# PROGRAM & ABSTRACTS

## International Symposium *on* Soil Organic Matter Dynamics: *Land Use, Management and Global Change*

Colorado Springs, Colorado, USA
July 6-9, 2009

Colorado State University

NRCS
Agricultural Research Service
Natural Resource Ecology Laboratory
Agricultural Sciences
Warner College of Natural Resources
International Plant Nutrition Institute (IPNI)
CSREES
25x'25 America's Energy Future
CCX Chicago Climate Exchange
CMC Carbon Management Center
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International Symposium on

# Soil Organic Matter Dynamics: Land Use, Management and Global Change

*July 6-9, 2009*

*Cheyenne Mountain Conference Center*

*Colorado Springs, Colorado, USA*

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Conference Program

## MONDAY, JULY 6:

8.00-5:00 pm Registration

8.30-3.30 Field trips

5.00-5.10 **Keith Paustian,** Conference Chair

5.10-5.20 **Abad Chabbi,** Past SOM Conference Chair

5.20-5.50 **Gary Peterson,** Past President, Soil Science Society of America

5.50- 6.40 Keynote: **Eldor Paul** "Soil organic matter dynamics: Looking to 2030 on the basis of 200 years of research."

7.00-10.00 Dinner (BBQ) & entertainment

## TUESDAY, JULY 7:

*Plenary session*: Climate and SOM dynamics
**Colorado Room:** Chairs – Peter Grace & Mike Ryan

8.00-8.40: Keynote, **Eric Davidson**: "A conceptual framework explaining the ubiquitous temperature dependence of decomposition of soil organic matter and apparent exceptions to the rule."

8.40-8.55: **R. Conant**: "Synthesis of recent studies investigating the relationship between soil OM lability and decomposition temperature sensitivity."

8.55-9.10: **M. Wetterstedt**: "Temperature sensitivity and substrate quality in needle litter decomposition."

9.10-9.25: **D. Hopkins:** "Soil organic carbon stocks and dynamics in long-term experimental grassland plots."

9.25-9.40: **J. Gillabel:** "Protection of SOM determines the temperature sensitivity of SOM decomposition." (presented by R. Merckx).

9.40-9.55: **M. J. Steinweg**: "Indirect evidence for reduced enzyme turnover under experimental drought at the Boston Area Climate Experiment"

Coffee Break

10.15-10.45: Invited, **Miko Kirschbaum:** "Climate change and SOM dynamics - Direct and indirect effects"

10.45-11.00: **M. Hoosbeek:** "Effect of free atmospheric $CO_2$ enrichment (FACE) on symbiotic $N_2$-fixation and soil carbon content and stabilization in a mixed deciduous stand in Wales, UK"

11.00-11.15: **P. Barré:** "Stable carbon in soils: insights from six long term bare fallow experiments"

11.15-11.30: **C. Rasmussen:** "Geologic control of soil carbon response to climate change: A dynamic interaction of soil minerals, temperature, and litter type"

11.30-11.45: **B. Foereid**: "Modelling changes in organic carbon in the soils of England and Wales"

11.45-12.00: General Discussion

12.00-1.30: Lunch Break

*Parallel Session 1:* Nitrogen and SOM dynamics

**Colorado Room:** Chairs – Paul Fixen & Ron Follett

1.30-2.10: Keynote, **Don Zak**: "Microbial responses to anthropogenic n deposition: Implications for the future functioning of terrestrial ecosystems"

2.10-2.25: **S. Frey:** "Soil organic matter responses to chronic nitrogen additions in a temperate forest"

2.25-2.40 **M. Bradford:** "Is rhizodeposited-carbon an important precursor for SOC? Exploring this question in the context of nitrogen and phosphorus fertilization experiments"

2.40-2.55 **E. Arellano:** "Short-term Effects of Biosolids Application on Nitrogen and Carbon pools in a Loblolly Pine (Pinus taeda L.) Plantation"

Coffee break

3.15-3.45: Invited, **John Grove**: "Fertilizer N and SOC in managed landscapes: Coupled, confounded and confused"

3.45-4.00: **S. Zingore:** "Influence of farmer management practices on soil organic carbon dynamics and maize productivity in smallholder farming systems in NE Zimbabwe"

4.00-4.15: **M. Dodd**: "Soil carbon and nitrogen changes over 20 years on New Zealand hill-country pastures receiving different phosphorus inputs"

4.15-4.30: **P. Eliasson**: "Carbon cost of nitrogen mineralisation in a dynamic forest ecosystem model"

4.30-4.45: General Discussion

*Parallel Session 2:* <u>SOM dynamics in flooded, organic, alpine and high latitude soils</u>
**White River Room:** Chairs – Jürg Fuhrer & Maury Mausbach

1.30-2.10: Keynote, **Jens Leifeld**: "Organic matter in soils of cold and wet ecosystems - anything different?"

2.10-2.25: **I. P. Harley:** "Plant-soil interactions, positive priming effects and patterns of soil C storage in arctic Sweden"

2.25-2.40 **C. Stewart:** "The influence of plant species on soil organic matter chemistry in Hawaiian soils"

2.40-2.55: **A. Koelbl:** "Development of bulk density and of total C and N distribution during paddy soil evolution."

Coffee Break

3.15-3.45: Invited, **Genxing Pan**: "Soil organic matter dynamics of rice paddies of China"

3.45-4.00: **R. Singaravel:** "Role of organic matter in sustaining fertility and productivity of problem soils of coastal ecosystem."

4.00-4.15: **L. S. Da Silva:** "Methane emissions by flooded soils from Rio Grande do Sul State, Brazil."

4.15-4.30: General Discussion

*Parallel Session 3:* Biofuels, SOM and net GHG balance

**Cheyenne Room:** Chairs – Stephen Ogle & Henry Janzen

1.30-2.10: Keynote, **Phil Robertson**: "Flies in the biofuels ointment: The complementary roles of SOM and nitrous oxide"

2.10-2.25 **M. Dondini:** "$^{13}C$ dynamics in soil aggregates across a soil profile under an established Miscanthus crop"

2.25-2.40 **H. Gollany: "**Simulating soil organic matter dynamics and effects of residue removal using the CQESTR model"

2.40-2.55 **N. Amougou:** "Management of *Miscanthus giganteus*: Impact on amount and quality of plant litters and their biodegradability in soil."

Coffee Break

3.15-3.45 Invited, **Bill Parton**: "Impact of biofuel cropping systems on greenhouse gas fluxes"

3.45-4.00 **B. VandenBygaart**: "Crop residue removal and fertilizer N: Effects on soil organic carbon on a long-term crop rotation experiment in a Udic Boroll."

4.00-4.15 **L. Ma**: "Long-Term Corn Stover Removal Effects on Soil Organic Carbon Dynamics as Simulated by RZWQM2"

4.15-4.30 **G. Velu:** "Potential of cellulose-producing actinomycetes from termite ecosystem in bioethanol production."

4.30-4.45: General Discussion

5.00-7.00: **Poster Session** (Poster Session is open throughout the Symposium, however, authors are requested to be present 5-7 PM)

7.00-8.30: Dinner

8.30-10.00: Informal workshop on global and national SOM networks

**White River Room**

## WEDNESDAY, JULY 8:

*Plenary session*: SOM, soil disturbance and tillage
**Colorado Room**: Chairs – Gary Peterson & Rich Conant

8.00-8.40: Keynote, **Roel Merckx**: "Soil tillage and carbon sequestration – The elusive link"

8.40-8.55: **J**. **Álvaro-Fuentes**: "Current and future soil carbon sequestration in semiarid Mediterranean conditions: quantifying management and climate effects."

8.55-9.10: **F. Matus**: "Carbon content in subtropical and temperate soil physical fractions as indicators of organic matter saturation."

9.10-9.25: **P. Gottschalk**: "Simulation of soil organic carbon response at forest-cultivation sequences using $^{13}C$ measurements."

9.25-9.40: **C.H. Lee:** "Effect of long-term fertilization on soil organic carbon accumulation and microbial community structure in rice paddy soil."

9.40-9.55: **G. Alberti:** "Effects of land use change and reduced tillage on the greenhouse gases balance in an Italian agro-ecosystem from Italian agricultural areas."

9.55-10.10: **M. Spohn**: "Impacts of land use on TOC, Chwe, carbohydrates, glomalin and water-stable aggregates in Gleyic Podzols and Haplic Gleysols – Analysis of a 220-year chronosequence."

Coffee Break

10.30-11.00: Invited, **D. Angers**: "Tillage and soil organic C: digging deeper into the soil."

11.00-11.15: **B. Sarapatka:** "Organic matter in the soil of pasture land with various intensity of use."

11.15-11.30: **I. Handayani: "**Soil organic matter pool dynamics following field succession in Sumatra, Indonesia."

11.30-11.45: **A. Swan:** "Socioeconomic and environmental factors that influence adoption of no-till in the Great Plains."

11.45-12.00: General Discussion

12.00-1:30: Lunch Break

*Parallel Session 4:* SOM and soil depth – controls on C and N balance
**Colorado Room**: Chair –Abad Chabbi

1.30-2.10: Keynote, **Cornelia Rumpel**: "SOM in deep soil horizons: what do we know about its participation in C and N cycles?"

2.10-2.25: **P. Baldrain:** "Transformation of soil organic matter by fungi and their extracellular enzymes in forest soils is controlled by soil depth and fungal community composition."

2.25-2.40 **E. R. Toosi:** "Evaluation of some chemical and spectroscopic parameters during the biodegradation of soluble organic matter."

2.40-2.55 **I. De Troyer:** "Large effects of land management on dissolved organic matter in surface layers of agricultural soils are attenuated at larger soil depth."

2.25-3.10: **M. Steffens:** "Stabilisation of soil organic matter in complete soil profiles of semiarid steppe soils after grazing cessation."

Coffee Break

3.30-4:00: Invited, **Bernd Marschner**: "Sensitivity of subsoil organic matter turnover to inputs of labile substrates."

4.00-4.15: **J. P. Croue**: "Structural properties of dissolved organic carbon in deep horizons of an arable soil"

4.15-4.30: **T. Eglin:** "Why is deep soil carbon old? A modelling approach." (presented by P. Barré)

4.30-4.45: **M. Braakhekke:** "Towards explicit representation of the vertical soil organic matter profile and surface organic layers in soil carbon models."

4.45-5.00: **J. Meersmans:** "Modelling the depth distribution of soil organic carbon, in relation to land use and soil type at the regional scale in northern Belgium."

5.00-5.15: **E. Blagodatskaya:** "Three sources partitioning of $CO_2$ efflux from soil to evaluate mechanisms of priming effects."

5.15-5.30: **S. Anusontpornperm:** "SOM and total nitrogen balance in soils after changes from forest to agriculture in humid subtropical highlands of Thailand."

5.30-5.45: **M. Sanaullah:** "Root-derived carbon and nitrogen turnover and stabilization in different soil fractions at major soil horizons."

5.45-6.00: General Discussion

*Parallel Session 5:* Soil C quantification for GHG accounting

**Cheyenne Room:** Chairs – Olof Andrén & Bill Parton

1.30-2.10: Keynote, **Steven Ogle**: "Quantifying soil organic c stock changes for GHG inventories: Approaches, uncertainties and future challenges"

2.10-2.25: **J-F. Soussana:** "Drivers of soil C sequestration in European grasslands inferred from flux measurements."

2.25-2.40 **B. van Wesemael:** "Dealing with uncertainties in extrapolating SOC data for regional inventories."

