mm $m^{-2}$ $y^{-1}$) and geological gradient in Switzerland. These sites are part of the Long-Term Forest Ecosystem Research (LWF) program of the Swiss Federal Institute for Forest, Snow and Landscape research (WSL). Results include temporally-resolved soil organic carbon turnover times well as soil carbon stocks and fluxes that are examined in the context of environmental and soil textural drivers. Statistical analysis on single time-point measurements on the regional scale, correlating radiocarbon signature to climatic variables indicate that soil texture (sand, silt, clay) has a larger impact than climate (temperature, precipitation). Estimates of soil carbon turnover time, carbon fluxes in a wide range of swiss ecosystems yield a detailed and improved understanding of top- and deep-soil carbon dynamics. Results indicate that turnover times increase exponentially and carbon efflux decreases exponentially with depth and that soil moisture plays an important role in retaining soil carbon. Overall, this study presents a new approach to soil carbon turnover modelling and uses a uniquely comprehensive dataset to provide an improved understanding of soil carbon dynamics across spatial and temporal scales.

## Controlling factors of soil organic carbon storage (SOC) in Swiss forest soils - the impact of land-use history, climate and soil chemistry

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Soil organic matter (SOM) is of great importance for key soil functions such as carbon sequestration, soil biodiversity determination and as a nutrient source. Soil organic carbon (SOC) storage is controlled by plant litter inputs, climate conditions, physico-chemical properties and land use; the quantitative importance of these factors is, however, not yet well understood. Our current knowledge on the drivers on soil C storage is primarily based on case studies and for larger scale data set it is difficult to disentangle various factors. In SOM models, physicochemical parameters such as pH or clay content, and land use history have not been yet well parameterized. Consequently this may lead to high discrepancies between simulated and observed SOC stocks.

We investigated the main controlling factors of SOC storage in the organic layer and in mineral soils of 1000 forest soil profiles across Switzerland. Our approach was threefold. Firstly, we reconstructed historical forest cover change, allowing us to estimate the minimal forest age of all sites and examine its effect on SOC stocks in combination with tree species composition, climate and soil physico-chemical parameters. Secondly, we studied the distribution of SOM along gradients in climate and soil properties, using density fractionation to examine the controlling factor for the stabilization of SOM. Thirdly, we applied a commonly used soil carbon model YASSO and examined the residuals between measured and simulated SOC stocks.

The results from the historical land-use change study indicate that forest age has a rather negligible effect on current SOC storage and that its effect is superimposed by other factors. In particular, in the organic layer, forest type and mean annual temperature indicated a strong impact on SOC stocks, whereas, in the mineral soil, mean annual precipitation and pH exerted the strongest influence on SOC storage. The fractionation study demonstrated that climate affects SOC stocks and SOM quality, especially in the particulate organic matter fraction, which is considered to be highly vulnerable. Specifically, we observed a decrease of SOC storage and C/N ratio under drier climatic conditions. The residual analysis demonstrated a good agreement between observed and simulated SOC storage in the Swiss Plateau and in the Alps but large discrepancies in the Jura and the Southern Alps - regions known to contain high contents of calcium and pedogenic oxides. This indicates that soil minerals act as SOM stabilizers and excluding soil chemical parameters in soil models leads to an underestimation of SOC stocks. In conclusion, we found that 1) soil chemistry exerts a dominant effect on SOC storage and stability; 2) forest age only have a small effect on SOC stocks; 3) climate affects SOC storage and quality, particularly the more labile fractions; and 4) incorporating soil chemistry in models would improve SOC modelling.

## Connecting biodiversity monitoring and soil inventory - A Swiss case study

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Switzerland is one of the first countries in the world to monitor its biological diversity. The Federal Office for the environment (FOEN) has launched a program for this purpose called Biodiversity Monitoring in Switzerland (BDM). According to the Convention on Biological Diversity various biodiversity targets were defined and the action plan strategy biodiversity Switzerland serves to implement these strategic goals. Unfortunately, up to very recently, soil was not part of these considerations.

In the Swiss biodiversity monitoring system a core indicator, Z9, is designed to document changes in species diversity of vascular plants and mosses in Switzerland's major habitats. Together with the current land use and general metadata like elevation, slope, exposition and geology these data are stored in a central database. Since 2001 the totally 1'600 sites based on a regular grid (6 by 4 $km^2$) are resampled in a 5 years interval. In the third sampling campaign (2011-2015) the setting was broadened by taking soil samples at all locations possible. At each site 4 replicates 0-20 cm were taken to provide predictions on plot scale variability. All samples were prepared in the laboratory of the Swiss Soil Monitoring Network.

Exploratory data analyses for pH-values revealed distinct patterns according to land use as well as to altitude; pH decreases from colline to alpine zones. Furthermore, regional analyses show enormous differences between the northern and southern side of the Alps.

Connecting measured soil parameters with the outcome of the BDM survey enables to determine the impact of environmental conditions on species diversity of vascular plants and mosses. More specific, the R-value in the BDM survey is replaced by measured pH values which improves the explanatory power of the correlation.

Therefore, connecting measured soil inventory data and plant and moss diversity information provide a clear added value to the Biodiversity Monitoring in Switzerland.

## Organic matter and porosity values as criteria for soil structure quality evaluation

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The evaluation of soil quality, and particularly soil structure quality, is at the core of soil sustainable management. However, quantifying soil structure quality with easy to perform and inexpensive methods remained out of reach until now. The first and main criteria used in soil quality indexes (SQI) is organic matter content (OM). Its relationships with structure and soil functions are well known. However, there is still a need for precise and substantiated recommendations on the desirable or optimum OM content a soil should have in agriculture.

Recent research results allow to propose structure and OM threshold values defining soil quality classes, with direct possible application in arable soil management and soil protection regulation. Moreover, simple methods allow the determination of these criteria by any user, such as soil protection specialist or even farmers themselves.

The structure quality is classified with Visual Evaluation of the Soil Structure at clod scale (Johannes et al., 2016). OM threshold values are determined based on soil structure quality classes and referring to the OM to clay content ratio (Johannes et al., 2017), in line with previous findings along the past decades (Feller and Beare, 1997; Dexter et al., 2008). The structure quality is assessed physically via volume measurements at a standardized matric potential as a function of water content at the same matric potential.

Both indices (OM to clay ratio and structure quality) allow to sharply improve the classification of the soils compared to currently used or recommended indices in Switzerland or worldwide. We believe they open the door to result oriented agricultural management schemes and environmental regulation of soil structure degradation, provided that complementary aspects such as sampling are treated.

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## Assessing the impact of agricultural management practices on soil quality - insights from the EU iSQAPER project

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Good soil quality is of fundamental importance to both local and global food production and to ecosystem resilience. Agricultural soils world-wide are subject to threats and pressures including: increasing demand for food and biofuels, changing diets, land degradation and associated productivity decline. Reliable knowledge and data help land users assess their soils and make well-informed decisions about its use. iSQAPER is a European H2020 project with 25 partners across Europe and China, coordinated by Wageningen University, The Netherlands. It aims for interactive soil quality assessment in Europe and China for agricultural productivity and environmental resilience, providing decision makers with science-based, easy to apply and cost-effective tools to manage soil quality and function. To achieve this, iSQAPER will review soil quality indicator systems, and identify knowledge gaps in the interactions between agricultural management activities and soil properties. A Soil Quality Assessment Tool will then be developed and supported with experimental activities to close identified knowledge gaps. Testing and validation is implemented through a multi-actor approach in 14 Case Study Sites across Europe, and innovative agricultural management practices (AMPs) are evaluated for their upscaling potential.

CDEs tasks are the identification of the relevant stakeholders, to apply and test the soil quality assessment tool with a variety of actors, to make an inventory of soil quality status and applied AMPs at the Case Study Sites and to evaluate innovative AMPs improving soil quality. For the soil quality and AMPs inventory at case study sites, a manual was developed in order to standardize and facilitate the task. The manual gives a clear and precise description on how to assess the indicators of soil quality based on Visual Soil Assessment Methodology (VSA). On the basis of a thorough analysis of the literature review in the topic, 11 indicators were selected. The manual contains a detailed monitoring plan including a list of indicators to use, description of their assessment, related scoring and additional references. The main aim of this inventory is to link AMP to the soil quality status at the case study sites, and to identify innovative practices that have improved soil quality. This inventory is completed together with the stakeholder in situ and scoring is done with the consent of the stakeholder as well. The inventory is done across a representative number of fields across the main pedo-climatic zones apparent in the Case Study Sites. The idea is to compare the soil quality of a farm where changes have occurred at least 3 years ago with another farm without changes in AMP within the same pedo-climatic zone and under comparable soil conditions, topography, etc., serving as control. The case study partners were requested to identify at least 3 different AMPs (or combinations) and 3 related controls. First results are available now. This assessment will be repeated in the next years, which will finally provide sound data on soil quality status and its improvement through AMPs across Europe.

## Bewertung von Ökosystemleistungen: Was ist der Beitrag unserer Böden? - EU-Projekt RECARE und Fallbeispiel Region Frienisberg

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Im RECARE Projekt (Preventing and Remediating degradation of soils in Europe through Land Care) arbeiten 27 Institutionen in einem multidisziplinären Team, um die aktuelle Gefährdung von Böden einzuschätzen und innovative Lösungen zur Prävention weiterer Bodendegradation in Europa zu finden. Eine Vielzahl von Prozessen wie Erosion, Verdichtung, Versiegelung und Verschmutzung bedrohen die Böden. Zum Erhalt ihrer natürlichen Funktionen und der damit verbundenen Dienstleistungen - z.B. Produktion von Nahrungsmitteln, Speicherung und Reinigung von Wasser oder Bindung von $CO_2$ und Nährstoffen - müssen Böden angemessen genutzt und geschätzt werden.

Weil Bodendegradation durch das Zusammenspiel von biophysischen, sozioökonomischen und politischen Faktoren verursacht wird und diese Faktoren innerhalb von Europa stark variieren, sind die damit verbundenen Probleme definitionsgemäss ortsspezifisch. Um die unterschiedlichen Bedingungen innerhalb von Europa zu berücksichtigen und durch eine innovative Kombination von wissenschaftlichem und lokalem Wissen angemessene Lösungsansätze zum Schutz der Böden zu suchen, wurden für das RECARE Projekt 17 Fallbeispiele ausgewählt. In einem dieser Fallbeispiele werden in der Region Frienisberg (Kt. Bern) Untersuchungen zur Verminderung der Bodenerosion durchgeführt. Dabei wird auch die Wirksamkeit des Lochsterns im konventionellen Kartoffelbau hinsichtlich Bodenfunktionen und Ökosystemleistungen sowie Kosten und Nutzen eruiert. Erste Resultate aus dem Feldversuch zeigen, dass mit dem Lochstern Regenwasser in den eigenen Reihen zurückgehalten, Stauwasser und Vernässung in den Senken weitgehend verhindert und Erosion minimiert werden kann.

Lösungsansätze für eine nachhaltige Bodennutzung können jedoch nur dann erfolgreich identifiziert, entwickelt, umgesetzt und evaluiert werden, wenn die vielfältigen Bedürfnisse der verschiedenen Akteure berücksichtigt werden. Eines der Ziele im RECARE Projekt ist es deshalb, Plattformen zur Förderung des Wissensaustausches und gemeinsamen Lernens zwischen verschiedenen Akteuren aus Praxis und Wissenschaft zu schaffen. Auf der Basis dieses Wissens entwickelt das Projekt eine Methodik zur Beurteilung des Einflusses von Bodendegradation sowie zur Bewertung nachhaltiger Bodennutzung auf Ökosystemleistungen. Grundlage dieser Methodik bildet ein aufgrund einer Literaturstudie angepasstes konzeptionelles Modell der bodenbezogenen Ökosystemleistungen. Die Methodik soll ermöglichen, die Ökosystemleistungen des Bodens zu identifizieren, soweit wie möglich zu messen und diese dann in Interaktion mit allen Beteiligten zu bewerten. Dieser Wert soll nicht in erster Linie ein ökonomischer sein, sondern ein durch einen gemeinsamen Lernprozess eruierten und ausbalancierten gesellschaftlichen Wert darstellen, der diesen Leistungen zugewiesen werden kann. Dies erlaubt es schliesslich, verschiedene Bodenschutzmassnahmen gegeneinander abzuwägen und so Entscheidungen evidenzbasiert zu füllen. Nebeneffekte auf andere Ökosystemleistungen, andere Regionen oder spätere Zeitpunkte (sogenannte „trade-offs“) sollen dabei in die Bewertung einfliessen. Die Methode soll möglichst einfach anwendbar sein, damit sie der Praxis dient, und trotzdem das verfügbare wissenschaftliche Wissen soweit wie möglich berücksichtigen. Sie kommt anschliessend in allen 17 Versuchsregionen des RECARE Projektes zur Anwendung.

## Les lignoformes, des formes d'humus encore peu étudiées

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Présenté lors de l'assemblée annuelle 2014 de la SSP, le projet international DecAlp (Effect of climate on coarse woody debris decay dynamics and incorporation into the soils of forested Alpine areas; decalp.org) arrive aujourd'hui à terme. Ce projet dépasse les frontières nationales afin de réunir des chercheurs de domaines variés (pédologie, géologie, microbiologie, phytosociologie, modélisation) dans le but principal d'élaborer communément un modèle de décomposition du bois mort et de son incorporation au sol.

Une partie de ce vaste projet s'est essentiellement concentrée sur les formes d'humus, et plus particulièrement sur celles inféodées au bois mort, appelées lignoformes. Les communautés lombriciennes gravitant autour de ces entités écologiques particulières ont également été investiguées. Le projet DecAlp est actuellement dans une étape de synthèse des résultats obtenus par les différents groupes de travail, nous proposons au cours de cette présentation de survoler les principaux résultats obtenus concernant les lignoformes, complété par un aperçu de communautés lombriciennes sous l'influence des accumulations de débris ligneux. Les deux points suivants seront ainsi présentés:

i) lignoformes

Parmi les nombreuses études consacrées au bois mort, peu d'entre elles considèrent celui-ci dans un contexte écosystémique étendu ainsi que son lien avec le reste de l'épisolum humifère sous-jacent. Après avoir présenté les principales caractéristiques du bois mort sur le terrain, les principaux acteurs impliqués dans son cycle de vie et le rôle primordial du bois mort dans de nombreux écosystèmes, nous présenterons le concept de lignoformes, les moyens de les étudier et les décrire ainsi qu'un système de classification développé expressément pour ces formes d'humus particulières.

ii) communautés lombriciennes et accumulations de débris ligneux

Les organismes vivants influencent la création et l'évolution des formes d'humus qui, en retour, peuvent leur servir d'abri ou encore de source d'énergie. Cette synergie est connue pour apporter directement ou indirectement de nombreux bienfaits à l'homme (services écosystémiques). Au sein d'un site d'étude d'apparence relativement homogène, la mosaïque spatiale et temporelle formée par les formes d'humus démontre une certaine hétérogénéité des méso- et micro-conditions environnementales. Cela permet à différentes communautés d'organismes de cohabiter sur une aire relativement restreinte. Cette hétérogénéité est renforcée par la présence d'éléments structurants tels que les accumulations de débris ligneux, qui auront potentiellement comme effet de diversifier les communautés d'organismes, conduisant ainsi à une plus grande diversité et complémentarité des services écosystémiques ainsi qu'à une meilleure résilience de l'écosystème considéré. Nous présenterons un exemple de l'influence concrète que peuvent avoir les accumulations de débris ligneux sur les communautés lombriciennes.