2.40-2.55 **S. Wuest:** "The importance of bulk density independent sampling for soil C quantification."

2.55-3.10: **G. Zirkle:** "Modeling carbon sequestration in home lawns."

Coffee Break

3.30-4.00: Invited, **Brian McConkey:** "Quantifying carbon change in Canadian cropland for greenhouse gas reporting."

4.00-4.15: **B. Kusumo:** "Measuring carbon dynamics in field soils using soil spectral reflectance: Prediction of maize root density and soil carbon content."

4.15-4.30: **I. Schöning:** "The effect of forest management on soil carbon stocks."

4.30-4.45: **A. Peressotti:** "Spatial application of DNDC biogeochemistry model and its potentiality for estimating GHG emissions from Italian agricultural areas."

4.45-5.00: **L. West:** "The National Cooperative Soil Survey and soil organic carbon inventories"

5.00-5.15: **R. C. Izaurralde**: "Simulating SOM dynamics and denitrification-nitrification processes with the EPIC model."

5.15-5.30: **E. Lokupitiya:** "Estimation of carbon cycling in croplands using SiBcrop model."

5.30-5.45: **C. Kome:** "Comparison of COMET-VR and SCI as Carbon Assessment Tools."

5.45-6.00: General Discussion

*Parallel Session 6:* SOM - global & regional perspectives

**White River Room**: Chairs – Jorge Etchevers & Gene Kelly

1.30-2.10: Keynote, **Daniel Hillel**: "An overview of soil, carbon, and climate change."

2.10-2.25: **U. Hamer**: "Land-use induced dynamics of soil organic matter and nitrogen in mountain soils of South Ecuador"

2.25-2.40 **M. Wattenbach:** "The carbon balance of European croplands: a trans-European, cross-site, multi model simulation study." (presented by P. Gottshalk)

2.40-2.55 **B. Wilson:** "Opportunities and barriers for the estimation and prediction of soil carbon at State and catchment scales in New South Wales, Australia."

2.55-3.10: **J. Wäldchen:** "Effects of historic forest management on carbon stores in soils in the Hainich-Dün Region, Central Germany."

Coffee Break

3.30-4.00: Invited, **C. E. P. Cerri**: "SOM - global and regional perspectives: a regulatory compartment of GHG levels in the atmosphere."

4.00-4.15: **S. Ghosh:** "Impact of land use variation on soil C change in different agricultural soils in NW New South Wales, Australia."

4.15-4.30: **S. Evans:** "The effect of precipitation and land use on carbon pool dynamics in Inner Mongolia, China."

4.30-4.45: **R. Kelly:** "Differential impacts of grazing and fire on central U.S. grasslands C and N balance under current and projected climate and atmospheric $CO_2$."

4.45-5.00: **M. A. Liebig:** "Grazing effects on net global warming potential in mixed grass prairie."

5.00-5.15: **J. Fuhrer:** "Cropland conversion to grassland: increasing or decreasing soil organic carbon?"

5.15-5.30: General Discussion

7.00-10.00: Social Dinner

## THURSDAY, JULY 9:

*Plenary session*: Developments in SOM characterization methods – what do they tell us about SOM dynamics? **Colorado Room:** Chair – Phil Sollins, Denis Angers

8.00-8.40: Keynote, **Ingrid Kögel-Knaber**: "SOM and soil architecture: developments in characterization methods.

8.40-8.55: **D. Curtin:** "On the use of physical fractionation methods to isolate the labile portion of soil organic matter."

8.55-9.10: **L. Mayer:** "Photodissolution of soil organic matter."

9.10-9.25: **M. Beare:** "Effect of extraction temperature on the composition and biodegradability of water-extractable soil organic matter."

9.25-9.40: **F. J. Calderon**: "Changes in mid-infrared spectral properties of soil fractions during incubation"

9.40-9.55: **G. P. Olchin:** "Modeling saturation and protection mechanisms of soil organic matter."

Coffee Break

10.15-10.45: Invited, **Johannes Lehmann:** "High spatial variability of soil organic matter detected by synchrotron-based spectroscopy."

10.45-11.00: **S. Sleutel:** "Organic matter in sandy cropland soils studied by combined density fractionation and pyrolysis field ionization mass spectroscopy"

11.00-11.15: **H. Throckmorton:** “Carbon turnover from diverse microbial groups in temperate and tropical forest soils.”

11.15-11.30: **M. Thevenot:** “Fate of lignins in soils: a review.”

11.30-11.45: **M. Kaiser:** “Separation of mineral associated organic matter from arable and forest topsoils by sequentially combined physical and chemical steps of fractionation.”

11.45-12.00: General Discussion

12.00-1.30: Lunch Break

*Plenary session*: SOM and SOM research in 2030 (invited speakers only)
**Colorado Room**: Chair – Eldor Paul

1.30-2.10: Keynote, **Henry Janzen:** “SOM research in 2030: what scientists then might ask of us now.”

2.10-2.50: Keynote, **David Schimel:** (Title TBA)

2.50-3:00: Discussion

3:00-3:30 Conference summary and adjournment: **Ron Follett**

# Oral presentations

## Plenary Session:

## "Climate and SOM Dynamics"

**A conceptual framework explaining the ubiquitous temperature dependence of decomposition of soil organic matter and apparent exceptions to the rule**

Eric Davidson

*The Woods Hole Research Center, USA*

Conceptual and numerical models of decomposition of soil organic carbon (SOC) often assign degrees decomposability, ranging from labile to recalcitrant substrates, which roughly correspond to ranges of turnover times, from fast to slow. However, this conceptual continuum confounds the effects of complex molecular structures of substrates with other factors that also slow rates of decomposition, such as physical and chemical protection of substrates in soil aggregates and on mineral surfaces. Hence, SOC can be old for a variety of reasons. This confusion has clouded related issues, such as the temperature dependence of decomposition of SOC. Decomposition of old SOC is sometimes reported as unresponsive to temperature, whereas Arrhenius kinetics dictate that decomposition of complex molecular structures should have high activation energies (high temperature dependence). I review the evidence for temperature sensitivity of decomposition of soil organic matter. I also offer a conceptual model that links Arrhenius and Michaelis-Menten kinetics to show that low substrate supply at microsites of enzymatic activity can obscure the temperature sensitivity dictated by Arrhenius kinetics. Enzymatic processes are always temperature dependent, and that dependence varies with chemical structure, but substrate availability at reactive sites also affects the net response of enzymatic activities to temperature. Combining Michaelis-Menten and Arrhenius kinetics with heterogeneous substrate supply provides a framework that is consistent with both basic principals, as we understand them, and observations of a significant fraction of SOC that cycles slowly.

**Synthesis of recent studies investigating the relationship between soil OM lability and decomposition temperature sensitivity**

Richard Conant, Eldor Paul, Matt Wallenstein

*Natural Resource Ecology Lab, Colorado State University, USA*

The question of how temperature sensitivity of soil organic matter (OM) decomposition varies with its lability is likely to be a main determinant of whether soils act as a sink or source for atmospheric $CO_2$ under the climate of the future. This question is unaddressed in leading climate-carbon models, masking a potentially large source of uncertainty with substantial implications for changes in soil carbon stocks. Kinetic theory suggests that biochemically complex OM substrates that normally resist decomposition should be more sensitive to temperature than labile substrates that decompose quickly. The wide variety of approaches have been employed to investigate this important issue have led to seemingly contradictory results. However, when stratified by the turnover time of soil OM being evaluated, the results suggest that studies investigating soil OM that turns over most slowly find results consistent with kinetic theory. We use this synthesis to identify knowledge and methodological gaps, and propose a path we think will be most fruitful for future investigation.

**Temperature Sensitivity And Substrate Quality In Needle Litter Decomposition**

Martin Wetterstedt, Tryggve Persson, Göran Ågren

*Department of Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden*

Kinetic theory suggests that the temperature sensitivity of decomposition of soil organic matter (SOM) will increase with increasing recalcitrance. This temperature-quality hypothesis was tested in a laboratory experiment. Microcosms with spruce needle litter were placed at 5, 15 and 25 ºC until the same cumulative amount of $CO_2$ had been respired. Thereafter, microcosms from each single temperature were moved to a second set of incubation temperatures of 5, 15 and 25 ºC. When compared at the same temperature, litterS pre-incubated at 5 and 15ºC had significantly higher cumulative respiration in the second incubation than litters initially placed at 25ºC, indicating a higher degree of stabilisation despite equal mass loss. $Q_{10}$ was always higher for the temperature step between 5 and 15ºC than between 15 and 25ºC. In agreement with the temperature-quality hypothesis, Q10 tended to increase with increasing degree of decomposition. The $Q_{10}$ measured immediately after the temperature switch upwards was significantly higher from that of two samples compared at constant different temperatures. In conclusion, the study yielded results that both supported and rejected the temperature-quality hypothesis. The non-supportive results might be explained by re-synthesis of stabilised organic matter, but need further studies.

**Soil Organic Carbon Stocks and Dynamics in Long-Term Experimental Grassland Plots**

D. Hopkins[1], I. Waite[2], T. O`Donnell[2]

[1]*Scottish Crop Research Institute, Dundee, UK*
[2]*University of Western Australia*

Concerns about the volatility of soil organic C (SOC) and the potential contribution it could make to atmospheric carbon dioxide, particularly under warmer climate conditions, have focussed attention on sites with long-term (decades or centuries) stable management and reliable baseline data which can be used to make accurate assessments of any changes. The Palace Leas Meadow Hay Plots in north-east England, UK, established in 1897, is the second oldest grassland experiment in the world and they have received known and constant management including fertilizer and manure applications ever since. Systematic, replicated measurements of the SOC and total N contents and the bulk densities were made in the 1980s for six contrasting plots at 3 cm depth increments down the profile to enable accurate estimates of SOC and N stocks to be made on an areal basis. We repeated these measurements in 2006 to enable a thorough examination of any changes in the amounts and distribution of SOC free from confounding influences of land-use change and uncertainties associated with the use of derived (rather than measured) bulk densities. There have been no consistent differences in the SOC stocks during the 20+ year sampling interval despite a detectable increase in soil temperatures over the same period. Measurements of SOC mineralization during laboratory incubation for 200 days and determination of soil microbial biomass indicated that the distribution of microbial activity differed between the plots, but these factors did not contribute to changes in the overall SOC stocks of the soils. The absence of consistent changes in SOC may suggest that any changes in SOC mineralization as a result of elevated soil temperature have been insufficiently large to be detected; or that feedback processes, such as increased primary production or partitioning of plant biomass below ground, have off-set any increases in SOC mineralization; or that the estimation of small changes in SOC stocks has been confounded by the spatial heterogeneity of the soils. The data also highlight the importance of bench-mark sites under stable management and with reliable base-line data for long-term monitoring of SOC, especially in an environmental change context.

**Protection of SOM determines the temperature sensitivity of SOM decomposition**

Jeroen Gillabel[1], Johan Six[2], Roel Merckx[1]

*[1]Dept. Earth & Environmental Sciences, K.U.Leuven, Belgium*
*[2]Agroecology Lab, UC-Davis, CA, USA*

Assessment of the impact of climate change on SOM storage relies on our understanding of the factors that determine temperature sensitivity of SOM decomposition ($Q_{10}$). SOM quality has been identified as a major controlling factor for $Q_{10}$, with lower quality SOM having higher $Q_{10}$. However, the effect of SOM protection as substrate limiting factor on $Q_{10}$ is much less investigated and understood. Still, the hypothesized attenuating effect of SOM protection can be important, especially in subsoils where SOM is generally of lower quality, but also better protected than in topsoils. Recently, we observed an attenuating effect of SOM protection on $Q_{10}$ in the subsoil of an agricultural soil profile. Here, we use Q10 and soil fractionation data of four soil profiles to confirm the previously observed attenuating effect, and to test whether $Q_{10}$ attenuation can be explained by variations in C distribution among SOM pools providing different levels of SOM protection. Investigated soils were formed on different parent materials and had textures varying from sandy loam over silt loam to silty clay. Soil was taken at different depths (down to 1 m), resulting in a total of 12 different soil samples. These samples were incubated at 25ºC and 35ºC for one year, with respiration rates measured frequently. $Q_{10}$ values were determined for different fractions of respired soil C, allowing the assessment of temperature sensitivity for SOM of decreasing quality. Furthermore, SOM is being fractionated into protected and unprotected pools. For topsoil samples, $Q_{10}$ values increased with decreasing SOM quality, while $Q_{10}$ values did not change or decreased with decreasing SOM quality for subsoil samples. This confirms our previous observation that the SOM quality effect on $Q_{10}$ was attenuated in the subsoil. SOM stability, the result of SOM quality and SOM protection, is expected to correlate positively with $Q_{10}$ only when SOM quality is the dominant factor for stability. For the most labile respired C, no correlation was found between $Q_{10}$ and SOM stability (determined as the inverse of the cumulative percentage C respired at 25ºC), while $Q_{10}$ of the most recalcitrant respired C correlated negatively with SOM stability. This suggests that SOM protection is an important controlling factor for stability. Results of correlations of $Q_{10}$ values with the amounts of C stored in either protected or unprotected pools will be presented at the symposium, and will allow for a more detailed understanding of how SOM protection can control temperature sensitivity.

**Indirect evidence for reduced enzyme turnover under experimental drought at the Boston Area Climate Experiment**

Megan Steinweg, Matthew D. Wallenstein

*Natural Resource Ecology Lab, Colorado State University, USA*

Currently there is little consensus on how soil organic matter decomposition will respond to climate change over the long-term. Moisture and temperature are key drivers of SOM decomposition rates, however it is not clear how changes in these drivers will affect the degradation of different soil compounds over the long-term with new climate regimes. Soil enzyme activity is a relevant metric of soil community function since it is related to decomposition of specific substrates in soil. Enzymes are released in response to what nutrients an organism needs as well as what is available in the soil matrix. We collected soils from the Boston Area Climate Experiment (BACE), an old field site located in Waltham, MA. There are three precipitation treatments and four temperature treatments arranged in a full-factorial design with three replicates. Precipitation treatments began in June 2007 while warming started in July 2008. Soils were collected in June 2008, August 2008 and January 2009, roots removed and stored at -80°C until enzyme analysis. Enzyme assays for β-glucosidase, cellobiohydrolase, xylosidase, N-acetyl glucosamidase, and leucine amino peptidase were performed at 15, 25 and 35°C using fluorescent substrates. These enzymes are involved in the cycling of carbon, nitrogen, and phosphorus in the soil. There was no effect of warming on enzyme activity, however the drought treatment decreased microbial biomass but significantly ($p<0.05$) increased activity of several enzymes in both August 2008 and January 2009 compared to control plots. Since enzyme activity is measured as potential activity, it is an indicator of the enzyme pool size. An increase in activity under drought could be due either to increased enzyme production, or decreased turnover rates. Under drought, the diffusion of enzymes, substrates and products is constrained and microorganisms may have increased enzyme production to compensate for lower specific enzyme activities. Alternatively, there may have been decreased enzyme turnover in the colder months leading to an increase in enzymes remaining from August which were more sensitive to warmer temperatures. The temperature sensitivity of enzyme activity was higher in the reduced precipitation treatment in January 2009. The increased temperature sensitivity could be explained by increased production of enzymes in late summer and a decrease in turnover during the winter, since enzymes produced during the summer generally have higher temperature sensitivities. These results indicate that precipitation reduction due to climate change may lead to increases in enzyme activity and soil organic matter decomposition.

## Climate Change and SOM Dynamics - Direct and Indirect Effects

Miko Kirschbaum

*Landcare Research, New Zealand*

Heterotrophic respiration has a strong temperature dependence. It thereby poses the potential danger of responding strongly to climate change, and in turn exert its own effect on the climate. If soil carbon is released with warming, the additional $CO_2$ in the atmosphere could lead to further global warming. However, despite the conduct of much experimental work, and repeated publication of summary articles, there is still no scientific consensus on the temperature dependence of heterotrophic respiration. Even when there is agreement on the basic processes, their inclusion in a predicted overall response to external perturbations, such as climate change, remains challenging. Generic response patterns to specific changes, such as warming, have therefore proven to be difficult to generate. Changing substrate availability is a particularly important interaction. If substrate supply changes during the course of measurements, or in response to specific treatments, it can greatly confound the apparent dependence on external drivers, such as temperature. There is a further important interaction between short-term temperature dependence of heterotrophic respiration and seasonally varying temperatures. It can modify the strong temperature dependence expressed in short-term studies into a weaker temperature dependence when it is integrated over longer time periods. Temperature also interacts with water limitations. In general, as temperature increases, systems are more likely to become limited by water stress. Even in systems where annual rainfall exceeds annual evapotranspiration, there may be periods of water shortage, and such periods are likely to intensify with increasing temperature. While warming with unchanging water limitations is expected to increase heterotrophic respiration, the pattern is less clear once interactions with changing water limitations are taken into account. There is a further interaction with nutrient limitations. If soil carbon is lost because of stimulation of heterotrophic respiration relative to the rate of carbon input, soil nutrients are mineralised. In nutrient limited systems, this will stimulate plant productivity, thereby increase carbon inputs into the system and help to stabilise carbon stocks. The converse occurs in systems that receive extra carbon inputs, such as due to $CO_2$ stimulated increases in productivity. In such systems, responses to $CO_2$ can be curtailed by nutrient feed-backs mediated via soil organic matter dynamics. This paper tries to discuss and summarise these key interacting processes and provide an assessment of the likely overall response of SOM dynamics to climate change. Part of that assessment will try to highlight current key knowledge gaps and uncertainties.

**Effect of Free atmospheric $CO_2$ enrichment (FACE) on symbiotic $N_2$-fixation and soil carbon content and stabilization in a mixed deciduous stand in Wales, UK.**

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Forest soils are hypothesized to become carbon sinks under increasing atmospheric $CO_2$ concentrations. Free air $CO_2$ enrichment (FACE) experiments have demonstrated increases in net primary production (NPP) and C storage in forest vegetation due to increased atmospheric $CO_2$ concentrations. However, the fate of this extra biomass in the forest floor or mineral soil is less clear. In addition, some combination of increased N uptake from the soil and/or more efficient use of the N already assimilated by trees is necessary to sustain increased rates of NPP under FACE. In 2004 a FACE experiment was initiated in a mixed deciduous stand near Bangor, Wales. Four ambient $CO_2$ and 4 FACE plots were planted with patches of Betula pendula, Alnus glutinosa and Fagus sylvatica and patches in which species were mixed. After four years of $CO_2$ treatment, only a shallow L forest floor litter layer had formed. Most above ground litter was incorporated in the mineral soil by bioturbation. We observed a decrease of leaf N content of Betula and Alnus under FACE, while the soil C/N ratio decreased irrespective of $CO_2$ treatment. We infer that increased N-use efficiency rather than increased N uptake from the soil is the mechanism by which increased NPP is sustained under FACE. Alnus assimilated N by taking it up from the soil and through symbiotic $N_2$-fixation. But the $N_2$-fixation / soil N ratio was not affected by FACE, i.e. Alnus growing in elevated $CO_2$ did not use the extra available NPP (labile C) to increase symbiotic $N_2$-fixation in order to meet the higher N demand under higher NPP. Total soil C and N contents increased irrespective of treatment and species as a result of land use change, i.e. due to afforrestation. We could not detect an additional C sink in the soil under increased $CO_2$ treatment. And, soil C stabilization processes were not enhanced under increased $CO_2$ treatment either. These results are compared to other temperate forest FACE experiments with respect to forest floor litter and SOM dynamics.

**Stable carbon in soils: insights from six long term bare fallow experiments**

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Understanding and modelling the dynamics of Soil Organic Carbon (SOC) with high turnover time is crucial to quantify and predict the ability of soil to sequester carbon. Long term bare fallow experiments, where organic C inputs are essentially zero for an extended period of time, are particularly relevant to investigate SOC with long turnover time. We have gathered a unique dataset combining soil, plant and climatic data monitored on six sites presenting different pedo-climatic conditions: Askov (Denmark), Kursk (Russia), Rothamsted (UK), Ultuna (Sweden), Grignon (France) and Versailles (France). We observed that SOC content is still significantly decreasing in all of these bare fallow experiments, even after a long period of time (50 to 80 years). The initial C content and land use strongly affected C dynamics. We then modelled SOC dynamics in bare fallow and adjacent control (cropped or grassland) plots using the ecosystem model ORCHIDEE, whose soil carbon module is derived from CENTURY. ORCHIDEE successfully reproduced carbon stock dynamics under both control and bare fallow plots for the six sites. The decomposition rates of SOC pools in control and bare fallow plots across sites allowed us to discuss the relative impact of land-use history and climate and textural parameters on labile and more stable soil carbon pools.

**Geologic control of soil carbon response to climate change: A dynamic interaction of soil minerals, temperature, and litter type**

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Temperate forest soil organic carbon (C) represents a significant pool of terrestrial C that may be released to the atmosphere as $CO_2$ with predicted changes in climate. To address potential feedbacks between climate change and terrestrial C turnover, we quantified forest soil C response to litter type and temperature change as a function of soil parent material. We collected soils from three conifer forests dominated by ponderosa pine (PP; Pinus ponderosa Laws.); white fir (WF; Abies concolor (Gord. and Glend.) Lindl.); and red fir (RF; Abies magnifica A. Murr.) from each of three parent materials, granite (GR), basalt (BS), and andesite (AN) in the Sierra Nevada of California. Field soils were incubated at their mean annual soil temperature (MAST), with addition of native $^{13}C$-labeled litter to characterize soil C mineralization under native climate conditions. Further, we incubated WF soils at PP MAST with $^{13}C$-labeled PP litter; and RF soils at WF MAST with $^{13}C$-labeled WF litter to simulate a migration of MAST and litter type, and associated change in litter quality, up-elevation in response to predicted climate warming. Results indicated that total $CO_2$ and percent of $CO_2$ derived from soil C varied significantly by parent material, following the pattern of GR>BS>AN. Regression analyses indicated interactive control of C mineralization by litter type and soil minerals. Soils with high short-range-order (SRO) mineral content exhibited little response to varying litter type, whereas PP litter enriched in acid-soluble components promoted a substantial increase of extant soil C mineralization in soils of low SRO mineral content. Climate change conditions increased soil C mineralization greater than 200% in WF forest-soils. In contrast, little to no change in soil C mineralization was noted for the RF forest-soils, suggesting an ecosystem specific climate change response. The climate change response varied by parent material where AN soils exhibited minimal change and GR and BS soils mineralized substantially greater soil C. This study corroborates the varied response in soil C mineralization by parent material and highlights how the soil mineral assemblage and litter type may interact to control conifer forest soil C response to climate change.