Au final, les résultats présentés permettront de se questionner sur la définition des limites mêmes du sol (par exemple, où la limite entre le sol et les annexes du sol telles que les accumulations de débris ligneux) et de pouvoir mieux décrire certains constituants du sol, menant ainsi à une meilleure et plus judicieuse protection de celui-ci. Les résultats obtenus sont également un pas supplémentaire vers une meilleure compréhension des différents types de matière organique présents dans le sol.

## Erfassen von Bodenerosion nach starken Niederschlagsereignissen und Abklärung der Effizienz von Bodenschutzmassnahmen aufgrund von Drohnenbildern, Feldmethoden und Befragungen

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Das Erosionsmonitoring-Projekt wird in Zusammenarbeit der HAFL, Changins, EIA-Fribourg und des CDE ausgearbeitet und untersucht Bodenerosion bei Starkniederschlagsereignissen. Dabei wird ein Fokus auf die Analyse der Effizienz von Bodenschutzmassnahmen gelegt. Zur Überwachung von Starkniederschlägen wurde ein Monitoringtool, auf der Grundlage von CombiPrecip Radar Daten von MeteoSwiss, entwickelt. Zudem wurden hochaufgelöste Drohnenbilder erhoben um eine Methode zur automatischen Vermessung der Erosionsrillen und -rinnen zu entwickeln.

Die im Rahmen dieses Projekts entwickelte Masterarbeit leistet einen Beitrag zum Verständnis der Ursachen von Bodenerosion und möglichen Erosionsschutzmassnahmen bei Starkniederschlägen. Dafür wurden vier Fallstudien nach Starkniederschlägen erhoben. In jedem der Fälle wurde möglichst nahe neben einem starken Erosionsereignis auch ein Vergleich erfasst, bei dem trotz gleich hohem Erosionsrisiko kein oder ein geringer Schaden entstanden ist. Dieser Vergleich von Fallstudien mit ähnlichem Risiko aber unterschiedlicher Nutzung und Bodenbearbeitung ermöglicht die Ausarbeitung von Ursachen und Massnahmen. Für den Vergleich wurden die Schläge anhand eines Feldprotokolls erfasst und skizziert, hochaufgelöste Luftbilder mit Drohnen aufgenommen, sowie strukturierte WOCAT-Interviews mit den LandwirtInnen durchgeführt.

Die Resultate zeigen, dass folgende Faktoren das Erosionsausmass bestimmen: die Bodenbedeckung, der Fruchtfolgefaktor, die beitragende Fläche eines Hangeinzugsgebiets und das Erosionsrisiko gemäss der ERK2. Abflussleitende Oberflächenformen, welche den Abfluss kanalisieren, sind dabei zentral bei der Bestimmung der Grösse der beitragenden Flächen. Die Fallstudien illustrieren, dass die leicht- bis mittelgeneigten und gleichzeitig langen Schläge, sowie die Muldenlagen im unteren Teil der Hangeinzugsgebiete, höchste Erosionsschäden aufweisen.

Folgende Massnahmen können über die Fallstudien hinaus zur Prävention von Bodenerosion durch Wasser beitragen:

- Schlaganordnung und die Fruchtfolge so aufeinander abstimmen, dass Fliesswege unterbrochen werden. Daraus folgt ein Wechsel von Sommer- und Winterkulturen innerhalb eines Hangeinzugsgebiets
- Bodenbedeckung konstant hoch halten
- Fruchtfolge auswählen, welche die Bodenstruktur erhaltet und auf eine schonende Bodenbearbeitung achten (auf Zeitpunkt des Befahrens bezüglich Bodenfeuchtigkeit und -bedeckung achten, sowie auf angetriebene Maschinen verzichten)

Die Arbeit zeigt, dass anhand von einfachen Mitteln, ohne Veränderung der Betriebsstruktur, Massnahmen gegen Bodenerosion an gefährdeten Stellen ergriffen werden können.

## Long-term monitoring of organic pollutants in soil: a conceptual approach to select pesticides potentially accumulating in soil

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The Swiss Soil Monitoring Network NABO was set up in the mid-1980s to detect temporal changes of soil quality in the long-term. Initially, soil pollution by heavy metals and acidification were the main issues. In the meantime the analysis of organic soil pollutants improved remarkably. Consequently, soil monitoring networks are able to integrate a larger array of organic soil pollutants using either samples from new sampling campaigns or archived soil samples. Due to the large number of organic chemicals and the limited financial resources, a well-defined conceptual approach is needed to define those to be integrated in soil monitoring. Therefore, we follow a stepwise approach taking into account:

(i) Prediction

(ii) Status survey

(iii) Risk assessment

(iv) Monitoring

This approach might be applied for various groups of chemical compounds. The present study focuses on pesticides. First, selected soil samples from NABO sites were used to establish a multi-residue analytical method (stage i; Krauss & Keller, 2010). Currently, the methodology is refined to analyse a broader range of pesticides; subsequently, it will be applied to agricultural NABO monitoring sites (stage ii). The target substances were selected using the following data bases and approaches:

- Results stage i: pesticides and transformation products detected in first screening.
- Management data of NABO sites: frequency and amount of pesticides used by farmers.
- Modelling soil concentrations: estimation of the temporal evolutions.
- Risk assessment: evaluation considering the estimated concentrations.

The intended analyses will provide an overview of the pesticides exposure of NABO soils. Thereafter, a risk assessment will help to rank the detected pesticide concentrations in soils (stage iii). However, this will involve various issues, e.g. the risk by mixtures of various substances (Wittmer et al. 2014), to finally decide which pesticides are to be monitored (stage iv).

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## Understanding the functional significance of microbial communities in soil C dynamics

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An underlying assumption of most ecosystem models is that soil microbial communities are functionally equivalent; in other words, that microbial performance under given conditions is not dependent on the composition or diversity of the communities. Although a number of studies have questioned this assumption, these models can adequately describe ecosystem processes such as soil C dynamics without an explicit description of microbial functional characteristics. I will present a series of experiments in which the relative importance of microbial communities and of the abiotic soil environment in regulating soil organic C decomposition has been tested. I will show that $CO_2$ production is greater in pores with larger neck diameters than in pores with smaller neck diameters, with maximal rates being found in pores with neck diameters between 15 and 60 µm. This suggests that the physical environment of the microbial communities regulates microbial decomposition or organic matter. However, there is a tight relationship between pore size class and microbial community structure and it is not clear whether the pore size class effect on organic C mineralisation is due to the presence of different microbial communities or because of the abiotic properties of the micro-environment if these communities. The relationship between total organic C in soil and microbial decomposition rates is well established, but here also, total organic C is confounded with microbial communities. I will present data from two reciprocal transplant experiments, in which microbial communities from different soils are incubated in different soil environments. These experiments suggest that the intrinsic properties of microbial communities (composition, diversity) have an impact on organic C decomposition when organic matter supply is sufficient for the intrinsic properties of the microbial communities to be expressed but that when substrate supply is low, mineralisation rates are related to the abiotic properties of the microbial environment.

## Hotsphere illumination

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Soils are the most heterogeneous parts of the biosphere, with an extremely high differentiation of properties and processes at all spatial and temporal scales. Importance of the hotspheres such as rhizosphere, detritusphere, porosphere (including drilosphere and biopores), hyphasphere and spermosphere, calls for spatially explicit methods to illuminate distribution of microbial activities in these hotspheres (Kuzyakov and Blagodatskaya, 2015). Zymography technique has previously been adapted to visualize the spatial dynamics of enzyme activities in rhizosphere (Spohn and Kuzyakov, 2014). Here, we further developed soil zymography to obtain a higher resolution of enzyme activities by enabling direct contact of substrate-saturated membranes with soil. For the first time, we aimed at quantitative imaging of enzyme activities in various hotspheres. We calculated and compared percentage of enzymatic hotspots of five hotspheres: spermosphere, rhizosphere, detritusphere, drilosphere and biopores. Spatial distribution of activities of two enzymes: β-glucosidase and leucine amino peptidase were analyzed in the spermosphere, rhizosphere and detritusphere of maize and lentil. Zymography has been done 3 days (spermosphere), 14 days (rhizosphere) after sowing and 21 days after cutting plant (detritusphere). Spatial resolution of fluorescent images was improved by direct application fluorogenically labelled substrates on the soil surface. Such improvement enabled to visualize enzyme distribution of mycorrhiza hypha on the rhizobox surface. Further, to visualize the 2D distribution of the enzyme activities in porosphere, we placed earthworms (Lumbricus terrestris), (drilosphere) and ground beetle species Platynus dorsalis Pont. (Coleoptera; Carabidae), (biopore), in transparent boxes for 2 weeks. The developed direct zymography visualized the heterogeneity of enzyme activities along and across the roots. Spatial patterns of enzyme activities as a function of distance along the root demonstrated plant specific patterns of enzyme distribution: it was uniform and homogenous along the lentil roots, whereas the enzyme activities in maize rhizosphere were higher at the apical or proximal root parts. The activity of leucine-aminopeptidase was higher at the apical parts and β-glucosidase activity was higher at both apical and proximal part of individual maize roots. Much higher activity of leucine-aminopeptidase and β-glucosidase per $mm^2$ of hotspots were found for rhizosphere (12-5 fold), drilosphere (10-4), spermosphere (9-4), biopore (9-1), hyphasphere (8-3) and detritusphere (5-2) compared to the bulk soil. Despite the transient nature of spermosphere, its microbial activities had long-lasting impact. We conclude that improved zymography is promising in situ technique to identify, analyze, visualize and quantify temporal-spatial distribution of enzyme activities in the various hotspheres.

## Composition and functions of microbial communities in top- and subsoils of degraded pasture ecosystems on the Tibetan Plateau

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Kobresia pygmaea grasslands of the Tibetan Plateau provide a tremendous sink for organic carbon (OC). They form the basis for local pasture economy, prevent soils from erosion, and retain large amounts of water for SE Asia. Overgrazing triggers grassland degradation by altering plant species composition, and destroying the protective Kobresia root mats leading to massive OC losses and ecosystem destabilization. In this study, degradation of Kobresia mats were thereby classified into six degradation stages.

The aim of this study was to determine soil organic matter (SOM) composition in relation to degradation and to analyze the effects of altered SOM composition on microbial community, composition and functioning. Vertical gradients of $^{13}C$ and $^{15}N$-values, neutral sugars, cutin and suberin contents, lignin phenol contents as well as microbial and fungal community compositions (t-RFLP analysis followed by MiSeq sequencing), and activities of six extracellular enzymes involved in the C, N, and P cycles were assessed.

Increasing degradation caused by intensive pasturing resulted in an increased OC decomposition demonstrated by decreasing $^{13}C$-, $^{15}N$-values and C/N ratio. The $^{13}C$ shift towards more negative values reflects the relative enrichment of $^{13}C$ depleted macro-molecules such as lignin and suberin/cutin during OC decomposition in the strongly degraded soils. Translocation of topsoil material into the subsoil with advancing degradation was indicated by increasing contributions of cutin to OC in the subsoils. Enzyme activities involved in the degradation of more complex OC compounds (e.g. fungal phenoloxidases) increased with changing SOM composition and were highest in the subsoil of strongly degraded stages 4 and 5, whereas other enzyme activities decreased. Decreasing overall enzyme activities and increasing activity of phenoloxidases were associated with progressive alterations in microbial and fungal community composition, which were most pronounced in the subsoil, e.g. a pronounced decline in the phylum of Actinobacteria. Bacterial diversity (Shannon-Wiener-Index) was particular responsive to the degradation of Kobresia root mats and declined significantly along the degradation sequence, while overall diversity of the fungal community remained similar. As microbial communities play a central role in soil biogeochemical cycles, we conclude that the observed alterations of microbial community structure and losses in bacterial biodiversity with Kobresia degradation may strongly affect ecosystem processes.

## Metabarcoding of Soil Microbial Communities for Soil Quality Monitoring

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Soil microbial community (SMC) structures and relative abundances on individual microbial populations have been shown to reflect alterations in soil quality and therefore have great potential to be used as indicators for soil quality monitoring. Microorganisms have various important functions in soil, which include nutrient cycling, soil structure, decomposition, plant growth promotion, as well as pathogenicity. It has also been shown, that SMCs are highly divers and that in one gram of soil up to billions of microorganisms representing thousands of species may live. Recent developments in molecular ecology have led to the development of molecular tools that allow to assess this diversity. SMCs can readily be detected through a DNA-based approach called metabarcoding. All DNA is extracted from a soil sample, and a marker sequence is used to identify microbial organisms. When independently resequencing the same DNA extracts, very similar SMC structures are found with Bray-Curtis similarities ranging from 0.8 to 0.9. This demonstrates the technological reproducibility of the approach.

We used metabarcoding to assess the relative importance of soil properties, land-use types (i.e. grassland, arable land, forest), land management (fertilization), and time to shape SMC structures. We analyzed three different systems: i) the NABObio system, representing 30 sites of the Swiss soil monitoring network (NABO) that were sampled for four years once every spring, ii) the KABO system, representing 152 sites across Switzerland, which belong to cantonal soil monitoring networks, that were sampled once, and iii) the DOK system, representing a field experiment in which 40 plots were sampled twice. A total of 592 soil samples were collected and bacterial and fungal communities were analyzed. Ordination analyses revealed that soils from different land-use types harbored distinct SMC structures. A canonical analysis of principal coordinates (CAP) correctly reclassified 98 % of bacterial and 99 % of fungal communities to the respective land-use type.

About 97 % of all NABObio samples were correctly classified to the individual site. All samples from the DOK experiment clustered together but slightly apart from other arable land sites. If analyzed separately, SMC structures from the DOK field showed differences between sampling years as well as fertilization regimes. Consequently, site properties have a stronger impact on SMC structures than temporal factors or land management. Our data strongly support that DNA sequence information are suitable to robustly assess SMCs and their habitat associations. Furthermore, SMC structures revealed stability over several years underlining their potential for use in soil quality monitoring. However, successful integration of SMC data into soil quality monitoring programs will depend on knowledge of their interactions with soil characteristics or on the detection of indicator taxa (or combinations of taxa) for specific habitat types or defined stresses.