**Modelling Changes in Organic Carbon in the Soils of England and Wales**

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The National Soil Inventory (NSI) of England and Wales originally sampled in 1980 and a proportion re-sampled between 1995 and 2003. This data showed consistent, large losses of carbon across land uses and soil types over the period of the NSI. The main causes were probably changes in land use and management over the preceding decades. But there is also the possibility that climate change was involved to some extent. In this study, we use the process-based model DAYCENT to test how much of the losses could potentially be caused by climate change given the model's assumptions and underlying understanding of carbon turnover in the relevant soil types. We use data on national soil properties held in the LandIS database, daily weather on a 50 km grid provided by the Joint Research Centre, and simple management scenarios appropriate for the major land use categories in England and Wales. We first fitted the initial distribution of soil carbon into pools to force the model to reproduce observed losses. We then ran the model with climate from before the first sampling, and compared the results to those obtained using actual climate.

# Oral presentations

## Parallel Session 1:

## “Nitrogen and SOM Dynamics”

**Microbial Responses to Anthropogenic N Deposition: Implications for the Future Functioning of Terrestrial Ecosystems**

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Soil harbors a phylogenetically diverse community of microorganisms whose physiological activity mediates the biogeochemical cycling of carbon and nitrogen (N) at local, regional, and global scales. These microbial communities are structured by the physical environment as well as the availability of growth-limiting resources (i.e., organic compounds in plant detritus). Presently, human activity is manipulating both the physical conditions and the availability of limiting resources to soil microbial communities at a global scale, but the implications of doing so for the future functioning of ecosystems is presently unclear. In this presentation, I will discuss the ways in which humans are manipulating the ecological constraints on microbial communities in soil, the compositional and functional responses that may result, and identify gaps in our knowledge that limit our ability to anticipate the response of microbial communities and ecosystem processes in a changing environment. Using a long-term, field experiment as an example, I will provide evidence that rates of atmospheric N deposition expected in the near future can down regulate the transcription of fungal genes with lignocellulolytic function, thereby significantly altering microbial community composition, slowing plant litter decay, and increasing soil C storage. This mechanism is not portrayed by any biogeochemical model simulating ecosystem response to atmospheric N deposition, and it demonstrates that microbial communities in soil may respond to a changing environment in ways that have unanticipated consequences for the future functioning of terrestrial ecosystems.

**Soil Organic Matter Responses to Chronic Nitrogen Additions in a Temperate Forest**

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This past year marked the 20th anniversary of the Chronic Nitrogen Addition Experiment at the Harvard Forest Long-term Ecological Research site in Petersham, MA, U.S.A. Started in 1988, the Chronic N experiment is an investigation into the effects of increasing anthropogenic atmospheric N deposition on forests in the eastern United States. Located in an old red pine plantation and a mixed hardwood forest the treated plots have received 50 and 150 kg $N/ha^{-1}/yr^{-1}$, as $NH_4NO_3$, in six equal monthly applications during the growing season each year since the start of the experiment. Additionally, the control and low N treatments were given a single pulse label of $^{15}NO_3$ and $^{15}NH_4$ in 1991 and 1992. Regular measurements have been made over the past 20 years to assess woody biomass production and mortality, foliar chemistry, litter fall, and soil N dynamics. Less frequent measurements of soil C pools, soil respiration, fine root dynamics, and microbial biomass and community structure have been made. For the 20th anniversary, an intensive sampling campaign was carried out in fall 2008 with a focus on evaluating how the long-term N additions have impacted ecosystem C storage and N dynamics. Our primary objective was to assess the amount of C and N stored in wood, foliage, litter, roots, and soil (to a depth of ~50 cm). We also wanted to examine the fate of N by comparing patterns of $^{15}N$ recovery to those observed previously. An additional objective was to further examine how chronic N additions impact microbial biomass, activity and community structure. Results to date indicate that chronic N additions over the past 20 years have increased forest floor mass and soil organic matter across the soil profile; decreased microbial biomass, especially the fungal component; and altered microbial community composition (i.e., significantly lower fungal:bacterial biomass ratios in the N amended plots).

**Is rhizodeposited-carbon an important precursor for SOC? Exploring this question in the context of nitrogen and phosphorus fertilization experiments**

Mark Bradford

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Global changes such as elevated atmospheric $CO_2$ concentrations and nitrogen (N) transport are altering the input rates of carbon (C) and N to soils. The resulting changes in C and N availabilities alter the magnitude of the imbalance between soil organic carbon (SOC) decomposition and formation processes, thereby affecting total SOC contents. However, we cannot reliably explain varying responses of SOC stocks in different environments to increased inputs. For example, positive, aboveground plant productivity responses to N fertilization may not necessarily translate to greater SOC stocks in grasslands and forests, although they do in annually-cropped systems. This may be because the majority of plant-C in non-cropped systems enters mineral soils via roots. Evidence suggests that of the root-C entering these soils, the dominant input is in the form of labile-C compounds (i.e. rhizodeposition). Undoubtedly, some of this rhizodeposited-C will be incorporated into SOC. I first describe two field and laboratory studies where factorial N and phosphorus (P) fertilization is coupled with SOC fractionation and stable isotope techniques. I use these examples to demonstrate that divergent effects of N and P, on the decomposition and formation of shorter- and longer-term pools of SOC, may in part be explained by fates of labile-C inputs to soils. I next describe a field N by P fertilization experiment where isotopically-enriched glucose and glycine, representative rhizodeposits, are added at realistic input rates and concentrations across the growing season. I report the fate of these simulated rhizodeposits in particulate organic matter and mineral-associated SOC fractions. As much as 76 and 36% of the C in the added glucose and glycine, respectively, is retained in the SOC. The majority of the C from these inputs enters the mineral-associated fraction. Added singularly, N and P fertilizer amendments do not alter the absolute amount and/or partitioning of the labeled C that forms SOC. However, together N and P fertilization significantly reduce the amount of labeled C in both SOC fractions. I discuss alternate mechanistic explanations of the fate of the glucose and glycine. The work shows that labile C compounds, despite their rapid turnover rates in situ, are not necessarily lost from soils. Instead, a substantial portion of the input enters SOC fractions of differing sink strength, and this portion is dependent on the identity of the compound. Furthermore, the impact of N fertilization on the fate of these compounds is strongly dependent on P availability.

**Short-term Effects of Biosolids Application on Nitrogen and Carbon pools in a Loblolly Pine (*Pinus taeda* L.) Plantation**

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Application of biosolids as an alternative source of N is becoming a common silviculture practices on pine forest. However, little is known about how biosolids type, application rate, and timing affect forest floor and soil N and C pools in loblolly pine plantations. The objectives of this study were to determine changes in C, N, Ca, and pH in the forest floor and mineral soil following surface application of biosolids. The study was established in a 17-year-old loblolly pine plantation in Amelia County, VA. Anaerobically digested (AD225), lime stabilized (LS225), pelletized (Pellet225) biosolids, and a conventional inorganic urea plus diammonium phosphate fertilizer (U+DAP225) were applied at a rate of 225 kg $ha^{-1}$ Plant Available Nitrogen (PAN) between March $5^{th}$ and $10^{th}$, 2006. Anaerobically digested biosolids were also surface applied at the rates of 900 kg PAN ha-1 and 1800 kg PAN $ha^{-1}$ (AD900 and AD1800). Anaerobically digested biosolids at the rate of 900 kg PAN $ha^{-1}$ were also applied on November $5^{th}$, 2005 (AD900F). 2 years after application, biosolids applied at the rate of 225 kg PAN $ha^{-1}$ had little effect on the average total N and C in the forest floor and mineral soil. The average total N in the forest floor in the AD225 treatment was 1005 kg $ha^{-1}$, 935 kg $ha^{-1}$ in the Pellet225, 852 kg $ha^{-1}$ in the LS225, 398 kg $ha^{-1}$ in the U+DAP225, and 331 kg $ha^{-1}$ in the control. Forest floor total C was greater than the control in the AD225 and the LS225 treatments. The average total C in the forest floor was 20900 kg ha-1 in the AD225, 21995 kg $ha^{-1}$ in the LS225, 17864 kg $ha^{-1}$ in the Pellet225, 14420 kg $ha^{-1}$ in the U+DAP225, and 12050 kg $ha^{-1}$ in the control. The application of biosolids significantly reduced C:N in the forest floor and the surface mineral soil in comparison to the control. Total Ca and pH significantly increased in the forest floor in the AD225 and LS225 treatments in comparison to the other treatments. There was no significant biosolids type effect on extractable Ca in the mineral soil. Soil pH significantly changed over time after application of biosolids. Higher application rates of biosolids significantly increased forest floor N and C accumulation. The average total N in the forest floor was 1005 kg $ha^{-1}$, 2075 kg $ha^{-1}$, and 3199 kg $ha^{-1}$ in the AD225, AD900, and AD1800 treatments, respectively. The average forest floor total C in the AD1800 treatment was 33051 kg $ha^{-1}$. The AD900 and the AD225 had 28672 kg $ha^{-1}$, and 20900 kg $ha^{-1}$, respectively. Total N in the AD1800 was greater than the AD225 and AD900 through all the soil profile. Season of application of biosolids did not significantly affect the forest floor. Soil total C and extractable Ca were greater in the AD900S than in the AD900F. Biosolids have the potential to be use as a source of N to improve tree growth. However, when biosolids were surface applied at the permitted rate of 225 kg PAN $ha^{-1}$, low impact on soil total N and C were detected. Increasing application rates increased N movement through the soil profile, with no effect on soil carbon.

**Fertilizer N and SOC in Managed Landscapes: Coupled, Confounded and Confused**

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Plant and microbial biomass formation stoichiometrically couple N and C – overlapping otherwise disparate biogeochemical cycles. Inputs of N are common in managed landscapes. Managed landscapes are characterized by greater N and C flows, both in and out. Prior to extensive N fertilizer inputs, outflows generally exceeded inflows. Other carbon oxidative agricultural practices (tillage and drainage) both predate, remain coincident, and are confounded, in time, with greater fertilizer N use in many agricultural landscapes. Soil amendment with fertilizer N is a relatively recent addition to the agricultural toolbox. Confounded management practices can confuse interpretations of fertilizer N:SOC investigations. In April, 2008 soil samples were taken, in 10 cm increments to a depth of 1 m, from four replicates of a 38 year long comparison of sod and monoculture maize (Zea mays L.), with a winter cereal cover crop, under no-tillage (NT) or moldboard plow (MP) management, at N application rates of 0, 168, and 336 kg N/ha. Without N addition, SOC loss was the same, regardless of tillage, though agronomic response data suggest depletion was slower under NT. At the agronomically appropriate N rate, SOC was somewhat greater, especially when NT reduced the oxidative force of the soil environment. At the excessive N rate, SOC was much greater, especially with NT. At this level of N input, maize residues exhibit lower C:N ratios and the coincidence of residual inorganic N with cereal cover crop seeding provided opportunities for greater autotrophic and heterotrophic biomass formation. The literature indicates that N addition to N responsive crop-soil situations often, but not always, results in greater autotrophic biomass. Greater inorganic N availability in N depleted soil environments often, but not always, results in greater heterotrophic biomass. The durability of newly formed organic compounds is largely independent of continued inflows of inorganic N and C. The fate of these compounds fates the C and N they contain. Evidence indicates that outflows still exceed inflow in many situations. Fertilizer N stimulates crop productivity, but much fixed carbon, and immobilized nitrogen, leaves the field. Within a given environment, microbial transformations of substrates tend to conserve N, relative to C. Inputs of N to managed landscapes may, at times, offer opportunities for greater SOC formation, if the manager can couple inorganic N and C inflows to cause more autotrophic, and/or heterotrophic, biomass formation. Maintenance of SOC in managed landscapes requires that the land manager understand (manipulate) these temporal opportunities.