## Combining position-specific $^{13}C$ labeling with $^{13}C$-PLFA analysis to assess microbial utilization of free versus sorbed Alanine

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Microbial utilization is a key transformation process of soil organic matter (SOM). Sorption of low molecular weight organic substances (LMWOS) to soil mineral surfaces delays and changes microbial uptake and therefore mineralization of LMWOS to $CO_2$, as well as all other biochemical transformations. We used position-specific labeling, a tool of isotope applications, combined with $^{13}C$-phospholipid fatty acid (PLFA) analysis, to assess microbial utilization of sorbed and non-sorbed Alanine in soil. Alanine as one of the quantitatively most important amino acid in soil links C- and N-cycles and therefore is a model substance for the pool of LMWOS.

To assess changes in the transformation pathways caused by sorption, we added uniformly and position-specifically $^{13}C$ and $^{14}C$ labeled Alanine to the Ap of a loamy Luvisol in a short-term (10 d) experiment. The respired $CO_2$ was captured and its $^{14}C$-activity was determined at increasing times intervals. Group-specific microbial utilization of Alanine's functional groups was evaluated by $^{13}C$-PLFA analysis.

Sorption delayed the release of labeled $CO_2$ and reduced initial respiration rate by 80%. Irrespective of sorption, the highest amount of C from the carboxylic group was respired, whereas C from the amino-bound group as well as from the methylic group were preferentially incorporated into PLFA. This is in accordance with the basic microbial metabolism of C-3 molecules in glycolysis. Reconstruction of microbial transformation pathways showed that the C-2 position of Alanine was lost faster than its C-3 position regardless of whether the molecule was used ana- or catabolically. The highest incorporations of all positions in PLFA were accomplished by Gram negatives. Free Alanine was preferentially used by highly competitive free living osmotrophs, while sorbed Alanine was more preferred by microbial groups that build larger amounts of biomass, e.g. biofilms and extracellular structures fixing hyphae. Remarkable is that both, those microorganisms that prefer free and those that prefer sorbed Alanine, do not belong to a common taxonomic or phylogenetic group, but they contain in each case both - pro- and eukaryotes and within the prokaryotes Gram positives and Gram negatives. Therefore, it is crucial to consider the ecophysiology of the microbial groups in their respective habitat to give evidence about their behavior instead of classifying microbial communities solely based on phylogenic or taxonomic properties. These findings could only have been achieved with the position-specific labeling approach, therefore this method will strongly improve our understanding of stabilization processes and soil C fluxes.

## Seasonal dynamics of soil microeukaryote communities along a gradient of disturbance in a restored floodplain (Thur River, Switzerland)

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Microeukaryotes play crucial roles in soil biogeochemical cycling because of their involvement in key processes, such as the degradation of the soil organic matter and nitrogen mineralization. The impact of microeukaryotes depends on their community structure, which varies spatially and temporally. However, despite a recent increase in soil environmental diversity studies, the spatiotemporal dynamics of soil microeukaryotic communities remains poorly documented. We assessed the patterns of soil microbial eukaryotic diversity and community structure across habitats and seasons using $^{18}$S Illumina high-throughput sequencing in a restored dynamic floodplain (Thur River, Switzerland). We sampled five contrasted habitats based on common environmental characteristics along a gradient of decreasing influence of the river; gravels, grass, willow bush, mixed forest, willow forest and pasture. Community variation among habitats was significantly greater than the seasonal variability. Interestingly, a parallel study on bacterial communities revealed an opposite pattern with the spatial pattern nested in the seasonal pattern. Phototrophic microeukaryote diversity and abundance peaked in the most frequently flooded area (soil gravel), suggesting that some of these organisms are aquatic, and are brought to the soil habitat during flooding events likely, thus increasing the overall diversity. Altogether, this study provides insight into the diversity and community composition of microeukaryotes in floodplains and illustrates that different factors drive the spatiotemporal patterns of bacterial and microeukaryote communities.

## Long- and short-term effects of mercury contamination on the soil microbiome

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Mercury (Hg) is a heavy metal occurring naturally in soil and can reach high concentrations in the environment due to anthropogenic activities. However, little is known on the effect of mercury (Hg) contamination in soil and its influence on the soil microbiome, especially its persisting effect. Long-term effect of Hg contamination on the soil microbiome (bacteria and fungi) was assessed in soils contaminated for more than 60 years.

Soils from four sites with different levels of total Hg concentration were sampled: High (36.1 ± 2.4 µg Hg $g^{-1}$ soil), moderate (3.0 ± 0.9 µg Hg $g^{-1}$ soil), low (0.25 ± 0.05 µg Hg $g^{-1}$ soil), and non-contaminated (0.19 ± 0.03 µg Hg $g^{-1}$ soil). In order to assess the short-term adaptation of these soils microbiomes to change of soil Hg concentration, an incubation experiment in microcosms was conducted where the soils from each long-term contaminated site were either spiked with 10 µg Hg $g^{-1}$ soil or with water only (control) and were incubated for 30 days. Bacterial and fungal community structures and compositions were assessed in the soils from the Hg contaminated sites (long-term effect of Hg) and from the soils spiked with Hg (short-term effect of Hg). Additionally, the earthworm gut microbiome from worms kept in contaminated and non-contaminated soils for a month was also investigated.

Results show a clear shift of both the bacterial and fungal community structures of the high and moderate contaminated sites. Surprisingly, bacterial and fungal diversity were increased in these two sites and soil respiration as well as microbial growth rates increased with Hg concentration in soil. No short-term effect of Hg was observed on the microbial community structure and composition, nor on the bacterial and fungal abundance and growth rates. Quantification of the mercury reductase gene (merA), a central gene for Hg resistance in microbial cells, reflected the amount of Hg in long-term contaminated sites, with number of merA gene copies 1.6 and 3.5 times higher than in the moderate and low contaminated sites, respectively. MerA also increased with short-term spiking of soil Hg concentration, independently of the original soil Hg concentration. The earthworm gut microbiome was strongly impacted by Hg; the bacterial and fungal diversity was ca. four times more important in the worms from the contaminated soil compared to the non-contaminated soil and both gut bacterial and fungal communities shifted strongly in the worm from the contaminated soils.

Overall, these data show a strong long-term impact of Hg contamination on the soil microbial diversity and functions. Contrastingly, no short-term shifts in the soil microbial communities and functions was observed, but increase in merA genes was detected as a short-term strategy to deal with higher amounts of Hg.

## We can compact a soil within seconds, but how long does it take a soil to recover from compaction damage?

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Soil compaction due to agricultural vehicular traffic alters the geometrical arrangement of soil constituents, thereby modifying mechanical properties and pore spaces that affect a range of soil functions, such as the soil gas and water transport capability and productivity. The ecological and economic costs of soil compaction relate to the cumulative loss of soil functionality (e.g., yield loss in agricultural systems) following a compaction event, integrated over the time period until a soil has effectively recovered to its pre-compaction functionality. While a soil can be compacted within a few seconds (during the passage of a vehicle), literature data suggest that the recovery is a disparately longer process that may extend over decades. Hence, the severity of compaction damage and the real compaction costs are largely governed by recovery time. Although the mechanisms relevant for soil structure recovery are generally well established, their quantitative and predictive representation remain limited.

This lecture discusses soil structure mechanisms and rates, and presents first results from the “Soil Structure Observatory (SSO)” field experiment that aims at providing long-term observation data on soil structure evolution after disturbance by compaction enabling quantification of compaction recovery rates and times. The key natural mechanisms involved in soil structure recovery following compaction include climatic and abiotic processes induced by wetting-drying and freezing-thawing phenomena, and biotic processes (root growth and root water up-take, burrowing of earthworms and other soil fauna, microbiological activity). Additionally, soil tillage plays an important role in soil structure dynamics. The SSO was established on a loamy soil at Agroscope Reckenholz/Zürich, and is intended as a long-term (> 10 years) field experiment. Three initial compaction treatments (using a two-axle agricultural vehicle with 8 Mg wheel load) were implemented in March 2014: compaction of the entire plot area (i.e. track-by-track), compaction in wheel tracks, and no compaction. After compaction, four post-compaction soil management systems were implemented: bare soil (BS), permanent grass (PG), crop rotation without mechanical loosening (NT), and crop rotation under conventional tillage (CT). BS and PG provide insights into uninterrupted natural processes of soil structure regeneration under reduced (BS) and normal biological activity (PG). The two cropping systems (NT and CT) enable insights into soil structure recovery under common agricultural practices with minimal (NT) and conventional mechanical soil disturbance (CT). A monitoring network was developed for continuous observation of soil state variables related to hydrologic and biophysical functions (soil water content, matric potential, temperature, soil air $O_2$ and $CO_2$ concentrations, oxygen diffusion rates and redox states) as well as periodic sampling and in-situ measurements of infiltration, mechanical impedance, soil porosity, gas and water transport properties, crop yields, earthworm populations, and plot-scale geophysical measurements.

## Utilisation des images aériennes à haute résolution pour documenter et mesurer de l'érosion en agriculture suite à des pluies intenses

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L'érosion des sols diminue à la longue leur fertilité par la perte de particules de terre en surface. Elle peut aussi contaminer les eaux avec des sédiments fins, des éléments nutritifs, et des pesticides. Les problèmes liés à l'érosion sont généralement connus mais les mesures prises pour les limiter sont souvent insuffisantes. De plus, il est difficile d'observer sur le terrain toutes les situations qui engendrent effectivement de l'érosion et de proposer des mesures ciblées en fonction des cas. Les nouvelles technologies telles que l'utilisation d'images aériennes prises par des drones, couplées à l'utilisation des données radar des précipitations offrent de nouvelles possibilités pour documenter ces situations et proposer des mesures préventives ou des solutions. Le projet Air-osion initié par l'Office fédéral de l'Environnement et composé de quatre partenaires (Changins, HAFL, UniBern, HEIA-FR) se base sur ces nouvelles technologies.

Les objectifs de ce projet sont de :

- Développer une méthode d'analyse des précipitations permettant de localiser automatiquement les zones de pluies intenses ;
- Documenter d'une part des événements érosifs linéaires par des mesures de terrain et des images prises avec un drone et d'autre part l'occupation du sol, les pratiques culturales et l'environnement parcellaire ;
- Automatiser une méthode de reconnaissance des rigoles d'érosion à l'échelle d'un agrosystème ;
- Automatiser une méthode de calcul du volume d'érosion et la valider par comparaison avec les mesures de terrain ;
- Établir un système de référence contrôlé pour valider les mesures du drone.

Les événements pluvieux intenses et leur localisation sont annoncés par un système d'alarme par e-mail mis en place pour ce projet. Sur le terrain, des mesures de l'érosion (largeur et profondeur moyenne) sont réalisées sur la longueur de la rigole à intervalles réguliers. La zone d'érosion est également photographiée par un drone.

L'analyse des images est composée de trois étapes. 1) reconstruction d'un modèle numérique pré-érosion basé sur le modèle numérique de surface obtenu suite au vol, 2) création d'un modèle différentiel de profondeur et 3) détection et calcul du volume des rigoles d'érosion. Ces étapes ont été réalisées avec des librairies numpy et openCV du logiciel Python.

La question s'est aussi posée de savoir s'il est pertinent de considérer les mesures manuelles comme des données justes et comparables pour valider cette méthode. Afin de s'assurer de la validité de cette dernière, un système de référence utilisant un laser scanner terre a été testé.

Les différents tests effectués ont permis de définir les conditions d'acquisition des images. Le contrôle visuel comparant la méthode de détection automatique et l'observation des ortho-photos du drone est très concluant. Concernant le volume, une bonne corrélation est observée entre les mesures de terrain et les images de drone. Ces images ont également permis une meilleure compréhension de l'écoulement des flux d'eau de la zone étudiée par rapport à un modèle numérique de terrain à 2 m. En effet, la haute résolution des images permet la prise en compte des traces de tracteur qui influent sur l'écoulement.

A terme, l'optimisation de cette méthode permettra premièrement de déterminer un volume de terre érodée à l'échelle d'une section d'un bassin versant et deuxièmement de mieux comprendre les phénomène érosifs d'une zone étudiée afin de pouvoir prévenir l'érosion par la suite. Enfin, cette méthode permet une meilleure documentation des cas d'érosion multi-rigoles notamment sur de grandes parcelles, comparé aux méthodes manuelles.

## Identification of spatiotemporal patterns of rainfall erosivity as decision support to erosion control in Switzerland

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Rainfall has direct impacts on soil mobilization by rapid wetting or splash and runoff effects and is one of the main driving forces of water erosion. A combination of rainfall amount and intensity is expressed as rainfall erosivity (R-factor) which is one of the five soil erosion risk factors (rainfall erosivity, soil erodibility, slope steepness and length, cover management, and support practices) in the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997; Foster et al., 2008).

As Switzerland has a high spatial and seasonal variation of climate parameters, the correlated rainfall erosivity can be expected to have a regional characteristic and seasonal dynamic throughout the year. The study of these spatio-temporal patterns is decisive in combination with the dynamics of the vegetation cover (C-factor) in order to allow for an accurate soil erosion risk assessment and thus a target-oriented management of agricultural practices and hazard controls.

The intra-annual variation of the R-factor was mapped by a monthly modeling approach to assess simultaneously spatial and monthly patterns of rainfall erosivity (Schmidt et al., 2016). We used a network of 87 precipitation gauging stations with a 10 min temporal resolution to extract the long-term (19.5 years) monthly mean rainfall erosivity ($R_{mo}$). Subsequently, the spatial and temporal pattern of $R_{mo}$ were explained based on a stepwise generalized linear regression (GLM) and significant spatial covariates like snow depth, a combination product of hourly precipitation measurements and radar observations (CombiPrecip), daily Alpine precipitation (EURO4M-APGD), monthly precipitation sums (RhiresM), and topographic parameters (elevation, slope, aspect derived from SwissAlti3D). The monthly R-factor for each month is mapped by summarizing the predicted R-factors of the regression equation and the corresponding residues which are interpolated by ordinary kriging (regression-kriging). Furthermore, we investigated the cumulative percentage of the daily R-factor within a year to assess the annual time period in which rainfall erosivity has its highest proportion.

Monthly rainfall erosivity maps of Switzerland confirm the high seasonality of rainfall erosivity with lowest national means in January (10.5 MJ mm $ha^{-1}$ $h^{-1}$ $month^{-1}$) and highest in August (263,5 MJ mm $ha^{-1}$ $h^{-1}$ $month^{-1}$). Likewise, a high spatial variability can be observed for Switzerland. The cumulative daily rainfall erosivity revealed on a national scale a share of 62% of the total annual rainfall erosivity within the period from June to September. Within the canton Ticino, even 70% was reached within the same period. The high percentage of rainfall erosivity within a short period of time (4 months) is likely to have a large impact on the soil erosion susceptibility since it may coincide with the lowest (after harvesting or grass cutting/ pasturing) and/or most unstable vegetation cover (after late sowing) (Hartwig and Ammon, 2002; Wellinger et al., 2006; Torriani et al., 2007; Prasuhn, 2011).

Our research highlight that rainfall erosivity in Switzerland has a very high variability within months and regions. The findings are of relevance for soil conservation planning and might be a basis for selective erosion control measures, such as a change in crop or crop rotation to weaken the rainfalls impact on soils and vegetation by increasing soil cover or stabilizing topsoil during these susceptible months.

## Analyse des risques d'érosion sur une exploitation agricole

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A l'heure actuelle, de nombreuses exploitations suisses sont sujettes à des dégâts d'érosion. La limite de perte tolérée en terre de 4 tonnes par hectare et par an pour les sols avec plus de 70 centimètre de profondeur est parfois dépassée. Cette quantité de terre fertile perdue est alarmiste pour l'OFAG. C'est pourquoi, une modification des règles concernant l'érosion va être appliquée dès 2017 dans le cadre de l'ordonance sur les paiements directs. En cas d'apparition d'érosion sur son exploitation, l'agriculteur sera dans l'obligation d'entreprendre des mesures sous peine d'être sanctionné par une diminution de contribution. Dans ce contexte une connaissance précise de parcelles les plus à risque et l'établissement d'un plan antiérosif sur l'ensemble de l'exploitation peut s'avérer nécessaire.

L'objectif de ce travail est de développer une méthode d'analyse simple, réalisable par le producteur en vue de déterminer les parcelles nécessitant prioritairement des mesures.

La carte des risques d'érosion prend surtout en compte les facteurs liés au relief. Dans cette étude, l'importance des propriétés des sols liée à leur exploitation a été mise en évidence en s'intéressant particulièrement à la structure du sol d'une exploitation représentative de la Broye Fribourgoise. Cette exploitation se compose de 30 hectares de SAU dont principalement des grandes cultures comme le tabac, la betterave, le maïs et le tournesol. Elle dispose également de vaches mères et de remontes d'engraissement pour un total de 12 UGB. Chaque parcelle a été digitalisée vectoriellement (logiciel QGIS). Les données de la rotation et des analyses de terre ont été inclues dans la table attributaire. Le risque d'érosion moyen donné par la carte des risques d'érosion (ERK) a été calculé. Ensuite, une évaluation visuelle de la structure du sol (VESS, 1 = bon, 5 structure dégradée) en champs a été réalisée sur chacune des parcelles à l'aide d'une bêche, et deux échantillons par parcelle ont été analysés. Enfin, le risque érosif des parcelles a pu être calculé grâce à la clé d'appréciation du risque érosif de la SRVA. Cette clé est plutôt théorique car elle se base principalement sur la topographie, la fréquence d'érosion et la rotation. Toutes ces données ont été mises en commun dans un projet lié à un système d'information géographique afin de pouvoir évaluer et prioriser les zones où seront prises des mesures.

Les résultats récoltés par les différentes méthodes ont permis de repérer les risques qu'encourent certaines parcelles. De manière générale, la rotation joue un grand un rôle sur la structure du sol. Les parcelles de l'exploitation ayant eu de la prairie dans la rotation au cours de ces dernières années ont montré une structure du sol très favorable subpolyédrique fine (note inférieure à 2). De plus, le manque de matière organique s'est fait ressentir sur une parcelle ne contenant que 1 % d'humus et présentant une mauvaise structure du sol (note proche de 4).

Cette étude a permis de constater que la méthode VESS est une approche adéquate pour l'analyse des risques d'érosion. Elle s'est montrée être une méthode facile et rapide, en plus d'être accessible par tout le monde. Des mesures ont été proposées à l'exploitant concernant les parcelles afin de lutter contre l'érosion sur celles présentant un risque.

## Few recurring types of microdomains define smallest units of soil functioning

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Soil aggregation is a key factor for a number of important biogeochemical processes (e.g. soil organic matter stabilization and nutrient and pollutant sorption) in soils. Although there is a large number of studies on the factors controlling such soil processes, it is still challenging to study these processes in-situ. However, it can be assumed that the spatial arrangement of organic and mineral soil constituents in soil aggregates and thus the aggregate structure determine the processes happening at the aggregate scale. Using nanoscale secondary ion mass spectroscopy (NanoSIMS) and a novel digital image processing approach, we extensively analyzed the spatial distribution of ions characteristic for mineral and organic soil components on the micrometer-scale in an intact soil aggregate. We were surprised that 40 spatially independent measurements could be statistically clustered in just two, complimentary types of micrometer-sized domains. Each domain is characterized by a micro-architecture built of a definite mineral assemblage with various organic matter forms and a specific pore system, each fulfilling different functions in soil. Our results demonstrate that the manifold mineral and organic soil components arrange in a limited number of micro-architectures because of self-organization and feedback mechanisms. These microdomains are the smallest units in soil that fulfill specific functionalities.

## Rainfall-induced aggregate breakdown as a determinant of size-selective sediment transport in soil erosion

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Aggregate stability is a major factor in determining soil erodibility under rainfall impact. It controls the dynamics of aggregate breakdown and thus determines the availability of fragments for size-selective sediment transport. Moreover, fine fragments resulting from rainfall-induced aggregate breakdown cause surface sealing, reducing infiltration capacity and thereby promoting surface runoff and water erosion.

We performed two field-plot experiments with artificial rainfall simulation to investigate how initial soil water content (IWC), rainfall intensity (RI) and addition of organic matter affect aggregate breakdown at the surface of an arable soil. In the first experiment, we quantified the temporal dynamics of aggregate breakdown under a very high and a medium-to-high rainfall intensity at dry and wet initial conditions. The fragment size distribution at the end of each respective rainfall event was significantly different among treatments. The results indicate that different aggregate breakdown mechanisms respond differently to the variation in experimental parameters. We propose a model that successfully describes the temporal evolution of fragment mean weight diameter (MWD) as a function of RI, IWC and initial aggregate stability.

In the second experiment, we investigated the influence of organic matter addition on aggregate stability and sediment size characteristics. By adding crop residues to the soil, we created two different initial aggregate stability. The results showed that the soil of the plots with organic inputs (OI) was less erodible than that with no inputs (NI). There was a substantial difference between OI and NI in surface runoff discharge rate and in sediment concentration. The sediment size distribution was dependent on discharge in a transport-limited condition where the runoff transport capacity was not sufficient to carry away all the erodible materials. Suspended particles (<20 µm) were highly enriched in sediments throughout the experiment, whereas for NI there was an increase in the coarse fraction (> 250 µm) towards the end of the rainfall events due to the increasing bed-load transport.

In summary, the results show that it is important to better characterize aggregate breakdown processes and to pay more attention to them in water erosion research.

## Dimensions of preferential flow

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Preferential Flow (PF) in soils is fast, limited to infiltration and occupies just a small portion of porosity.

Hagen-Poiseuille's law is expanded to a viscous flow approach (VF) and applied to fast water content measurements, thus rendering a quantitative PF-characterization with but two parameters. The approach is based on permeable-media flow as a thin laminar film that is completely described with the film thickness $F$ (m) and the vertical contact area $L$ ($m^2\ m^{-3}$) per unit volume of soil between the mobile water and the sessile soil parts. According to VF, $L$ is also the locus of the transfers of water, solutes, particles, and heat during PF.

Input to the soil surface is a pulse with the volume flux density $q$ ($m\ s^{-1}$) that lasts from $T_B$ to $T_E$ (s). Further, the film's wetting front moves vertically down with a constant velocity of

$$v = \frac{Z}{t_W(Z) - T_B} \tag{1}$$

where $t_W(Z)$ (s) is the arrival time of the front at depth $Z$ (m). According to VF is

$$v = F^2 \frac{g}{3 \cdot \eta} \tag{2}$$

where $g$ (= 9.81 $m\ s^{-2}$) and $\eta$ (≈ $10^{-6}$ $m^2\ s^{-1}$) are acceleration due to gravity and kinematic viscosity, respectively. Hence,

$$F = \left( 3 \cdot v \cdot \frac{\eta}{g} \right)^{1/2} \tag{3}$$

The mobile water content $w$ ($m^3\ m^{-3}$) follows from the increase of the volumetric water content θ ($m^3\ m^{-3}$) during the film's passing, while $w < \theta$. Under consideration of (3), $L$ follows from

$$w = F \cdot L \tag{4}$$

The presentation will focus on the basics and the protocol of the VF-methodology. The *F*- and *L*-parameters from over 200 in-situ measurements and from numerous column experiments will be introduced, including the significance of *L* in view of delayed Br-breakthrough. Examples from hydrogeology and neutron radiography will offer preliminary upper and lower limits of the spatio-temporal frame of the VF-approach, while order-of-magnitude considerations will build a bridge from the viscous flow considerations to other approaches of preferential flows in soils.

## Release, biomethylation and biovolatilisation of metals and metalloids in soils. Relevance for biogeochemical cycles and future implications.

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Inorganic pollutants such as arsenic, antimony and mercury can be found at very high concentrations in soils due to human activities (e.g. shooting ranges, industry) but also naturally (e.g. As-rich bedrock). These metals are usually bound to iron and manganese (oxy-)hydroxides under oxic conditions. However, when flooding occurs, they can be released to the pore water by reductive dissolution and become available to microorganisms, plants and animals. Furthermore, once released, they can also be transported to groundwater. This phenomenon is extremely relevant since climate experts predict an increase of extreme weather events, such as flooding, in the future and because many polluted area are situated in floodplains.

Additionally, arsenic, antimony and mercury, once released, can be methylated and volatilised by microorganisms. These two intertwined biological mechanisms are very relevant to the global biogeochemical cycle of each metal but it is also necessary to understand them in order to conduct proper soil pollution assessments. Indeed, microorganisms transform inorganic metals to organometallic compounds (e.g. $Hg^{2+}$ to methylmercury, $MeHg^{+}$) which have different toxicity, mobility and even physico-chemical properties. Unfortunately, these mechanisms are not well understood in soils and this is partly due to a lack of appropriate analytical and sampling methods. It is especially the case for antimony since only very few studies investigated its biomethylation and biovolatilisation although it is a toxic compound often compared to arsenic.

During this talk, new results on the release upon flooding of arsenic, antimony and mercury in contaminated soils as well as the influence of agricultural practices will be shown. Also, new analytical methods to sample and analyse the different methylated and volatile species of these three relevant pollutants will be demonstrated. Finally, we will provide new insights on the importance of biomethylation and biovolatilisation with regards to global biogeochemical cycles and pollution assessment. This research brings together analytical scientists, microbiologists and soil scientists and provides a framework for studying the future consequences of heavy metal pollution in soils.

## Land-atmosphere exchange of Hg - from industrially contaminated sites to remote boreal peatlands and forest ecosystems

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Characterizing magnitude and controls of mercury (Hg) exchange between terrestrial surfaces and the atmosphere is fundamental for assessing Hg global biogeochemical cycling and its risk for environmental and human health. While the quantity of anthropogenic Hg emissions has been continuously updated with reasonable consistency since the 1990s, the estimate of natural emissions is still poorly constrained with a large uncertainty (-513; 1653 Mg $y^{-1}$, Agnan et al., 2016). Therefore, fully understanding the Hg cycling on an ecosystem scale has become our long-term research goal. Here we present results from Hg land-atmosphere exchange studies from both an industrially contaminated site and a remote boreal peatland.

Due to improper Hg discharge from a chemical factory, more than 100 properties in Visp and Raron, Switzerland, contain Hg concentrations above 2 mg Hg $kg^{-1}$ in the topsoil. Emission of gaseous elemental Hg (GEM) was quantified over 9 properties with average soil Hg concentrations ranging from 0.5 to 310 mg $kg^{-1}$ using a novel dynamic flux chamber. The property GEM flux averaged between 38 and 1258 ng $m^{-2}$ $h^{-1}$ and showed a strong and significant correlation with total Hg in soils ($r^2$ = 77 %, $p < 0.01$). Annual GEM emissions projected from all properties (8.6 $km^2$) amount to 4.5 kg and constitute about 0.5 % of the total Hg emissions in Switzerland. Consequently, Hg accumulated in topsoils (~4.9 tons, estimated down to 20 cm depth) may represent a long-term source of atmospheric Hg. Accordingly, remediation measures to reduce GEM emission and the subsequent deposition elsewhere is recommended.

Peatlands are hotspots of Hg transformation. We used a novel micrometeorological system to derive the first annual Hg budget for a remote peatland in Sweden, based on continuous measurement of the peatland-atmosphere exchange of GEM using the relaxed eddy accumulation approach. Here we show that evasion of Hg was eight times greater than stream Hg export, and more than twofold higher than Hg in wet bulk deposition. The net efflux results most likely from recent declines in atmospheric Hg concentrations (Amos et al., 2015) that have turned the peatland from a net sink into a source of atmospheric Hg. The strong Hg evasion suggests that open boreal peatlands and downstream ecosystems will recover more rapidly from past atmospheric Hg deposition than previously assumed. Our next steps will be to assess the largest uncertainties in GEM fluxes which stem from the ocean and forests. This knowledge is of great importance to understand the effectiveness of Minimata Convention on Hg reduction in fish in aquatic systems.

## Green manure and long-term fertilization effects on soil zinc and cadmium availability and uptake by wheat (Triticum aestivum L.) in a Swiss field trial

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Zinc (Zn) deficiency in humans due to imbalanced diets, based on staple foods with low Zn contents, is a global nutritional problem, especially in low-income countries. Cereals containing little Zn are often grown on soils with low phytoavailable zinc concentrations which depend on soil properties such as pH, calcium carbonate, iron and manganese oxides, total zinc and organic matter content (OM). pH, total zinc and OM can be influenced by mineral fertilizer application or organic matter management practises. The current study assessed whether farmyard or green manure application could increase soil Zn availability and wheat grain Zn concentrations (biofortification). The toxic element cadmium (Cd) was also investigated as wheat is a major contributor of Cd to human diets. Clover and mustard green manure (Sinapis alba L. and Trifolium alexandrinum L.) and subsequent wheat growth (Triticum aestivum L.) was studied on split-plots of a field trial managed with farmyard manure (FYM) or mineral fertilizers (NPK) for 65 years. Soil Zn and Cd availabilities were measured by the diffusive gradients in thin films (DGT) method at several wheat growth stages along with dissolved organic carbon (DOC), total free amino acids (TFAA) and soil mineral nitrogen ($N_{min}$) extracted with 2 M KCl. Zn and Cd concentrations were measured in the wheat shoots over the growth period and in the shoots and grains at harvest. Contrary to mustard, clover green manure increased $N_{min}$ concentrations and wheat biomass, however neither increased grain Zn concentrations due to a dilution effect when more biomass was produced. DGT available Zn and Cd increased temporarily after application of farmyard manure because of inputs of available Zn and Cd and after mineral nitrogen fertilization because of exchange of ammonium with Zn and Cd adsorbed to soil particles or due to acidification effects. This resulted in higher grain Zn concentrations on FYM than NPK treated soils. The concentrations of DOC and TFAA which can complex and mobilize soil Zn were also higher in FYM soil at wheat tillering and flowering and positively correlated with DGT Zn and Cd. Furthermore, DGT Zn and Cd concentrations correlated positively with Zn and Cd concentrations in wheat shoots and grains. This study revealed that green manures were ineffective in wheat Zn biofortification in soils containing sufficient available Zn and that temporal dynamics in Zn and Cd availability during wheat growth as affected by fertilization practises are detectable by DGT.