**Influence of Farmer Management Practices on Soil Organic Carbon Dynamics and Maize Productivity in Smallholder Farming Systems in NE Zimbabwe**

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Improved understating of long-term impact of differential resource management practices on soil organic C (SOC) is required to develop interventions for sustainable soil fertility management in African smallholder faming systems. Access to organic resources differs substantially among farmers in NE Zimbabwe, and this has implications of variability of SOC and crop productivity within smallholder farming landscapes. We applied a dynamic model (FIELD) to explore short- and long-term consequences of different strategies for use of fertilizer and manure on long-term SOC, soil N supply and available P on sandy and clay soils. FIELD simulated a rapid decline in SOC and maize yields when native woodlands (FZ1) were cleared for maize cultivation without fertilizer inputs coupled with removal of crop residues (to mimic in-situ grazing). This is typical management on plots belonging to poor farmers without cattle and plots distant from homesteads on wealthy farms, resulting in a zone of depleted soils (FZ4) that covers 55% of the area under cultivation in the case study village. Yield responses generated by FIELD showed a succession of constraints to crop production with decreasing SOC, increasing the complexity of soil fertility management options required to increase productivity. On the sandy soil, insignificant maize response to fertiliser application was predicted below a critical SOC content limit of 0.5%. The extremely low SOC contents on the FZ4 of the sandy soil were associated with multiple constraints to maize productivity, including multiple nutrient deficiencies, high acidity and low water availability. Applications of at least 10 t manure $ha^{-1}$ $yr^{-1}$ for about 10 years were required to restore maize productivity to the yields attainable under FZ1. Long-term (>30 years) application of manure at 5 and 3 t $ha^{-1}$ resulted in SOC levels comparable to zones of high (FZ2) and medium (FZ3) soil fertility observed on farms of cattle owners. Targeting manure application to maintain SOC at about 60% (sandy soil) and 50% (clay soil) of contents under native woodlands was necessary to achieve 90% yield attainable under FZ1. The dilemma for restoration of soil fertility is that poor farms with the most depleted fields and the smallest areas of land are also the ones without access to manure. Preventing degrading systems under cultivation is difficult, particularly in low input farming systems, and attention should be paid to judicious use of the limited nutrient resources to maintain levels of soil fertility that support good crop response to fertilizer application.

**Soil Carbon and Nitrogen Changes Over 20 Years on New Zealand Hill-Country Pastures Receiving Different Phosphorus Inputs**

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Recent measurements on New Zealand lowlands have demonstrated unexplained soil C and N losses over a 20-25 year period. To determine whether these losses were also occurring in hill country pastures, we analyzed archived soil samples collected between 1983 and 2006 at the Whatawhata Research Centre in the Waikato Region. Soil samples (0-75 mm) had been collected from easy (<15 deg) and steep slopes in paddocks that were fertilized with six different loading rates of P (ranging from 0 to 100 kgP/ha/y since 1985), the primary limiting nutrient for grass-clover pastures in these hill country farms. The range of P fertilizer treatments allowed us to test whether P inputs would regulate changes in soil C and N. While there were significant temporal changes in C and N ($P<0.05$), these were not unidirectional and rates of change were not dependent on P loading rate. On average, soil C initially increased during the first 6 years of the trial at 1.56 t/ha/y and 1.06 t/ha/y on easy and steep slopes, respectively. Over the subsequentl 17 years, there was no significant change in soil C on the easy slopes but soil C declined at 0.45 t/ha/yr on the steep slopes. Similarly, soil N increased between 1983 and 1989 at 144 kg/ha/yr and 82 kg/ha/y on easy and steep slopes, respectively. Post-1989, small but significant losses of total N were measured on the steep slopes of 27 kg N/ha/y ($P<0.05$) with no change on the easy slopes. Two potential causal factors for these decadal-scale patterns are identified, operating via the mechanism of changes in primary productivity. These were a change in fertilizer type, and a series of relatively dry summers during the 1990s. These significant inter-annual changes of soil C and N will complicate attempts to measure long-term changes in soil organic matter associated with land use change and management practices.

**Carbon Cost of Nitrogen Mineralisation in a Dynamic Forest Ecosystem Model**

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This presentation investigates the interactions of carbon (C) and nitrogen (N) mineralisation under the assumption that increasing availability of N in litter may interfere with turnover rates of soil organic matter (SOM). In order to test the above, we implemented into the Q plant-soil model a flexible sensitivity mechanism allowing decomposer efficiency to depend on soil N availability, thus acting on rates of C and N mineralisation. The simulated effect of N-fertilisation under flexible decomposer efficiency was a less positive response of tree growth than when decomposer efficiency was fixed. Experimental data from the literature, showing a decline in tree growth response to a series of fertiliser applications, support the results. Simulations with flexible decomposer efficiency where N was deposited in small annual doses over a century resulted in less ecosystem C storage compared to runs where decomposer efficiency was fixed. The explanation to the less C storage capacity under flexible decomposer efficiency is that the flexibility mechanism feeds back on the inputs and outputs of soil C with two opposing effects: (i) more N becomes retained in the soil instead of contributing to plant growth, leading to a reduction of both tree growth and litter input; while (ii) soil heterotrophic respiration declines due to increasing decomposer efficiency, however not enough to sufficiently balance the lower soil C store resulting from declining litter input. One explanation to the weaker than expected growth response to N fertilisation could be a shift in the microbial community towards more efficient microorganisms having a higher demand on N. The response strength in terms of ecosystem C storage to N depends on initial N status in the soil. Therefore, the amount of N retained in the ecosystem appears to be one key issue for evaluation of how the ecosystem C sink responds to additional inputs of N.

# Oral presentations

# Parallel Session 2:

# “SOM Dynamics in Flooded, Organic, Alpine and High Latitude Soils”

**Organic Matter in Soils of Cold and Wet Ecosystems - Anything Different?**

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Soil organic matter (SOM) dynamics in cold and wet ecosystems is far less well understood than that of soils in warm-temperate ecosystems. This is in sharp contrast to their significance in the global carbon cycle given the huge amounts of organic matter globally accumulated for example in peatlands or high latitude soils. Recent evidence suggests that permafrost soils alone may store as much carbon as temperate and tropical soils together. Under cold and wet conditions rates of elemental cycling often are small owing to the unfavourable conditions for organic matter turnover and, partially, plant growth. Global warming and land-use change are supposed to alter the amount of carbon stored in cold and wet ecosystems. In case of peatland drainage and permafrost collapse, also the role of these soils as a source for methane and thus their greenhouse gas balance becomes affected. Despite naturally low carbon cycling or accumulation rates, the response of SOM in cold and wet ecosystems to changing environmental conditions is often rapid with SOM loss rates exceeding those from mineral soils in warmer climates sometimes by orders of magnitude. In the case of peatland fires, this may lead to catastrophic events. Taken together, feedbacks are possibly strong, thus making these ecosystems potential hotspots in terms of climate change. Predicting the fate of SOM in cold and wet soils by using SOM turnover models requires a deepened understanding of those processes that keep the carbon in soil. In this paper, the focus is on SOM dynamics in cold high latitude/altitude soils and peatlands and these systems are discussed in view of three hypotheses: Soils in high latitude / alpine regions and peatlands are rich in SOM due to retarded decomposition Their SOM is labile They are particularly vulnerable to global environmental change

**Plant-Soil Interactions, Positive Priming Effects and Patterns of Soil C Storage in Arctic Sweden**

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With global warming predicted to alter the distribution of different plant communities across the planet, it is extremely important to improve our understanding of how the whole plant-soil system controls patterns of soil C storage. In arctic Sweden, as one moves from mountain birch forest into the surrounding tundra-heath, the amount of C stored below ground increases as the organic soil horizon deepens. Over the coming decades, the treeline is expected to advance, making it important to understand how soil C cycling is controlled in these ecosystems. During the mid-20$^{th}$ Century, nuclear weapons testing released $^{14}C$ into the atmosphere, providing a global tracer that can age the $CO_2$ released from plants and soils. We used $^{14}CO_2$ measurements to investigate whether the age of C released from vegetated plots, and clipped and trenched (CT) plots (i.e. a treatment which limits the input of recently-fixed C), changed with seasonal shifts in plant activity and temperature. On the heath the mean age of C respired from the control plots ranged from 4 to 6 years old, while the $CO_2$ released from the CT plots was older, ranging from 5-11 years old. In the forest, the mean age of C respired from the control plots ranged from 1 to 6 years old, with the $CO_2$ released from the CT plots again being older (4-9 years old). Therefore, overall, the C respired from the heath system was slightly older. At the tundra-heath site, as expected the difference in the age of C respired from the control and CT plots was greatest mid-season, during the period of peak photosynthesis, reflecting the contribution of recently-fixed C in the control plots. In contrast, in the birch forest, the difference between the two plot types in terms of the age of respired $CO_2$ was smallest mid-season, despite plant activity in this ecosystem also peaking at this time. To explain this result, in the vegetated birch forest plots, the decomposition of older, $^{14}C$-enriched soil C must have been stimulated mid-season. Such positive priming effects may explain the thinner organic horizon in the forest, and leads to the suggestion that tree encroachment into the heath could increase the decomposition of older organic matter resulting in an overall loss of soil C.

**The influence of plant species on soil organic matter chemistry in Hawaiian soils**

Catherine Stewart, Jason Neff

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Soil organic matter (SOM) inherits much of its chemical structure from the dominant vegetation, including phenolic (lignin-derived), aromatic, and aliphatic (cutin and wax-derived) compounds. Soils may either inherit plant tissue characteristics that influence soil decomposition and turnover rates through litter quality and decomposition or have a similar soil chemical composition due to common process of soil formation through microbial degradation. Our objective was to determine the chemical signature of fern and angiosperm vegetation types and trace the preservation or loss of those compounds into the soil. We collected live tissue, litter, roots, and soil (<53 μm) from four dominant vegetation types including two angiosperms (Cheirodendron) and (Metrosideros) and two non-polypod basal ferns (Dicranopteris) and (Cibotium) on two different aged lava flows in Hawaii. We characterized plant and soil chemistry via pyrolysis-gas chromatography-mass spectrometry. We found distinct chemical differences between angiosperm and fern tissue with angiosperms containing larger proportions of polysaccharides and the ferns more lignins. Within lignins, the angiosperms contained more guaiacyl (G-) and syringyl (S-) derived subunits and the fern species had greater relative abundances of p-coumeryl (P-) lignin subunits and tannin-derivatives. There was a general decrease of lignin-derived phenolic compounds from live to litter to soils and an increase in more recalcitrant, aromatic and aliphatic C. Original plant chemistry was most evident at the young site, suggesting that nutrient limitation or litter quality effects constrained soil development compared to the older site. Recalcitrant fern-derived cutin and leaf waxes (alkene and alkanes structures) were evident in the soils, but clear species differences were not observed. Although ferns contain distinct lipid and wax-derived compounds, soils developed under fern do not appear to accumulate aliphatic waxes in the SOM.