## Field scale Boscalid residues, degradation and half-life estimation in a sandy soil

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The environmental fate of organic pesticides has become focus of research in the last decades and the persistence of several compounds in soil is well documented. However, the fate of Boscalid as a relative new fungicide is not yet completely unraveled.

The aim of this study was to analyze the environmental fate of Boscalid in a sandy soil. Three years after the second application on a cropland site in Kaldenkirchen, Germany, 65 undisturbed soil samples from the plough layer were derived.

Boscalid residues were extracted using Accelerated Solvent Extraction (ASE) and measured with UPLC-MS/MS. The Boscalid residues ranged between 0.12 and 0.53 µg $kg^{-1}$ with a field mean of 0.20 ± 0.09 µg $kg^{-1}$. These results differed considerably from the predicted field concentration of 16.89 µg $kg^{-1}$ (calculated from the application rate) and half-lives ($DT_{50}$) of 104-182 days compared to 345 days reported in literature. Adjusting the extraction efficiency to 20 % could not explain the large difference. Therefore, a laboratory incubation study with $^{14}C$-labeled Boscalid was conducted to measure the $DT_{50}$ under controlled conditions. Here, the $DT_{50}$ values were found to be smaller than stated in literature (297-337 compared to 345 days) but still much larger than the $DT_{50}$ based on the field-study values (104-182 days). Our results indicate that Boscalid dissipation under field conditions is much faster at agricultural sites with sandy soil type as expected from laboratory incubation experiments.

## Uranium in soils, ground- and spring waters in the canton of Berne

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Comparatively high concentrations of U (up to 30 µg $L^{-1}$) were found in a number of drinking water wells in the canton of Berne. Drinking waters are the main source for human U uptake and high drinking water concentrations may have negative consequences for human health. As there is no obvious geological reason for the high U concentrations in the waters, the high concentrations might have an anthropogenic reason. To test the influence of mineral P fertilizers, which frequently show elevated U concentrations, we sampled agricultural sites around 4 drinking water wells with elevated concentrations. Additionally, we conducted tracer experiments to test of the transport of U along preferential flow path, at three soils with different physicochemical properties and monitored U concentrations and $^{234/238}$U activity ratios at two wells for one year. The agricultural surface soils showed elevated U concentrations compared to background (forest) soils, while subsoil concentrations were not significantly different. The $^{234/238}$U activity ratios indicated higher extractability of fertilizer derived U compared to the natural U. The preferential flow path (indicated by brilliant blue) showed no enrichment of U compared to the soil matrix. The U concentrations and $^{234/238}$U activity ratios in the well waters showed very little variations over the year, indicating no seasonal fertilization related leaching. In summary, fertilizer derived U accumulates in the topsoil, but does not seem to significantly migrate to the groundwater. The elevated U concentrations in the wells are probably may be related to specific geological features at the sites.

## Cadmium fluxes in Swiss arable farming systems

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The application of mineral phosphate (P) fertilizer leads to an unintended input of Cadmium (Cd) into arable farming systems. The introduced Cd can be immobilized by the soil, leached into the groundwater or taken up by plants. Cadmium is toxic for plants and humans and can reach a biological half-life of up to 10 years in human bodies. Because of Cd's accumulative characteristics, already low concentrations in edible crop parts can pose a risk for human health. Long-term observations conducted by the Swiss Soil Monitoring Network (NABO) revealed that Cd concentrations in Swiss agricultural soils have not changed in the last decades despite the fact that 45% of the mineral P fertilizers used in Switzerland exceeded the Swiss chemical risk reduction ordinance limit of Cd (FitzGerald & Roth 2015). Consequently, there must be an undetected sink of Cd. The goal of this joint project of the University of Berne, ETH Zürich and the NABO was to quantify Cd fluxes in Swiss arable farming systems in the field and with the help of experiments under controlled conditions.

Cadmium budgets of three arable sites were determined by measuring the soil concentrations and all inputs (bulk deposition, mineral P fertilizers, manure and parent material) and outputs (seepage water, wheat and barley harvest) during one hydrological year (May 2014 - May 2015). Furthermore, Cd cycling in the same soil-plant systems were assessed in a pot experiment using radioactive $^{109}$Cd to trace mineral P fertilizer-derived Cd. Additionally, novel natural abundance stable isotope approaches were applied to the field and greenhouse experiments to trace Cd sources and to elucidate processes of plant physiological Cd cycling.

All three study sites lost Cd, on balance, with the cultivation of wheat and accumulated Cd with the cultivation of barley. Beside the crop type, the major drivers of the Cd budgets were mineral P fertilizers and to a minor extent manure application. Cd concentrations of the applied mineral P fertilizers were below the Swiss average of 67 mg Cd $kg^{-1}$ P (Gisler and Schwab 2012). Recalculations of the Cd budgets with the Swiss average value revealed Cd accumulations for all three sites and both cultivation types (+0.01 to +1.14 g $ha^{-1}$ $y^{-1}$).

Phosphorus fertilizers are a substantial source of Cd to Swiss agricultural systems contributing to long-term Cd accumulation in part of the Swiss arable soils. However, our radio tracer experiments have shown that most fertilizer-derived Cd is not directly taken up by the plant but stored as readily plant available Cd in the soil. To define the fate of this residual of fertilizer derived Cd, the influence of the altered Cd pool on soil-plant fluxes needs to be further investigated. Uptake and retranslocation of Cd in the plant is driven by physiological processes to reduce toxic Cd impacts. These processes result in large stable isotope fractionation of Cd compared to the limited range of isotope fractionation in the Cd sources. Therefore, it is not possible to trace the sources of the plant Cd with stable isotopes precisely. However, Cd stable isotopes might be used for rough estimations to differentiate between anthropogenic and geogenic Cd in arable soils.

## Interaktionen zwischen Mikroorganismen, Bodenstruktur und Phosphorverfügbarkeit

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Phosphor (P) ist ein essentieller Nährstoff für alle Organismen. Durch die Adsorption von Phosphat an der Festphase des Bodens ist jeweils nur ein Bruchteil des gesamten P in Lösung und pflanzenverfügbar. Neben Sorptionsprozessen spielen aber auch Mikroorganismen eine Rolle im P-Kreislauf, insbesondere bei der Mineralisierung von organisch gebundenem Phosphor. In diesem Vortrag wird die Bedeutung der Phosphormineralisierung unter verschiedenen Landnutzungen und Umweltbedingungen gezeigt. Anpassungen von Mikroorganismen an P-Mangel werden anhand von Studien mit Isotopenmarkierung und Sequenzierung funktioneller Gene vorgestellt. In einem Fallbeispiel aus den Tropen wird zudem der Einfluss von Pflanzen auf Bodenstruktur und P-Verfügbarkeit thematisiert. Abschliessend wird diskutiert, welche Bedeutung die vorgestellten Prozesse in Agrarökosystemen haben können.

## Phosphorus (P) balances and P availability in a field trial comparing organic and conventional farming systems.

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The adequate supply with phosphorus (P) is crucial to maintain constant yields in all cropping systems. It remains yet unclear whether P in organic farming systems may become a limiting factor for plant nutrition in the long term.

The DOK long-term field trial was established in 1978 to compare different farming systems. The trial consist of two organic (biodynamic (DYN), bioorganic (ORG)) and two conventional treatments (using farmyard manure plus mineral fertilizer (KON) and mineral fertilizer only (MIN, established in 1985)). In a control treatment (NON) no fertilizer is applied. The fertilization for the organic treatments DYN and ORG is defined on manure production of 1.4 livestock units (since 1992), while before that 1.2 livestock units were used as reference. Fertilization on the conventional treatments KON and MIN is defined by Swiss fertilization guidelines. Treatments DYN, ORG and KON are maintained at full fertilization level (2) as well as halved fertilization level (1) while treatment MIN is only maintained at fertilization level 2. All treatments are maintained with the same crop rotation with a period of 7 years.

An annual P-balance was calculated, based and the input factors 1) fertilization, 2) seeds and 3) deposition and the output factors 4) removal with crop yields and 5) leaching. Factors fertilization and removal with crop yields were based on documentation since trial establishment. Factor seeds was estimated based on documented quantity of used seeds per treatment and factors deposition and leaching were estimated by values available in literature. Additionally, P availability was determined via isotopic exchange kinetics (IEK) experiments after each crop rotation period (7 years). The IEK experiments allow to estimate the rate of P exchange from soil into soil solution and thus to estimate plant P availability over a cropping period.

Main influencing parameters of the P-balance were the factors fertilization and the removal with cropping products. Other inputs (deposition, seeds) and outputs (leaching) were of minor importance for the outcome of the balance for all treatments. For the treatments $KON_2$ and M we observed a slightly positive P-balance of 3 and 6 kg/ha*year, respectively. All other treatments showed a negative P-balance, even in the systems with high fertilization levels ($DYN_2$ and $ORG_2$). The deficit in the P-balance was even more pronounced in the farming systems with reduced fertilizer application rates $DYN_1$, $ORG_1$ and $KON_1$ (-11 to -13 kg/ha*year). The unfertilized control (NON) showed the highest deficit with -19 kg/ha*year. The calculated P-balance suggests that the full fertilization level in treatments $DYN_2$ and $ORG_2$ is not sufficient to mitigate the entire P removal. This deficit is even more pronounced on treatments with less fertilization. In the long term, this fertilization practice may lead to P limitation, especially in the organic treatments.

Phosphorus availability determined by IEK in the top soil (0-20 cm) declined with time in all treatments. This decline may currently already limit crop yield in some farming systems, yet, a redistribution of P from deeper soil layers seems to mitigate this limitation. Additionally, the relatively high P-status in the soil prior to initiation of the DOK trial may currently still buffer against severe P-limitation for plants. The results of this study will be discussed in regard to sustainable P use in different farming systems.

## Nitrogen balances in organic and conventional farming systems: The efficiency-sustainablity dilemma

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Nitrogen balances in long-term field trials provide detailed information on N-supply, N-efficiency and potential for N-loss of the overall system. Additionally, the results of such N-balances can be linked to parameters of sustainable land use such as soil quality. These linkages enable new insights into the evaluation of N-balances and places state of the art knowledge into perspective. The aim of this study was a) to calculate the N-balance of the DOK long-term field trial over a period of 35 years and to derive the nutrient use efficiency (NUE) of each farming system. Additionally, we aimed b) to link the N-balances with changes in the soil N-stocks and the NUE to re-evaluate sustainability indicators.

The DOK long-term field trial (initiated in 1978) consists of two organic treatments (biodynamic (DYN), bioorganic (ORG)) and two conventional treatments, one with farmyard manure and mineral fertilizer (KON), one with mineral fertilizer only (MIN, since 1985). Treatments DYN, ORG and KON are maintained at two levels of fertilization: level 2 equals full fertilization while level 1 equals half fertilization. Treatment MIN is only maintained at fertilization level 2 (MIN2). The long-term field trial is maintained with a seven year crop rotation. For the period 1978-2012 an N-balance was calculated by comparing annual inputs with outputs. The considered input factors were 1) fertilization, 2) deposition, 3) seeds and 4) N derived by symbiotic $N_2$-fixation (Ndfa). In the outputs 5) the removal of cropping products and by-products was considered. Changes in the soil N-stocks were determined based on annual soil analyses for soil depth 0-20 cm and normalised by soil density for 2500 tons of soil per ha.

The N-inputs accounted for approximately 110 (NON) to 300 ($KON_2$) kg N $ha^{-1}$ $year^{-1}$, the N-outputs ranged from 140 (NON) to 250 ($KON_2$) kg $ha^{-1}$ $year^{-1}$. The output was exceeded by the input in treatment NON by 25 kg $ha^{-1}$ $year^{-1}$. In contrast, in the systems at half fertilization level $DYN_1$, $ORG_1$, $KON_1$ and in the treatment with mineral fertilization at the full fertilization level ($MIN_2$) the balances were almost neutral. In the treatments with full fertilization a positive balance was calculated, which resulted in an annual surplus of approximately 33 kg $ha^{-1}$ $year^{-1}$ for treatments $DYN_2$ and $ORG_2$ and surplus of 50 kg N $ha^{-1}$ $year^{-1}$ the conventional treatment $KON_2$. The soil N-stocks were altered accordingly in trial negative or neutral balances: Treatment NON, without any fertilization, lost approximately 30 kg N $ha^{-1}$ $year^{-1}$, followed by treatment $MIN_2$ with full mineral fertilization (20 kg N $ha^{-1}$ $year^{-1}$). Treatments with a halved fertilization treatment lost approximately 16 kg N $ha^{-1}$ $year^{-1}$, in treatments with fully fertilization ($ORG_2$ and $KON_2$) the loss was less pronounced (7 kg N $ha^{-1}$ $year^{-1}$). Only in treatment N no loss in soil N-stocks was observed. The NUE (defined by kg N output per kg N input) resulted in values > 100 % for the not fertilized treatments NON and around 100 % for the treatments at half fertilization level ($DYN_1$, $ORG_1$, $KON_1$) as well as treatment $MIN_2$. For treatments with full fertilization level $DYN_2$, $ORG_2$ and $KON_2$ a NUE of approximately 85 % was calculated. By considering the N-input from soil more realistic NUEs of below 100 % were reached.

The N-balance of the DOK long-term field trial is based on a solid set of data collected over several decades. It is therefore surprising to observe an overall high NUE (81-96 % of the applied N) in all treatments. The treatments with half fertilization as well the treatment with full mineral fertilization ($MIN_2$) showed the aimed neutral N-balances and had the highest NUEs of approximately 93 % of the applied N. We did not observe a difference between organic and conventional farming systems. However, we observed a decrease in NUE with increasingly positive N-balances on the full fertilization level of 85 % for $DYN_2$ and $ORG_2$ and of 81 % for treatment $KON_2$. Soil N-stock losses were most pronounced in treatments with balanced or negative N-balances, in other words, in treatment with lowest risk for N-losses. A sustainable ($DYN_2$) or rather sustainable ($ORG_2$, $KON_2$) soil management practise was thus linked with higher N-losses. The N-loss potential accounted for 34, 39 and 56 kg N $ha^{-1}$ $year^{-1}$ for treatments $DYN_2$, $ORG_2$ and $KON_2$, respectively.

## The C:N:P:S stoichiometry of soil organic matter

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The formation and turnover of soil organic matter (SOM) includes the biogeochemical processing of the macronutrient elements nitrogen (N), phosphorus (P) and sulphur (S), which alters their stoichiometric relationships to carbon (C) and to each other. We sought patterns among soil organic C, N, P and S in data for about 2000 globally distributed soil samples, covering all soil horizons. Included were 350 samples from the forest soil data base of the Swiss Federal Research Institute WSL comprising a representative selection of forest soil types of our country.

For non-peat soils, strong negative correlations ($p<0.001$) were found between N:C, P:C and S:C ratios and % organic C, showing that SOM of soil samples with low organic C concentrations (high in mineral matter) is rich in N, P and S. The results can be described approximately with a simple mixing model in which nutrient-poor SOM has N:C, P:C and S:C ratios of 0.039, 0.0011 and 0.0054, while nutrient-rich SOM has corresponding ratios of 0.12, 0.016 and 0.016, so that P is especially enriched in nutrient rich SOM compared to nutrient poor SOM. The trends hold across a range of ecosystems, for topsoils, including O horizons, and subsoils, and across different soil classes. The major exception is that tropical soils tend to have low P:C ratios especially at low N:C. We suggest that nutrient rich SOM comprises compounds selected by their strong adsorption to mineral matter. The stoichiometric patterns established here offer a new quantitative framework for SOM classification and characterisation, and provide important constraints to dynamic soil and ecosystem models of carbon turnover and nutrient dynamics.

In this presentation, apart from discussing the described general trends, emphasis is laid on a closer inspection of the Swiss forest soil data. As a particularly consistent data subset in terms of methods and comprehensive coverage of soil profiles, it allows for a more detailed analysis, e.g., of small systematic deviations in specific soil types. For example, subsoils of podzolized soils appear to exhibit a weaker enrichment of N when compared to other soil types.

**Reference**

Tipping E., Somerville C.J., Luster, J. 2016. The C:N:P:S stoichiometry of soil organic matter. Biogeochemistry 130: 117-131

## The impact of soil biota on nitrogen losses and nutrient use efficiency - a multidisciplinary approach

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Nutrient loss is a major problem in agro-ecosystems as it not only reduces biodiversity and plant productivity but also significantly contributes to eutrophication of surface water and global warming. However, there is a lack of knowledge about mechanisms which could prevent nutrient losses from ecosystems. In agriculture, there is the need to develop sustainable production systems that support soil biodiversity and ecosystem multifunctionality. In previous studies, our group demonstrated the beneficial effect of soil biota on nutrient uptake and nutrient use efficiency. Moreover, a diverse soil community had the potential to lower $N_2O$ emissions, a greenhouse gas which significantly contributes to global warming. A special role was contributed to arbuscular mycorrhizal fungi (AMF). This group of soil fungi forms a symbiotic relationship with the majority of plant species and plays a critical role in nutrient cycling. In earlier work, we showed the relevance of AMF in the reduction of nutrient losses (e.g. $N_2O$ emissions). As a next step, we build on this knowledge and use a multidisciplinary approach to better understand the mechanisms by which AMF reduce nutrient losses in agro-ecosystems. Microcosms with tomato plants will be set up in the greenhouse using a mycorrhizal and non-mycorrhizal control treatment while manipulating nutrient availability following a similar approach as described in Bender et al. (2014, ISME Journal). Plant yield, various soil characteristics, nutrient cycling as well as soil biodiversity will be tested after three months of plant growth. Gas emissions ($N_2O$, $^{15}N_2$ and $^{15}N_2O$) will be measured following an induced denitrification event and leachates will be collected after a simulated rainfall. Furthermore, will also measure expressions levels of specific genes involved in the nitrogen cycle (e.g. nirK, nirS, nosB and nosZ). We hypothesize that (I) AMF reduce $N_2O$ and $N_2$ emissions, (II) that high nitrogen fertilization levels enhance denitrification rates and (III) also lower AMF abundance, possibly resulting in even higher rates of denitrification. Our results could not only provide new knowledge about the role of AMF in ecosystems but also help designing agricultural production systems in a sustainable way.

## Root growth and plant zinc uptake in response to heterogeneous soil moisture, phosphorus and zinc distribution

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Roots perform many functions that are crucial for plant growth and survival, including the extraction of water and nutrient elements. The distribution of these resources is often very non-uniform in the field soils, also on the scale of individual root systems. In response to this heterogeneity, plant root systems can be quite plastic. Many plants allocated roots preferentially to soil patches enriched in water and nutrients such as phosphorus (P). Little is known about how heterogeneity in soil resources affect root growth allocation and how non-uniform root growth allocation in response to such heterogeneity affects the uptake of other solutes from soil.

In this study we focused on preferential root allocation of some common crop plants, representing different root systems, to different types of lateral heterogeneity in soil moisture, P, and Zn distribution and its effects on the uptake of zinc (Zn), when patches with enrichment in moisture or P in a soil were co-located, disjunct or overlapping with Zn-enrichment. In addition, the potential suitability of neutron tomography (NT) to monitor non-invasively the development of the three-dimensional (3D) root system architecture of seedling was tested and an image processing method was developed. And this method has been put into practice to analyze root growth in response to soil nutrient heterogeneity.

The results show that the morphological responses of root systems to soil moisture and nutrient heterogeneity can vary greatly among different plant species. Preferential root allocation in response to localized enrichment in soil P and root growth responses to heterogeneity in soil texture can have a significant effect on the uptake of heterogeneously distributed Zn, in some plants, e.g. cucumber (for water and P) and wheat (for P), while not affecting it in others, e.g. lupin. The dependence of this plasticity in root growth responses to soil heterogeneity on plant nutrient status in the case of P and Zn indicates that it is subject to plant-specific optimization strategy in foraging for water and nutrients. Root volumes determined by the analysis of NT imaging after the image processing method were closely correlated with the respective values of root length and root biomass determined by conventional root analysis. In response to P and Zn heterogeneity, both the primary roots and lateral roots grew preferentially towards the section enriched with both P and Zn.

The results of this study suggest that further research into root allocation strategies is of great importance to predict how the uptake of nutrients and other solutes by crop plants depends on the heterogeneity of their distribution in soil which in turn can be of great help in breeding new crop plant cultivars and for improving cultivation practices. In addition, for the first time that root growth responses to soil nutrient heterogeneity have been analyzed under in situ conditions using NT.

## Bodenschutz in den Alpen – Verbesserungspotenziale des Bodenschutzprotokolls der Alpenkonvention

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Die Alpenkonvention hat sich grenzüberschreitend die Erhaltung und den Schutz der Alpen unter umsichtiger und nachhaltiger Nutzung der Ressourcen zum Ziel gesetzt. Eine dieser Ressourcen ist der Boden, welche in diesem Rahmen durch das Bodenschutzprotokoll berücksichtigt wird. Als übergeordnetes Rechtsinstrument zielt dieses auf die Verringerung quantitativer und qualitative Bodenbeeinträchtigungen. Hierbei müssen unterschiedliche Nutzungsansprüche ausgewogen berücksichtigt werden. Das Umweltbundesamt hat den deutschen Vorsitz der Alpenkonvention 2015/2016 sowie das Jahr des Bodens 2015 zum Anlass genommen, im Rahmen des Umweltforschungsplans (UFOPLAN) eine Bilanzierung des Bodenschutzprotokolls durchzuführen, was von einem Konsortium um blue! Advancing european projects GbR umgesetzt wurde.

Die Autoren stellen zunächst fest, dass das Bodenschutzprotokoll als übergeordnetes Rechtsinstrument auf nationalstaatlicher Ebene aufgrund einer Reihe an Gründen sehr unterschiedlich umgesetzt bzw. angewendet wird. Ziel der UFOPLAN-Studie war daher Maßnahmen zu identifizieren, mit denen das Bodenschutzprotokoll gestärkt werden könnte. Hierfür wurden sechs Themenbereiche identifiziert.

1. Gemeinsames Monitoring
   Bisher fehlt ein gemeinsames Bodenmonitoring. Gefordert werden hier klare Bewertungsgrundlagen (z.B. Gefährdungskarten, Karten zur Bewertung der Bodenfunktionen) als Arbeitshilfe in der Bewertung und Planung. Hierfür müssten Ziele und Maßnahmen im Bodenschutzprotokoll klarer definiert werden.

2. Anstrengungen zur Reduktion des Flächenverbrauchs
   Der Flächenverbrauch im Alpenraum ist nach wie vor zu hoch. Dies liegt nach Ansicht der Autoren an zu weichen hoheitlichen Standardinstrumenten im Bereich des Bodenschutzes. Hier muss alpenweit das Bodenbewusstsein gestärkt und die Definition eines guten Bodens vereinheitlicht werden.

3. Austausch und Wissenstransfer
   Es fehlt bei den Akteuren alpenweit oft das Wissen, wer sich im Bereich Bodenschutz um welche Projekte kümmert. Wichtig erscheint in diesem Zusammenhang v.a. die stärkere Einbindung lokaler Akteure.

4. Rechtliche und administrative Umsetzung
   Eine von den Autoren bilanzierte unzureichende rechtliche Umsetzung des Bodenschutzprotokolls könnte durch strengere Auslegung und Handhabung bestehender Regelungen verbessert werden.

5. Einbindung in globale Nachhaltigkeits- und Bodenschutzziele
   Es wird von den Autoren gefordert, dass auf Basis der ‚Sustainable Development Goals' der Vereinten Nationen bei der Landnutzung viel stärker der Erhalt der ökologischen Funktionsfähigkeit von Böden berücksichtigt werden muss. ‚Gesunde Nahrungsmittel' können hier als Vehikel in die Öffentlichkeit dienen.

6. Verlinkung von Bodenschutzthemen mit Klimaschutzeffekten
   Der Beitrag von Böden über die Kohlenstoffspeicherung zum Klimaschutz ist Bodenschutzprotokoll nicht ausreichend gewürdigt. Gerade im Rahmen der Alpenkonvention könnte eine Verknüpfung zwischen Bodenschutzaktivitäten und Klimaschutzzielen erfolgen.

Viele der durch das Konsortium angesprochenen Punkte lassen sich durch intensivere Kommunikation zwischen Wissenschaftlern, Verwaltung, Natur- und Bodenschutzverbände, bodenkundlichen Gesellschaften und natürlich die Landwirte und andere Landnutzern (was, so glauben wir, in der Schweiz bereits recht gut funktioniert).

## Bodenfruchtbarkeit erhalten - Erträge steigern - eine Quadratur des Zirkels?

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Böden sind die Grundlage für die Ernährung der wachsenden Weltbevölkerung. Die Nahrungs- und Futtermittelproduktion wird aber durch andere Nutzungsformen wie die Produktion von Faser- und Energiepflanzen zunehmend konkurrenziert. Der enormen Steigerung der Erträge durch eine intensive Landwirtschaft steht die Gefährdung der Bodenfruchtbarkeit gegenüber: Weltweit gehören der Verlust der organischen Bodensubstanz, Erosion, Verdichtung, Versauerung und Versalzung zu den grössten Belastungen des Bodens. Es stellt sich daher die Frage, mit welchen landwirtschaftlichen Praktiken und Systemen sich die Böden verbessern lassen und die Produktion auf lange Sicht gesteigert werden kann. Im Vortrag werden verbesserte Praktiken wie biologischer Landbau, Minimalbodenbearbeitungsverfahren (No-tillage, reduced tillage), organische Düngung und Fruchtfolge einer kritischen Analyse unterzogen. Zudem wird der Einsatz von mikrobiellen Inkulanten zur Ertragssteigerung und Verbesserung der Bodenfruchtbarkeit diskutiert. Ergebnisse von globalen Literaturstudien und eigenen Experimenten zeigen, dass mit biologischem Landbau und Minimalbodenbearbeitungsverfahren Schlüsselindikatoren der Bodenfruchtbarkeit wie die organische Substanz, die mikrobielle Biomasse sowie die Aggregatstabilität gefördert werden. Biolandbau produziert hingegen im Durchschnitt weniger Ertrag, und auch No-tillage führt weltweit gesehen zu geringfügigen Ertragsminderungen. Je nach Kultur und Klimagebiet variieren aber die Ertragsrelationen stark. Dem Anbau von Leguminosen und der Rezyklierung von Ernterückständen zur Ertragssteigerung kommt dabei eine herausragende Bedeutung zu. Auch durch moderne Biotechnologien wie dem Einsatz von mikrobiellen Inokulanten sind substanzielle Ertragssteigerungen durch eine effizientere Düngerausnutzung möglich. Eine jüngst durchgeführte Meta-Analyse zeigt, dass das Ertragssteigerungspotenzial von Inokulanten insbesondere in trockenen und tropischen Klimagebieten gross ist. Die Kombination verschiedener verbesserter landwirtschaftlicher Praktiken erscheint daher ein probates Mittel, Ertragssteigerungen unter gleichzeitiger Schonung der Ressource Boden zu erzielen.

## 1. Local effects of deadwood on soil organic matter composition in an Alpine setting

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Deadwood, an important feature of natural and managed forests, comprises all standing or lying woody residues in a forest. Coarse woody debris (CWD) is referred to residues of larger dimensions: logs, snags and coarse roots. CWD is known to decompose very slowly and can remain on the forest floor for decades to centuries before being completely incorporated into the soil and/or mineralised. Scarce information however is available of how CWD and its decay influence soil properties (in Alpine areas) and vice versa. In this case study we compared soil properties under laying CWD in an advanced decay stage (soft structure, oval section, moss cover) with forest soils that were not covered by CWD. The investigation area is a large coniferous forest in Val di Rabbi (Trentino) in the southern Alpine belt in northern Italy having a subalpine climate. Two sites having a different altitude (1200 and 1400 m a.s.l.) were investigated, both of them at north-exposure. At both sites the forest is dominated by *Picea abies* L. Soil samples were collected at three depths: 0-5 cm, 5-10 cm and 10-15 cm, under dead wood (CWD samples) and on sites having no CWD cover (control samples). Bulk density, pH, C, N and related stocks and the aromaticity and hydrophobicity of the organic carbon using Diffuse Reflection Infrared Fourier Transform (DRIFT) were measured. Soil properties under CWD logs are different to those without CWD. These differences are, however, mostly restricted to the top 5 to top 10cm of soil. The soil under CWD is denser than the soil without CWD. In general, the soil is slightly more acidic with CWD, but only in the first 5 cm of depth. At soil depths of 0-5 cm and 5-10 cm, the carbon and nitrogen content were lower under CWD. Due to the opposite trend of bulk density, the C and N stocks under CWD are not differing. In the top 10cm of the soil, the C/N ratio was mostly higher under CWD. Furthermore, hydrophobicity of soil organic matter was clearly elevated under CWD. The elevation, and thus climatic conditions, only exerted some minor effects on the carbon stocks (higher stocks at the higher elevation) and pH (that decreased with increasing altitude). We conclude that the local effects of CWD in an advanced decay stage are traceable mostly in the top 10 cm of a soil. The CWD, that may lie for several decades on the forest floor, seems to create particular conditions for organic matter decay and the formation of soil organic matter. The stronger hydrophobicity of soil organic matter under CWD, for instance, and the higher C/N ratio indicate qualitative differences that are due to the organic matter input (tannins and lignin by-products derived from the decomposing logs) and different microbial activities, on the other hand. CWD thus may account distinctly for the variability of soil organic matter quality and microbial activity.