**Development of bulk density and of total C and N distribution during paddy soil evolution**

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In the Zhejiang province (Yangtze River Delta, China), during the past 2000 years new farmland was created through consecutive land reclamation by protective dikes. The construction of the dikes is historically well-dated and provides a unique chronosequence of soil formation under agricultural use. Parts of the land were used for paddy rice, other parts for a variety of non-irrigated crops (control sites). This provides the unique opportunity to document the effect of soil redox conditions over long time periods on the evolution and distribution of soil organic matter (SOM) properties during pedogenesis. In June 2008, soil profiles of a chronosequence ranging from 50 to 2000 years of land use were sampled, including paddy sites and control sites. Additionally, a geostatistical sampling approach was used in order to analyze the spatial variability of SOM parameters of differently aged paddy plots. These samples have been taken with an auger. From the soil profiles, first analyses include bulk density, total C and N as well as organic C (OC) concentrations. From the auger samples, the data of the spatial distribution of OC and N in the 1000 y paddy site are already available. The results show distinctly different depth distributions between paddy and control sites. The paddy soils are characterized by low bulk densities in the puddled layer (in average 1.1 g $cm^{-3}$) and higher values in the plow pan (approx. 1.6 g $cm^{-3}$), and the control plots by relatively homogeneous values throughout the profiles (1.3 to 1.4 g $cm^{-3}$). The dense plow layer was already established in the relatively young 50 y old paddy site. In contrast to the carbonate-rich control sites, we found a significant loss of carbonates during paddy soil formation (decalcification of the upper 20 cm in 100 y old paddy soils, decalcification of the total soil profile in paddy soils older than 700 y). OC concentrations in the upper A horizons were found to be constant throughout the chronosequence (approx. 15 mg $g^{-1}$). The spatial distribution of OC and N in the topsoil of the 1000 y paddy site show a higher range, a higher (semi-)variance and a stronger spatial dependence compared to the subsoil. Furthermore, the spatial pattern of OC and N is considerably different between top- and subsoil, indicating that OC distributions below the plow layer are controlled by different processes compared to the puddled topsoil. We conclude that paddy soil formation is firstly characterised by short-term processes (physical processes, approx. 50 years) including the formation of the plow layer, which leads to a cutting-off between top- and subsoil. Secondly, long-term processes like decalcification and OC accumulation occur, but the translocation of OC and N between top- and subsoil is impeded by the plow layer.

**Soil organic matter dynamics of rice paddies of China**

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China's agriculture faces a great challenge of increasing cereal production for the increasing population and of enhancing mitigation of the increasing greenhouse gas emission from the rapidly developing industrialization. Rice production had been given priority for food security consideration since 1950's and reached a total grain production in 20 Mt in late 1990's. Rice cultivation area was peaked at 3.6 Mha in late 1970's and declined to 3.0 Mha in 2000's with an area reduction extension in East and South China and extension in North and Northeast China. While topsoil SOC of rice paddies was found at 14.2±3.2 g/kg in contrast to 10.3±4.3g/kg of dry croplands in early 1980's, giving a mean topsoil SOC storage of 10tC/ha higher than the dry croplands. SOC accumulation at topsoil was evidenced generally in rice paddies across China since 1980's at a mean annual increase to the background level at 0.65% in contrast to 0.73% of dry croplands. However, this accumulation was found greatly enhanced as the annual increase to the background level had been statistically observed at 0.7-1.9% under compound fertilization and combined organic/inorganic fertilization and 2.0% under conservation tillage compared to 1.4-2.9% and 1.5% for dry croplands respectively. An annual SOC sequestration had been estimated as 9.15±14.0 Tg C in rice paddies compared to 25.7±61.4 Tg/ in dry croplands since 1980's. It is of key importance that SOC accumulation facilitates rice productivity probably through improved N efficiency, supporting a Win-Win effect of S sequestration for agricultural production and climate change mitigation. Nevertheless, the SOC dynamics also varied with soil types and geographical regions as SOC dynamics in rice paddies seemed to be controlled by mutual interactions of soil-crop-microorganisms under rice production systems varying both in time and space. This deserves further study for pursuing strategy approaches for enhancing both rice productivity and C sequestration in rice agriculture of China.

**Role of organic matter in sustaining fertility and productivity of problem soils of coastal ecosystem**

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Coastal ecosystem is one of the major ecosystems of the world. It provides livelihood security of 60 per cent of human population. The coastal ecosystem is highly fragile and the production system in this region are constrained by several soil health problems like salinity, sodicity, sea water intrusion, erosion, leaching and nutrient deficiency etc. India has 8,129 km long coastline. This vast tract face serious problems of soil salinity over an area of 3.1 m ha accounting for 30 per cent of the total salt affected lands in the country. The saline soil dominates the low lands characterised by sandy loam to clayey texture, slight to highly alkaline reaction, low organic carbon and deficiency of nitrogen, phosphorus and zinc. Under low land conditions, rice is the dominant crop grown with realisation of poor economic yield by farmers. The uplands of coastal ecosystem are dominated by light textured sandy soil which has low clay, poor organic matter, exchange capacity, biological activity and micronutrient deficiency. The addition of organic matter benefits the sustainability of any agricultural system by multitude of role in soil by improving physical properties, plant nutrients, enhancing exchange capacity and stimulating biological activity. The coastal ecosystem is endowed with rich potential of several organic sources like farmyard manure, coirpith, casuarina leaves, green leaf manure etc. which can be effectively recycled to address the soil related constraints and to sustain fertility and productivity of the soil. Experiments were carried out with the application of organic manures of the coastal areas for the management of nitrogen and phosphorus nutrition of low land rice. In the sandy soils of the coast, laboratory and field experiments were carried out with zinc, boron along with organics and humic acid application. To increase the micronutrient efficiency under stress conditions, technology was also developed to fortify the organic manures with micronutrients like Zinc, iron and boron and evaluated under both upland and low land conditions. The results of the various experiments carried out with organic matter showed the beneficial role of organics in restoring the fertility and productivity of coastal problem soil. This paper discuss the results of various laboratory and field experiments with special reference to improvement in physical properties, macro and micro nutrient availability, soil microbial and enzymatic activity with organic matter addition in coastal ecosystem.

**Methane emissions by flooded soils from Rio Grande do Sul State, Brazil**

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In agriculture, lowland soils for irrigated rice production could be considered a major source of $CH_4$ emission. After flooding, $CH_4$ is produced by anaerobic bacteria (methanogenic) using organic acids in soil solution, especially acetic acid, produced by soil organic matter decomposition during soil reduction reactions The objective of this work was to evaluate methane emission in lowland soils from Rio Grande do Sul (RS) State, Brazil, and its relation with soil chemical properties and soil reduction reactions after flooding. Six soils collected in different rice croplands in the RS where used: Santa Maria (Albaqualf, and Endoaqualf), Pelotas (Albaqualf), Uruguaiana (Udorthent), Cachoeirinha (Endoaqualf) and Santa Vitória do Palmar (Hapludoll), with different chemical and physical properties. Nine kilograms of each soil were put in a PVC container, with three replications, and distributed in a completely randomized design, and cultivated to flooded rice. The $CH_4$ emission evaluation was performed using another PVC container, forming a chamber that was attached at the top of the vase through a channel filled with water to connect the container to the chamber. The air samples were taken weekly from 3 to 66 days after flooding had started, by sampling the air inside the chamber with a polyethylene syringe (20 mL), in four time intervals of five minutes. At the same time of air collection, a sample of soil solution was collected. After soil solution suction, pH, redox potential (electrode of Ag/AgCl and platinum ring), iron, manganese, calcium, magnesium, phosphorus and sulfur content were measured. There are different methane emission potentials among lowland soils from Rio Grande do Sul State, Brazil. Methane emission only started when most of the inorganic composts were reduced, such as nitrate, manganese, iron and sulfate. After this, methanogenic bacteria start to use organic acids as final electron acceptors and release methane. The beginning of methane emission is dependent upon the soil reduction rate, indicated by release of iron and manganese and values of pH and redox potential, but the intensity and duration of emission of methane seems to be associated with other soil attributes and/or plant characteristics.

# Oral presentations

# Parallel Session 3:

# “Biofuels, SOM and Net GHG Balance”

**Flies in the Biofuels Ointment: The Complementary Roles of SOM and Nitrous Oxide**

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The emergence of a cellulosic biofuels industry offers environmental outcomes that could be very different from those of grain-based systems: agricultural landscapes that accumulate carbon, that conserve nitrogen and phosphorus, and that lose only small amounts of nitrous oxide to the atmosphere. Fields in these landscapes are planted to perennial crops that require less fertilizer, that have the ability to trap nitrate and phosphorus that would otherwise be transported to groundwater and streams, and that accumulate carbon in both soil organic matter and roots. If mixed-species assemblages at either the field or landscape scale, they additionally provide biodiversity services such as pest protection and disease suppression, as well as cultural and wildlife amenities.All of this depends, however, on selecting the right mix of biofuel crops and managing them in a way that optimizes their environmental benefits and avoids known environmental costs. First and foremost is their contribution to $CO_2$ stabilization. Understanding the range of practices that provide equivalent or near-equivalent $CO_2$-mitigation potentials allows more options for building systems that provide other benefits as well. Key to maximizing $CO_2$-mitigation are management practices that maximize SOM accumulation and $N_2O$ conservation vis a vis farming costs and fuel offsets.What we currently know about biofuels sustainability is that first, it will take a substantial amount of land regardless of whether biomass is used to produce liquid fuel or electricity. Second, we know there are right and wrong ways to deploy and manage the systems that will provide this biomass. Right approaches allow us to reap biogeochemical and biodiversity benefits. Wrong approaches amplify the current shortcomings of intensive grain-based agriculture. Third, we know that right outcomes are not guaranteed, either nationally or internationally.Only by full consideration of key biogeochemical processes can we expect the development of a sustainable cellulosic biofuels industry.  The science needs are substantial but tractable.

**Carbon sequestration under Miscanthus: a study of $^{13}C$ distribution in soil aggregates**

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The growing of bioenergy crops has been widely suggested as a key strategy in mitigating anthropogenic $CO_2$ emissions. However, the full mitigation potential of these crops cannot be assessed without taking into account their effect on soil carbon (C) dynamics. Therefore, we analyzed the C dynamics across four soil depths (0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm) under a 14 years old Miscanthus plantation, established on former arable land. An adjacent arable field was used as a reference site. Combining soil organic matter (SOM) fractionation with $^{13}C$ natural abundance analyses, we were able to trace the fate of Miscanthus-derived C in various physically protected soil fractions. Integrated across the whole soil profile, the total soil organic carbon (SOC) stock was significantly higher under Miscanthus than under arable land (24 vs. 16 kg C $m^{-2}$). This difference was largely due to the input of new C; under the plantation, 9 kg C $m^{-2}$ was Miscanthus derived. Almost 87% of the total C content under Miscanthus was found in the upper 30 cm. Macroaggregates (M) under Miscanthus contained 9 kg C $m^{-2}$ in the 0-15 cm layer, and 7 kg C $m^{-2}$ in the 15-30 cm layer. These values was significantly higher than C contents of the same fraction in the arable land. Under Miscanthus, the microaggregate within macroaggregates fraction (mM) contained 5 kg C $m^{-2}$ at both 0-15 cm and 15-30 cm depth. In the arable soil, this fraction contained 3 kg C $m^{-2}$. The C in the mM was 2 kg C $m^{-2}$ higher in the Miscanthus soil at both depths, and it accounted for 46% and 55% of the difference in whole SOC stocks, at 0-15 cm and 15-30 cm respectively. Analysis of the intra-microaggregates POM suggested that the increase C storage in mM under Miscanthus was caused by a decrease in turnover of M. Thus, the difference in C content between the two land use systems is largely caused by soil C storage in physically protected SOM fractions. Our results show that when Miscanthus plantations are established on former arable land, the resulting increase in soil C storage contributes considerably to Miscanthus $CO_2$ mitigation potential.