## 2. Oxalate-carbonate pathway around Tamarindus indica (Fabaceae)

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The Oxalate-Carbonate Pathway (OCP) is a process by which oxalate, produced by oxalogenic trees, is oxidized by soil oxalotrophic bacteria in interaction with Fungi. This process results in a local soil alkalinization, possibly leading to a long-term soil carbon sequestration. In Madagascar, the OCP was investigated around twelve large-sized Tamarindus indica (Fabaceae). Three soil profiles were dug around each tree. In addition, one profile was sampled 15 m away as a reference soil. Samples from all the different soils were taken at various depths and field evaluations of the $pH_{H2O}$, the grain size distributions, and the carbonate presence were assessed. There are three reference sandy soils, i.e. soils characterized by acidic pH (5.5-6.5), acidic-neutral pH (6.5-7), and alkaline pH (pH=7-7.5). The soil texture under the trees is assumed to be similar to their distant counterparts. Soils influenced by the OCP have a pH around 8. Differences of soil pH between tamarinds and reference soils reach 1 to 2 units. Carbonate was detected mainly under tamarinds, which are associated with reference soils at alkaline pH. This suggests that carbonate precipitation is enhanced in this case, and that the original pH (before OCP settlement) is an important factor accounting for the amount of carbonate accumulation.

## 3. Der Einfluss des Lochsterns auf Erosion und Staunässe im konventionellen Kartoffelanbau? ein Feldversuch in der Region Frienisberg

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In ganz Europa wird zurzeit beobachtet, dass Böden aufgrund des Klimawandels und zunehmender menschlicher Aktivitäten einer wachsenden Gefährdung ausgesetzt sind. Eine Vielzahl von Prozessen wie Erosion, Verdichtung, Desertifikation, Versiegelung und Verschmutzung bedrohen die Böden und stören ihre natürlichen Funktionen. Zum Erhalt ihrer natürlichen Funktionen und der damit verbundenen Dienstleistungen - z.B. Produktion von Nahrungsmitteln, Speicherung und Reinigung von Wasser oder Bindung von $CO_2$ und Nährstoffen - müssen Böden angemessen genutzt und geschützt werden. Im RECARE Projekt (Preventing and Remediating degradation of soils in Europe through Land Care) haben sich 27 Institutionen zu einem multidisziplinären Team zusammengeschlossen, um gemeinsam die aktuelle Gefährdung von Böden einzuschätzen und innovative Lösungen zur Prävention weiterer Bodendegradation in Europa zu finden.

In diesem Zusammenhang wird während zweier Jahre (2016-2017) der Einfluss des Lochsterns (Dyker) auf Oberflächenabfluss, Infiltration, Staunässe, Erosion, Entwicklung der Kulturen und Ernteertrag auf verschiedenen Kartoffelfeldern in der Region Frienisberg untersucht. Hinter der Kartoffelsetzmaschine angehängt, gräbt der Lochstern mit seinen Schaufelrädern Löcher in die Sohle der Furchen zwischen den Kulturdämmen. Die Spitze der “Schaufel” dringt in den Boden ein und wirft im Nachlauf den Boden schräg ab. Die durch den Lochstern erzeugten Löcher sollen die Wasserinfiltration verbessern und dadurch

i) das Wasser in den eigenen Reihen für die Kulturen zurückhalten,

ii) Stauwasser und Vernässung in den Senken verhindern und

iii) den Oberflächenabfluss und damit Erosion minimieren.

Um die Wirksamkeit des Lochsterns im konventionellen Kartoffelanbau erheben und messen zu können, wurden im ersten Versuchsjahr die Kartoffeln auf mehreren Feldern reihenweise abwechselnd mit und ohne Lochstern gesetzt.

Drohnenbilder, Fotos und Vermessungen der Furche zeigen, dass auf Feldern mit einer gewissen Hangneigung (> 5 %) die mit dem Lochstern bearbeiteten Furchen im Verlauf der Wachstumsperiode der Kartoffeln deutlich weniger Erosionsspuren aufwiesen und dass in der Akkumulationszone weniger erodierter Boden abgelagert wurde als bei unbearbeiteten Furchen. Weiter zeigt eine Serie von Drohnenbildern eines Feldes mit einer leichten Senke den Einfluss des Lochsterns auf Infiltration und der damit verbundenen Staunässe. In den Furchen, in welchen der Lochstern zum Einsatz kam, wurde das Regenwasser gleichmässig in den Löchern zurückgehalten, konnte an Ort infiltrieren und floss nicht in der Senke zusammen. Anders in unbearbeiteten Furchen, in welchen sich der Oberflächenabfluss in der Senke sammelte. Durch das gesammelte Wasservolumen wurde die Infiltrationskapazität des Bodens überschritten und das Wasser stand über mehrere Tage in den Furchen. Dadurch entstandenen in den Erddämmen zwischen den unbearbeiteten Furchen anaerobe Bedingungen, in welchen die Kartoffelpflanzen nicht mehr wachsen konnten, was zu einem Ernteausfall führte.

Diese ersten Messungen und Untersuchungen zeigen einen positiven Einfluss des Lochsterns auf Erosion und Staunässe im konventionellen Kartoffelanbau und tragen dazu bei, nach Abschluss der Studie eine generelle Aussage zu der Wirksamkeit des Lochsterns hinsichtlich Bodenfunktionen und Ökosystemleistungen sowie Kosten und Nutzen machen zu können.

## 4. How many spade tests are needed to characterize a field? 1. Case of homogeneous soil

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Spade text is receiving growing interest for the characterization of the soil structure quality, in particular the VESS method (Visual Evaluation of the Soil Structure) (Ball et al., 2007), because it allows fast and inexpensive scoring (Baize et al., 2013) with good relations to physical measurements (Guimarães et al., 2013; Johannes et al., 2016).

However, the sampling requirements are not precisely described. These should be based on spatial variability analysis, but we such results are not available in the literature, so far.

The aim of this study is to provide bases for the design of VESS spade test sampling networks: for a given field, how many spade tests should be performed, and where to locate them. In a first step, the case of homogeneous soil was considered.

A 3.2 ha field belonging to a unique soil and topographic unit was selected. A grazed meadow was seeded in summer 2016 after an autumn wheat crop, and the sampling took place in October 2016.

117 VESS scoring were performed on a stratified random sampling network, out of which 15 spade tests were located under wheel tracks and 15 on the field margins. No statistical difference was observed between the trafficked places and the other spade tests. The average scoring was 2.32, which corresponds to a good structure according to (Ball et al., 2007), in good agreement with the presence of the meadow. The coefficient of variation of the VESS scores was 10 %. The semi variogram of the VESS scores (figure 1) showed no autocorrelation of the scores, which means that in that case the VESS scores are randomly distributed with a small variance.

The number of spade tests required to characterize the field can be calculated from these results, which yields 1, 2, 3, and 12 spade tests for 0.2, 0.15, 0.1 and 0.05 confidence intervals, respectively (Figure 2).

These results are preliminary and apply to a homogeneous field. The estimated number of spade test is small compared to empirical estimations of the literature. In a next step fields showing evidence of spatial heterogeneity (compaction, topography and soil units) will be analyzed similarly.

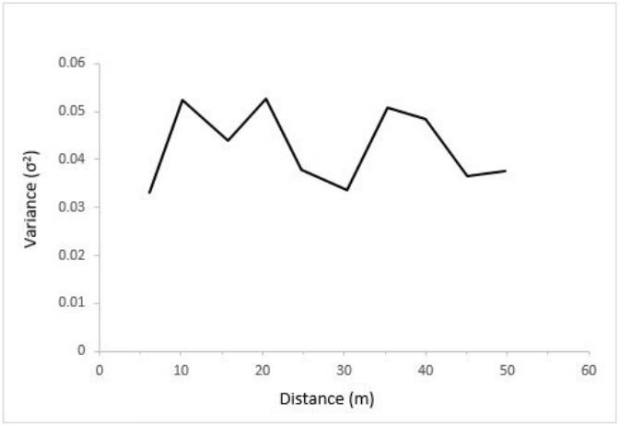


Figure 1. Semi variogram of the VESS scores.

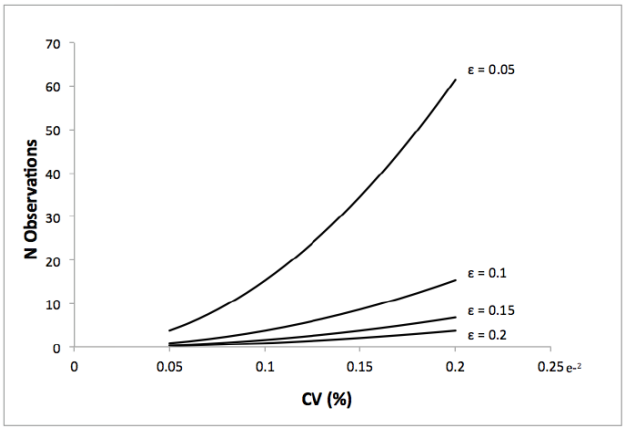


Figure 2. Number of spade tests required according to confidence intervals.

## 5. Präferenzielle Flüsse in Lysimetern

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Ein Lysimeter kontrolliert den Zu- und Abfluss von Wasser und Stoffen eines begrenzten Bodenvolumens. Wäge-Lysimeter ermöglichen zudem die Berechnung der Evapotranspiration durch die Schliessung der Wasserbilanz. Mit zusätzlicher Instrumentierung des umgrenzten Bodenkörpers können Transportvorgänge, wie zum Beispiel präferenzielle Flüsse, räumlich und zeitlich feiner aufgelöst werden. Hydromechanisch betrachtet stellt die Bodenplatte des Lysimeters eine undurchlässige Schicht dar, die im zu vergleichenden ungestörten Boden meistens nicht vorkommt. Die Bedeutung dieses Lysimeterartefaktes ist Gegenstand jahrzehntelanger Diskussionen. Präferenzielle Flüsse im Boden sind schnell, beschränken sich auf die Infiltration, verlaufen im partiell gesättigten Porenbereich und beanspruchen einen geringen Anteil davon. Gelöste Stoffe können mit dem Präferenziellen Fluss rasch in beachtliche Tiefen verlagert werden. Damit gleiten sie zum Beispiel wirkungslos am Wurzelbereich vorbei und können das Grundwasser unbeabsichtigt beeinträchtigen. Das Gesetz von Hagen-Poiseuille beschreibt den laminaren Fluss in konzentrischen Leitbahnen in Abhängigkeit der Viskosität, des Druckgradienten und der vierten Potenz des Radius. Eine Erweiterung dieses Gesetzes beschreibt den Präferenziellen Fluss als dünnen Film, der über geeignete Fliesswege im Boden gleitet. Filmdicke F (im typischen Bereich von 10 bis 100 µm) und das Ausmass der Kontaktfläche L des Films pro Volumeneinheit Boden (im Bereich von 200 bis 2000 $m^2\ m^{-3}$) beschreiben quantitativ den Prozess. So können zum Beispiel gelöste Stoffe aus dünnen Wasserfilmen wegen ihrer weiten Kontaktflächen effizient herausgefiltert werden, was sich unter anderem am verzögerten Tracer-Durchbruch zeigt. Agroscope betreibt seit 2009 eine neue Lysimeteranlage mit 72 Gefässen. Diese enthalten monolithisch entnommene Ackerböden mit einer Oberfläche von 1 $m^2$ und einer Tiefe von 150 cm. 12 dieser Lysimeter sind wägbar und mit diversen Messsonden in verschiedenen Bodentiefen ausgestattet. Der Poster gibt einen Einblick in den Ansatz des Präferenziellen Flusses. Er zeigt mit Beispielen aus den 8-jährigen Messreihen der Agroscope-Lysimeteranlage wie oft und mit welchen Anteilen Präferenzielle Flüsse und schnelle Stofftransporte auftreten. Auch wird vorgeführt, wie das durch die undurchlässige Lysimeterbodenplatte verursachte Artefakt quantitativ zu beurteilen ist.

## 6. Vorkommen und Verteilung von Zirkonium in ausgewählten Böden im Kanton Zürich.

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Trotz seiner Häufigkeit in der Umwelt findet das Element Zirkonium in der Bodenkunde wenig Beachtung. In der Schweiz existieren keine rechtlich bindenden Grenzwerte für Gehalte im Boden, nur Orientierungswerte im Zusammenhang mit einer Gefährdungsabschätzung. In dieser Arbeit wurde Zirkonium aus bodenkundlicher Sicht näher untersucht. In einem ersten Teil wurde mittels einer Literaturübersicht aufgezeigt, aus welchen Quellen Zirkonium stammt, wie es sich im Boden verhält und welche Gefahren von ihm ausgehen. Insbesondere toxikologische Aspekte standen dabei im Vordergrund. In einem zweiten Teil wurde anhand von Oberboden- und Profilproben aus Wäldern im Kanton Zürich untersucht wie der Gehalt von Zirkonium im Boden in Beziehung zu den Parametern Schluff, Boden-pH, organischer Substanz, Bodentiefe und anderen Elementen steht. Weiter wurde die räumliche Verteilung des Zirkoniums analysiert. Ein Teil der Proben wurde neben der Analyse mittels Röntgenfluoreszenz (XRF) auch mittels Königswasser aufgeschlossen und durch ein optisches Emissionsspektrometer mit induktiv gekoppeltem Plasma (ICP-OES) auf den Zirkoniumgehalt hin untersucht. Die Literaturübersicht zeigte, dass Zirkonium ein geringes toxisches Potential besitzt. Weiter kann es sich leicht im menschlichen Körper verteilen und in unterirdischen Pflanzenteilen akkumulieren. Die Analyse der Bodenproben zeigte, dass ein starker Zusammenhang zwischen Schluffanteil und Zirkoniumgehalt besteht. Weiter nimmt der Gehalt an Zirkonium im Boden mit der Tiefe ab. Dies lässt sich einerseits durch die Verwitterungsresistenz erklären, anderseits durch die geringe Mächtigkeit der schluffreichen Lössschichten an den Standorten. Titan und Lanthanoide zeigten eine starke Korrelation mit Zirkonium. Diese Elemente sind mit Zirkon Mineralien vergesellschaftet und ebenfalls sehr Verwitterungsresistent. Die organische Substanz zeigte keine Korrelation mit Zirkonium. Bei tiefem Boden-pH war die Zirkonium Konzentration in den Proben tendenziell höher. Die räumliche Analyse lässt darauf schliessen, dass hohe Zirkoniumwerte im Kanton Zürich in Böden auftreten, die seit der Risszeit eisfrei blieben und auf denen sich aeolische Ablagerungen bilden konnten. Der Aufschluss mittels Königswasser erwies sich als wenig Effizient, es wurde nur zwischen 2.3 und 7.4 % des im XRF gemessenen Zirkoniums im ICP-OES detektiert.

## 7. Verhalten von geogenem Thallium in Böden auf der Erzmatt bei Buus

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Der hohe Eisengehalt und die geringe Fruchtbarkeit des Bodens auf der Erzmatt bei Buus im Baselbieter Jura waren schon seit langer Zeit bekannt. Vor bald 100 Jahren zeigte eine erste wissenschaftliche Arbeit (Truninger, 1922), dass sich der Boden auf der Erzmatt aus einer hydrothermalen Vererzung im Trigonodusdolomit gebildet hat und stark mit Arsen (As) belastet ist. Seit Anfang 2013 wurde das Gebiet der Erzmatt durch das Amt für Umwelt und Energie des Kantons Basellandschaft untersucht (AUE, 2016). Es zeigte sich, dass die Böden auf der Erzmatt (1.5 ha) auch sehr hohe Gehalte an geogenem Thallium (Tl) aufweisen. Auch über die Erzmatt hinaus weisen die Böden deutlich erhöhte Tl- und As-Gehalte auf. Basierend auf der Analyse von Trinkwasser-, Getreide- und Milchproben wurde in Absprache mit dem Bewirtschafter beschlossen, dass die zentrale Erzmatt in Zukunft nicht mehr als Weide genutzt und in eine Dauerbuntbrache umgewandelt wird (AUE, 2016). Das Verhalten von Tl in Böden wurde bis anhin nur wenig untersucht. Aufgrund der hohen Tl-Gehalte bietet sich die Erzmatt für Studien zum Langzeitverhalten von Tl in belasteten Böden an. Zudem bietet der Standort interessante mineralogische Einblicke (Majzlan et al., 2016). In einer ersten bodenchemischen Arbeit haben wir mittels spektroskopischer Röntgenanalysen und chemischer Extraktionen die Form und Löslichkeit von Tl im Boden der Erzmatt untersucht (Voegelin et al., 2015). Die Resultate zeigen, dass Tl in der verwitterten Erzschicht primär in zwei Mineralen vorkommt: als einwertiges Tl(I) in Jarosit ($(K,Tl)Fe_3(SO_4)_2(OH)_6$) und als dreiwertiges Tl(III) in Avicennit ($Tl_2O_3$). Die Aufnahme von Tl(I) im Tonmineral Illit ($K_{0.65}\ Al_{2.0}\ Al_{0.65}\ Si_{3.35}\ O_{10}(OH)_2$) stellt den wichtigsten bodenspezifischen Retentionsmechanismus dar. Aus der Kombination der spektroskopischen und chemischen Daten lässt sich folgern, dass ein grosser Teil des Tl fest in Illit eingebaut ist, was auf das hohe Alter der Kontamination zurückgeführt werden kann, und die relative geringe Verfügbarkeit von Tl in den Böden von Buus erklärt. Nur ein kleiner Anteil (~5 %) des totalen Tl liegt austauschbar an Illit gebunden vor und dürfte die Löslichkeit des Tl im Boden bestimmen. In einer laufenden Doktorarbeit (Kollaborationsprojekt Eawag-PSI, finanziert durch SNF) untersuchen wir die Sorption von Tl an Illit und anderen Bodenmineralien im Labor und in Bodenproben aus Buus. Ziel dieser Arbeit ist, ein quantiatives Modell zur Beschreibung der Löslichkeit von Thallium in belasteten Böden herzuleiten. Eine offene Frage ist, ob erhöhte geogene Tl-Gehalte in Boden oder Grundwasser auch andernorts in der Schweiz auftreten.

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## 8. Bodendaten „à la carte“ und Ökonomie

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Im Rahmen eines Forschungsauftrages des BAFU[1] wurden die Bedürfnisse und der davon abzuleitende Bedarf an Bodendaten auf der Basis bereits existierender Studien und persönlicher Interviews mit Fachleuten erhoben. Die Arbeitsmethodik war auf den „Kundenkontakt“ ausgerichtet. Die Bedürfnisse der Bodendatennutzer wurden mittels Interviews nachfrage- und nicht angebotsorientiert erhoben, um davon in einem nachfolgenden Schritt den konkreten Datenbedarf ableiten zu können. Die befragten Nutzerkreise stammten aus der Praxis, der Verwaltung und der Forschung aus allen relevanten Bereichen, die bereits Bodendaten nutzen oder in Zukunft nutzen könnten.

Das Ergebnis nach der Bewertung der 17 durchgeführten Gespräche und nach Sichtung der neueren Literatur ist eindeutig: In der Schweiz besteht ein grosser und vielfältiger Bedarf an Bodendaten in fast allen durch die Interviews abgedeckten Anwendungsgebieten. Diese Ergebnisse wurden in einer umfangreichen Ergebnis-Matrix festgehalten, die den Datenbedarf für viele Nutzungs- und Anwendungsbereiche detailliert auflistet.

Am häufigsten wurden Attributdaten wie die Wasserhaushaltsgruppe, die Körnung und damit die Bodenart, der Skelettgehalt, die pflanzennutzbare Gründigkeit, zusammen mit dem Boden(-unter)typ, nachgefragt. Meistgenannte Pedotransfer-Funktionen waren die ‚nutzbare Feldkapazität im effektiven Wurzelraum‘, gefolgt von der ‚effektiven Lagerungsdichte‘, den Eckwerten der pF-Kurven sowie der Verdichtungsempfindlichkeit und der Sorptionsfähigkeit für Schadstoffe.

Als Empfehlungen gilt: Für viele Gebiete der Schweiz sind detaillierte Bodendaten mit flächenhaft erhobenen Aussagen erwünscht, z.T. unabdingbar. Punktdaten allein genügen den Ansprüchen der meisten Nutzergruppen nicht. Verlässliche Modellansätze für die Gewinnung von Bodenflächendaten sind in der Praxis noch weitgehend unbekannt. Im Berggebiet erschwert die kleinräumig grosse Heterogenität der Böden die Erfassung von Boden-Daten. Gefragt ist eine „alpin“ ausgerichtete Methodik.

Die Erhebung von Bodendaten gilt als kostenintensiv. Den Kosten sind aber Leistungen und der Erkenntnisgewinn gegenüber zu stellen: Es geht darum, zu eruieren, wieviel die potentiellen Bodendatennutzer bereit sind, für Bodeninformationen aufzuwenden. Zudem stellt sich die Frage, für welche Art von Bodendaten bezüglich räumlicher und inhaltlicher Auflösung das höchste Interesse besteht? Eine Untersuchung des JRC für Bodeninformationen aus dem Jahre 2013 zum Thema Zahlungsbereitschaft WTP (Willingness-to-Pay)[2] kommt zum Schluss, dass die Zahlungsbereitschaft für hoch auflösende, grossmassstäbige und interpretierte Anwenderkarten am höchsten ist. Für solche ‚functional soil maps‘ (nicht zu verwechseln mit Bodenfunktions-Karten) besteht die Bereitschaft, bis zu 450 €/ha zu investieren, also etwa in der gleichen Grössenordnung, wie der Aufwand für eine ha Bodenkartierung in der Schweiz gemäss heutigem Stand der Technik (FAL-Kartiermethode+) beträgt.

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## 9. Bodenfeuchtesensoren, eine brauchbare Alternative zu Tensiometern auf Baustellen?

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Tensiometer spielen eine zentrale Rolle für die Beurteilung der Tragfähigkeit des Bodens auf Baustellen. Gleichzeitig sind Tensiometer relativ wartungsintensiv und bei den meisten Tensiometern, die in der Praxis zur Anwendung kommen, werden die Daten nicht automatisch übertragen. Es stellt sich darum die Frage, ob nahezu wartungsfreie Matrixpotenzialsensoren deren Signale automatisch aufgezeichnet und verschickt werden können, Tensiometer für den Bodenschutz auf Baustellen teilweise oder ganz ersetzen könnten. Aus diesem Grund wurden auf einer Baustelle in Fehraltorf und bei der Bodenfeuchtemessstation in Wädenswil während mehrerer Monate Vergleichsmessungen von PlantCare-Sensoren und UMS-Tensiometern gemacht.

Die bei Bewässerungssteuerungen erfolgreich eingesetzten PlantCare-Sensoren messen das Matrixpotenzial indirekt, indem der Wassergehalt in einem Filz, der mit dem Boden in Kontakt steht, gemessen wird. Dabei setzt man voraus, dass das Matrixpotenzial im Filz dem im Boden entspricht. Der Wassergehalt im Filz wird indirekt über die Abkühlgeschwindigkeit eines Wärmepulses bestimmt, basierend auf den stark unterschiedlichen Wärmeleitfähigkeiten von Luft und Wasser. Die Übereinstimmung der Werte von Tensiometern und PlantCare-Sensoren war in vielen Fällen gut, aber vor allem in Fehraltdorf, reagierten in zwei Situationen nach Niederschlägen die Sensoren teilweise nicht oder nicht vollständig auf die veränderten Bedingungen. In diesen Fällen wäre die Tragfähigkeit des Bodens massiv überschätzt worden. Dieses Verhalten kann die Folge der unterschiedlich grossen Poren des Filzes und des Bodens sein. Wenn die Poren des Filzes deutlich gröber sind als jene des Bodens, kann sich bei sinkender Saugspannung an der Grenze zwischen Boden und Filz eine Kapillarsperre bilden. Die Konsequenz davon ist, dass der Sensor nach einem Niederschlagsereignis eine zu hohe Saugspannung anzeigt.

Dieser Effekt war in Fehraltorf (29T/37U/34S) mit einem schwereren Boden demnach auch wesentlich ausgeprägter als in Wädenswil (21T/34U/45S), wo in dieser Periode keine entscheidungsrelevanten Unterschiede festgestellt wurden. Bei der Bewässerung ist vor allem der Austrocknungsvorgang wichtig. Entsprechend behindern etwas gröbere Poren im Filz verglichen mit dem Boden den Wasserfluss zwischen den beiden Medien nicht. Im umgekehrten Fall, bei der Benetzung, wenn das Wasser vom Boden in den Filz fliessen muss, kann sich jedoch eine Kapillarsperre ausbilden. Diese Kapillarsperre kann bei stark abweichenden Porengrössen den Gleichgewichtszustand verhindern. Um diesen Effekt zu vermeiden hätte der Filz idealerweise die gleiche Porenstruktur wie der Boden Nach den vorliegenden Vergleichsmessungen ist der Einsatz der Sensoren im aktuellen Entwicklungsstand für eine Anwendung im Bereich Bodenschutz limitiert auf leichte bis allenfalls mittelschwere Böden.

## 10. DecAlp ; Une histoire internationale dans les Alpes italiennes (Trentino, IT) à propos de bois mort, de sol et du climat

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Le bois mort joue un rôle important dans la majorité des écosystèmes terrestres (stockage du carbone, biodiversité, stabilisation des pentes). Bien que maillon essentiel du cycle du carbone en milieu forestier, les processus concernant l'intégration du bois mort au sol sont encore largement sous-étudiés. Combinant approches empiriques et expérimentales in situ le long d'une séquence altitudinale reflétant différentes zones climatiques (1000 à 2000 m d'altitude, exposition Nord et Sud), ce projet se concentre sur la décomposition des débris ligneux grossiers (CWD; coarse woody debris) et leur intégration au sol via l'épisolum humifère, sous l'action des organismes vivants et en tant que fonction du climat. Afin de mieux comprendre les différentes échelles spatiales et temporelles impliquées, les activités de recherche inclues dans ce projet peuvent être groupées selon 3 compartiments distincts: (i) débris ligneux grossiers, (ii) formes d'humus et (iii) matière organique du sol. Les questions de recherche sont principalement liées aux sujets suivants : (i) Quels sont les effets du climats sur les processus de décomposition des CWD, et ce particulièrement pour les sols en zones alpines? (ii) Quelles sont les échelles temporelles impliquées dans la décomposition des CWD en tant que fonction du climat? (iii) Quels sont les liens entre les mécanismes de décomposition et la distribution spatiale des formes d'humus? (iv) Dans quelle mesure les formes d'humus peuvent-elles être utilisées pour mieux comprendre la répartition de la faune du sol et effectuer une extrapolation spatiale? De telles connaissances ne peuvent être acquises que grâce à une approche interdisciplinaire où des chercheurs de domaines variés - sciences forestières (WSL), biologie du sol et écologie (département de microbiologie, Université d'Innsbruck ; laboratoire Sol & Végétation, UniNe ; département de géographie, Université d'Osnabrück), foresterie (BOKU, Vienne) et chimie du sol (département de géographie, Université de Zurich) - travaillent ensemble. Un des principaux objectifs de cette collaboration est l'élaboration d'un modèle de décomposition des CWD et de leur intégration dans le sol via l'épisolum humifère. Arrivant à terme, ce projet est actuellement dans une phase de synthèse des résultats obtenus par les différents groupes de travail et les résultats seront communiqués prochainement. Les activités de recherche menées à l'Université de Neuchâtel sont principalement liées à l'étude de la végétation, de la faune du sol (communautés lombriciennes) et aux formes d'humus, spécialement les lignoformes, formes d'humus inféodées au bois mort. Les résultats obtenus dans ce contexte permettent notamment d'approfondir les connaissances des différents types de matière organique du sol. Ces résultats sont aisément transposables aux recherches en cours à la HAFL (groupe « sol ») concernant les matériaux tourbeux en contexte agricole.

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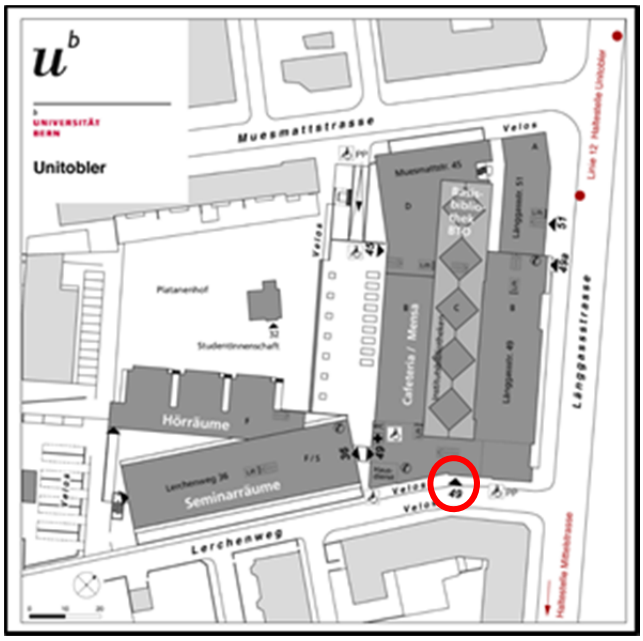


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