**Simulating Soil Organic Matter Dynamics and Effects of Residue Removal Using the CQESTR Model**

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Concern about $CO_2$ emissions and fossil fuel supplies has increased interest in using crop residues for biofuel production. However, maintaining soil organic matter (SOM) is vital for maintaining soil productivity. Our objectives were to simulate long-term SOM dynamics of a sandy loam soil using the CQESTR model, and examine the effect of tillage and residue harvest on SOM content. A long-term tillage and crop management study was initiated in 1979 at the Clemson University Pee Dee Research and Education Center on a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudult) of the Mid Coastal Plain region of South Carolina. Four residue harvest scenarios (H0, H50, H66, and H90, representing conditions where 0%, 50%, 66% and 90% of the crop biomass was harvested) were implemented at two harvest stages: SP, 1979- 2002; and SF, 1995-2014. The model was used to simulate SOM dynamics under two tillage practices, disking (DT) and conservation tillage (CS) using paratill. Results were compared with measured values. CQESTR captured year to year variation in SOM content well. Without residue removal, average increases of 0.18 and 0.66 g SOM kg/yr were predicted for DT and CS, respectively. The increase in SOM was attributed to change in crop rotation and improved management practices. Higher SOM stocks under CS than under DT were due to lower OM mineralization rate with less tillage. CQESTR predicted 3.2 and 7.7 g SOM/kg losses in the top 5-cm under DT and CS during 23-yr of 66% residue harvest (H66), respectively. Losses of 10.6 and 7.0 g SOM/kg in the top 5-cm were predicted for CS under the SP-H90 and SF-H90 harvest simulation scenarios, respectively. The predicted loss of 10.6 g SOM/kg in the 0- to 5-cm depth is 70% of the amount of SOM gained (15.1 g SOM/kg) after implementing CS since 1979. This decrease in SOM could reduce nutrient availability and consequently reduce the production capacity of this inherently low SOM soil. The quantities of crop residue that can be sustainably harvested are directly influenced by initial SOM concentration of a soil. Large-scale residue removal for bioenergy must be balanced with other critical functions that agricultural lands provide, including nutrient and water cycling, and C sequestration, for the maintenance of soil productivity. More long-term field data is required to validate predicted SOM stocks under a wide range of soil, climatic conditions, and management practices including crop residue harvest scenarios.

**Management of Miscanthus—giganteus: Impact on amount and quality of plant litters and their biodegradability in soil.**

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The growth of energy crops impact the amount and nature of crop residues recycled to the soil and therefore affect the nutrient cycles. In the case of Miscanthus, a perennial rhizomatous grass (C4-plant), the option of harvesting the crop at maximum biomass production would prevent leaf senescence and the remobilization of nutrients from tops to rhizomes. In that context, the objective of our work was (i) to compare the impacts of harvest strategy on the amount and chemical characteristics of Miscanthus senescent leaves, roots and rhizomes, (ii) to establish the relationship between their chemical quality and their potential biodegradability in soils. The established Miscanthus, three years old at the start of experiment, was grown at INRA in Northern France. Rhizomes and roots were sampled in 2007 and 2008, at two crop stages: in autumn, at maximum biomass production before N remobilization from leaves to rhizomes occurs (early harvest), and during winter at plant maturity (late harvest). Between the two dates of harvest, senescent leaves were collected on the soil surface. The dry matter, C and N in senescent leaves, roots (0-30cm) and rhizomes were quantified and biochemically characterised. Incubation was performed in controlled conditions (15ºC, -80 kPa) during 1 year, to determine C and N mineralization. On average aboveground biomass was 21 and 16 t DM ha$^{-1}$ at early and late harvests, respectively. The senescent leaves falling down represented on average 3t DM ha-1, i.e. 1500 kg C and 14 kg N ha$^{-1}$. The DM accumulated belowground was 17 t DM ha$^{-1}$, i.e. 8500 kg C and 305 kg N ha$^{-1}$ in rhizomes plus roots, 90 % being as rhizomes. The rhizomes DM did not vary significantly between the two harvest times. Conversely the chemical quality of rhizomes changed: the soluble fraction increased from 28 % DM at early harvest to 33 % at late harvest, while the lignin content decreased from 16% to 13%. This evolution was attributed to nutrient remobilization from aboveground to rhizomes. Roots contained higher amount of lignin (20 %) and their composition did not change between the two harvest dates. After 1 year of incubation, the cumulated amounts of C mineralized were 56%, 49% and 30% of added C for rhizome, senescent leaf and root, respectively. The ranking in cumulative $CO_2$ mineralized agreed with the chemical composition, a larger soluble content and a lower lignin content (like in rhizome) leading to a faster decomposition.

**Impact of BioFuel Cropping systems on Greenhouse Gas Fluxes.**

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Biofuel crops have the potential to provide renewable sources for transportation fuels and electricity. This talk will compare the net greenhouse gas fluxes associated with biofuel cropping systems and will focus on the changes in soil carbon and $N_2O$ fluxes. Results show that perennial cropping systems (e.g.: switchgrass, Miscanthus, poplar and native grasslands) have the potential to store soil carbon and reduce $N_2O$ fluxes. Soil tillage practices have the potential to substantially modify the net greenhouse fluxes from biofuel cropping systems. The results will show that $N_2O$ fluxes are one of the major components of the net greenhouse balance and that there are large differences in $N_2O$ fluxes from different biofuel cropping systems.

**Crop residue removal and fertilizer N: Effects on soil organic carbon on a long-term crop rotation experiment in a Udic Boroll**

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Biofuels can be produced by converting cellulose in crop residues to ethanol. This has recently been viewed as a potential supplement to non-renewable energy sources, especially in the Americas. Nonetheless there has been little consideration for the effects of residue removal on soil quality and soil organic carbon (SOC). A 50-yr field experiment conducted on a Udic Boroll was analyzed to determine the influence of (i) removing approximately 22% of the above-ground wheat (*Triticum aestivum* L.) residue each crop year, and (ii) N and P fertilization on soil carbon (C) in the top 15 cm depth of a fallow-wheat-wheat rotation. The study was conducted from 1958 to 2007 on a clay soil, at Indian Head in sub-humid southeast Saskatchewan, Canada. Soil C concentrations and bulk densities were measured in the 0-7.5- and 7.5-15-cm depths in 1987, 1996 and 2007 and soil C changes were related to C inputs estimated from straw and root yields calculated from regressions relating these to grain yields. Two soil organic matter models [the Campbell model and Introductory Carbon Balance Model (ICBM)] were also used to simulate and predict the effects of the treatments on soil C change over time, and to estimate likely soil C change if 50% or 95% of above-ground residues were harvested each crop year. Crop residue removal reduced cumulative C inputs from straw and roots over the 50-yr experiment by only 13%, and this did not significantly ($P>0.05$) reduce soil C throughout the experiment duration. However, after 50 years of applying N fertilizer at recommended rates, soil C increased significantly by about 3 Mg $ha^{-1}$ compared to the non-fertilized treatment. The simulated effect of removing 50% and 95% of the above-ground residues suggested that removing 50% of the straw would likely have a detectable effect on the soil C, while removing 95% of the straw certainly would. Both models performed effectively in simulating soil C trends. Measurements and model simulations suggest that adoption of no-tillage without proper fertilization will not increase soil C. Although it appears that a modest amount of residue may be safely removed from these Udic Borolls (Black Chernozems) without affecting the soil C, this would only be feasible if accompanied by careful fertility management. However, simulation results suggest that removing greater than 50% of the surface residue could have a deleterious effect on soil quality and this fact has been typically absent from the mindsets of those developing policies and technologies for the use of cellulosic ethanol as a biofuel.

**Long-Term Corn Stover Removal Effects on Soil Organic Carbon Dynamics as Simulated by RZWQM2**

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Under the pressure to find renewable energy resources, corn stover is a likely source for cellulosic based ethanol production. This practice, however, raises concerns for soil quality and soil sustainability, especially in the corn belt of the USA. As a result, numerous studies have been conducted recently to monitor soil C, soil microbes, and soil structure changes after crop residue removal. In this study, we present long-term simulation results of corn residue removal effects on soil C dynamics with the USDA-ARS Root Zone Water Quality Model (RZWQM2). These effects were evaluated under different tillage treatments (till vs. no-till) and crop rotations (continuous corn vs. corn-soybean). The model was calibrated and validated in Iowa using 26 years of field data. Results showed that (1) removing corn stover reduced annual mineralization of N; (2) soil carbon dynamics depended on initial soil C pool partitioning; (3) no-till treatment increased soil C only in the top 0-4 cm of the soil profile; (4) retaining at least 50% surface residue in the field was desirable to maintain soil quality; and (5) microbial growth was higher with more stover left in the field.

**Potential of Cellulase producing Actinomycetes from termite ecosystem in bioethanol production**

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Actinomycetes were isolated from the below ground ecosystem. These were found to be predominantly cellulase producers which has potential in the conversion of lingo- cellulosic waste into simple sugars through saccharification viz., sugarcane bagasse which may ultimately be used as feed stock for bioethanol production. At different periods of interval, different isolates of Streptomyces showed a maximum cellulase activity (2.5U/ml ) at 1% CMC and pH 6.5. The temperature optima was in the range of 35-40ºC. Comparatively the enzyme activity was at its highest after an incubation period of 9 days. The pretreatment of 100g of sugarcane bagasse with 1% $H_2SO_4$ followed by 10 ml of crude cellulase enzyme extract of Streptomyces resulted in the release of maximum amount of reducing sugars (21.8 mg/ml) in a pilot scale study. After saccharification, the fermentation process initiated by the inoculation of Saccharomyces cerevisiae at 5-10% reducing sugar as sole carbon source yielded 3.5% ethanol. Utilization of renewable resource is now of a growing interest for the production of clean energy fuels.

# Oral presentations

# Plenary Session:

# "SOM, Soil Disturbance and Tillage"

**Soil Tillage and Carbon Sequestration – The Elusive Link**

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The relation between tillage and soil organic matter dynamics has been elucidated in numerous studies, at scales stretching from the aggregate to the field level. As in most other current research, these studies often reflect a persistent inadequacy in scaling up meticulous descriptions of soil processes at microscopic or soil profile scale to a regional or global scale. In this presentation, we will highlight a few examples, demonstrating this discrepancy between our understanding of a process at the micro-scale and the lack thereof at a larger scale. While the emphasis will be on the relation between disturbance and soil organic matter stocks, we will also use a number of other examples relevant to soil organic matter dynamics. The actual interest in the dynamics of dissolved organic matter (DOM) for its role on carbon fluxes between terrestrial/aquatic ecosystems and the atmosphere is a first one. At lab and lysimeter scale, significant progress has been made to unravel the relations between origin and quality of the DOM measured in soil solution or in water leaving the vadose zone. Yet, so far we failed to deliver a good understanding of the dynamics and quality of DOM in surface waters at regional and even less so at global scales. For example, while at profile scale, high flow rates imply low DOM concentrations in the leachate, the opposite seems true for studies at catchment scale. Similarly, most carbon sequestration studies rarely address issues at scales larger than a field plot. Hence very often misleading conclusions are drawn. Reduced tillage is conventionally considered as benign for organic matter conservation. At soil aggregate, microplot or even field scale this is obvious and the positive effects on soil quality are beyond doubt. However, when the relations between erosion and carbon sequestration are analyzed at the scale of a watershed, positive feedback effects on carbon storage rather than carbon losses due to erosion emerge. The latter study suggested an erosion-induced sink strength of 0.12Pg C. year$^{-1}$. The above points to a number of uncertainties still impairing unequivocal statements about the role of tillage in the climate change debate. Apart from the scale effects, uncertainties still dominate the description of decomposition of SOM when buried in depositional areas or –more general – in deeper soil layers. Finally, ways to enhance SOM levels depend on soil type and are not always easily implemented in resource-poor conditions as for instance in Sub-Sahara Africa.

**Current and future soil carbon sequestration in semiarid Mediterranean conditions: quantifying management and climate effects**

Jorge Álvaro-Fuentes[1], Maria Victoria Lopez[2], José Luis Arrúea[2], Carlos Cantero Martinez[3], David Moret[2], Keith Paustian[1,4]

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In agroecosystems, soil organic carbon (SOC) sequestration by changes in management can help to offset anthropogenic $CO_2$ emissions. Globally, estimates of SOC sequestration rates differ according to the management regime (e.g. tillage, crop rotations, etc.), climate, and soil characteristics. Consequently, climate change will have a significant impact on the potential effects of management on SOC dynamics. In semiarid Mediterranean agroecosystems, the historical management has been intensive tillage together with low input systems (e.g. cropping-fallow). In these conditions, potential for SOC sequestration could be significant and the combined effects of future climate with management require further investigation. This study was divided into three parts. First, we analyzed the effects of tillage (no-tillage, reduced tillage and conventional tillage) and cropping intensification (continuous cereal system vs. cereal-fallow rotation) on SOC sequestration under current climate conditions with data obtained from long-term tillage experiments (>15 years) located in Spain. In a second part we used the previous data to validate the Century model in semiarid Mediterranean conditions. Finally, we used the Century model to simulate the future effects of climate and management on SOC dynamics during the period 2008-2100. Climate projections from two general circulations models (GCM2 and ECHAM4) driven by two IPCC climate scenarios (A2 and B2) were used for the SOC simulations. Management scenarios consisted of different cropping and tillage systems. Results showed that cropping intensification and tillage reduction are current and future potential strategies to increase SOC in semiarid Mediterranean and consequently to offset anthropogenic $CO_2$ emissions.

**Carbon content in subtropical and temperate soil physical fractions as indicators of organic matter saturation**

Francisco Matus[1], Claudia Hidalgo[2], Isabel Estrada[2], Aurelio Baez[2], Mariela Fuentes[2], Carlos Monreal[3], Jorge Etchevers[2]

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It have been envisaged that agricultural soils, having lost much of their native carbon (C), can reverse back with a significant C sink capacity. Increasing C inputs rates by improving soil fertility and productivity of cropland and pastures to build up a new steady state of C can be easily lost under intensive tillage. The approach to study this is usually done by physical fractionation from incomplete soil dispersion. However, a general conclusion drawn from various studies is difficult because limited soil dispersion yield particle size fractions from a mixture of primary and secondary soil structure. This is important when evaluating the effects of soil management on soil C sequestration, since the physical fractions and the entire soil have been proposed to have a finite capacity to hold SOM. Most studies related to soil C saturation combine the silt- and clay-size fraction and very few of them use the silt and clay fractions as distinctive C pool separately. The latter, in our view is essential, because the silt, unlike the clay fraction, cannot be considered to retain SOM by physicochemical mechanism; rather it is the habitable pore space for microorganism of few microns. This explanation can be sustained only if the C associated to the clay fraction can show a saturation behavior, while in the silt fraction it increases with SOM content. Our approach was that the soil can act as C sink or C source depending at the extent to which physical fractions are saturated with SOM. This was achieved by ultrasonic energy dispersion from subtropical and temperate soils under forest, pasture and cropping. The same approach was used in allophanic soils where most SOM is bound to Al and Fe oxides. The results indicate that most soils are saturated with SOM in its clay fractions as revealed by an asymptotic relationship between C in the whole soil and its content in this fraction. Silt exhibited an upward, nearly linear C accumulation, while the sand fraction did not show consistent results, which is possible if both, silt and sand are not influenced by the saturation processes. Typical saturation values of clay fraction for all soils ranged between 2 and 22 g C/kg soil. Our findings are in line with those of others and help establish the importance and need to consider the rationale for design strategy of C sequestration in fully clay saturated soils.

**Simulation of soil organic carbon response at forest-cultivation sequences using 13C measurements**

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Deforestation activities are the biggest contributors to carbon dioxide emissions due to land use change (Houghton, 2003). When deforestation is followed by continuous arable cropping a permanent decline of between 22 and 42% in the soil organic carbon (SOC) has been reported (Guo & Gifford, 2002) . This systematic loss of soil carbon (C) is mainly attributed to the loss of physically protected SOC (Balesdent et al., 2000). The Rothamsted Carbon model (RothC; Coleman & Jenkinson, 1996) does not include a description of the processes of physical protection of SOC and so losses of C during continuous cultivation of previously uncultivated land are not likely to be accurately simulated. Our results show that in the first years following deforestation, RothC does not capture the fast drop in forest derived soil C. However, the model does accurately simulate the changes in SOC derived from the following crops. Uncertainty in input data and accounting for erosion does not explain the underestimation of decomposition after deforestation by RothC. However, the ability of RothC to simulate changes in the forest derived SOC can be greatly improved with an implementation of a simple approach to account for SOC dynamics due to the loss of physically protected C. This approach implements a new soil carbon pool into RothC which represents the labile but protected carbon fraction which builds up under land uses with no disturbance and which looses its protection once the soil is cultivated. The calibration of the new pool is based on the use of $^{13}$C natural abundance in conjunction with soil fractionation.

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**Effect of long-term fertilization on soil organic carbon accumulation and microbial community structure in rice paddy soil**

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The effect of long-term fertilization on soil organic carbon (SOC) accumulation, and soil biological properties in the plough layer in a rice paddy soil in southern Korea were investigated in relation to the continuous application of chemical fertilizers (NPK), straw based compost (Compost), combination these two (NPK + Compost) for more than 40 years: NPK (N–P–K = 120–34.9–66.7 kg $ha^{-1}$ $yr^{-1}$ during 1967–1972 and 150–43.7–83.3 kg $ha^{-1}$ $yr^{-1}$ from 1973 to present), Compost (10 Mg $ha^{-1}$ $yr^{-1}$), a combination of NPK + Compost, and no fertilization (control). Fertilization significantly improved rice productivity, and the combined long-term fertilization of chemical and compost amendment was more effective on increasing rice productivity and soil nutrient balance than single compost or chemical fertilizer application. Continuous compost application increased the total SOC concentration in plough layers. In contrast, inorganic or no fertilization markedly decreased SOC concentration resulting to a deterioration of soil physical health. Most of the SOC was the organo-mineral fraction (<0.053 mm size), accounting for over 70% of total SOC. Macro-aggregate SOC fraction (2–0.25 mm size), which is used as an indicator of soil quality rather than total SOC, covered 8–17% of total SOC. These two SOC fractions accumulated with the same tendency as the total SOC changes. Comparatively, micro-aggregate SOC (0.25–0.053 mm size), which has high correlation with physical properties, significantly decreased with time, irrespective of the inorganic fertilizers or compost application, but the mechanism of decrease is not clear. Fertilization had a significantly beneficial impact on soil microbial properties, and, in particular, continuous compost fertilization improved markedly soil microbial properties compared with chemical fertilization only. The ratio of fungi to bacteria was apparently increased by long-term fertilization, but no difference between chemical and organic fertilization. The ratio of gram(+) bacteria to gram(-) was markedly increased by single compost application, but decreased by chemical fertilization. Big difference of microbial community structure was found among Control, NPK, and Compost, but NPK+Compost treatment showed similar microbial community structure with Compost. In conclusion, the combined fertilization of chemical and organic amendments could be more rational strategy to sustain soil productivity as well as improve health statues than the single chemical fertilizer or compost application.

**Effects of land use change and reduced tillage on the greenhouse gases balance in an Italian agro-ecosystem from Italian agricultural areas**

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Mitigation strategies for the reduction of carbon dioxide emissions are the central focus of the Kyoto Protocol and international scientific efforts. Agriculture plays a substantial role in the balance of the most significant greenhouse gases ($CO_2$, $N_2O$, $CH_4$), to be mostly attributed to the practices management. Recent literature has shown that the largest differences in net global warming potential among different cropping systems are related to soil carbon changes and $N_2O$ emissions. Different agricultural strategies have been suggested and tested in order to reduce atmospheric $CO_2$ by increasing soil organic carbon (i.e. no-till farming, and less-intensive conservation agriculture), among which, land use change from croplands to grasslands is expected to be the most effective strategy for carbon mitigation potential. However, the magnitude of the change in net ecosystem C fluxes and N losses could be expected to vary with type of crops and grasslands, and also with soil characteristics and climate. Thus, more data are needed over a wide range of ecosystems to verify and generalize the mitigation strategy options. In this study, we present two years data on the combined effects of land use change (LUC) of cropland (Zea mays L.) to alfalfa-hay (Medicago sativa L.) and of two tillage systems (conventional tillage and reduced tillage) on C and N cycles in an high production area of Northern Italy. Net ecosystem production (NEP) and net biome production (NBP) have been tracked by measuring $CO_2$ fluxes with paired eddy covariance stations (EC) and continuous heterotrophic soil respiration measurements (SR). Periodic $N_2O$ and $CH_4$ measurements have been performed too. The comparison showed that LUC from corn to alfalfa-hay reduced NBP by -132 g C $m^{-2}$ at the end of the second year. The reduced tillage was effective in increasing C-NBP in corn (+150 g C $m^{-2}$ at the end of the second year), but, if the increase in $N_2O$ emmissions is taken into account, reduced tillage allowed to decrease emissions of 59 gC $m^{-2}$.

**Impacts of Land Use on TOC, Chwe, Carbohydrates, Glomalin and Water-Stable Aggregates in Gleyic Podzols and Haplic Gleysols - Analysis of a 220-Year Chronosequence**

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Mineral hydromorphic soils play an important role in the terrestrial carbon cycle. However, little is known about their carbon sequestration potentials under different types of land use. The main objective of this study was therefore to investigate the impact of land use on the organic matter in a 220-year chronosequence of mineral hydromorphic soils under arable use. To compare the carbon fractions of the arable sites to those of differently used soils permanent pasture and permanent forest sites were included in the study. TOC, hot water extractable carbon, carbohydrates, glomalin and water-stable aggregates were analysed in the upper 20 cm of over 70 Gleyic Podzols and Haplic Gleysols in Northwest Germany. In addition clay content and oxalate-soluble Fe and Al were quantified. It was found that all organic soil components and the content of water-stable macroaggregates correlated very significantly with the duration of arable land use of the soils. Within only 45 years of arable land use the TOC content decreased by 83% (from 79.3 to 12.9 g/kg), the content of hot water extractable carbon decreased by 75% (from 1.46 to 0.36 g/kg) the percentage of water-stable macroaggregates decreased by 77% (from 17.5 to 4.0%) and the concentration of glomalin diminished by 75% (from 7.83 to 1.98 mg/g). The results confirm a close link between land use, TOC content, soil aggregation and the mycorrhizal protein glomalin. There was, however, no strong correlation of TOC and neither the content of clay nor the concentration of oxalate-soluble Fe and Al. This calls into question their importance for the stabilization of organic matter in the analyzed soils and underlines the function of soil aggregation as a stabilization mechanism of the organic matter in the upper soil horizon of these sandy humus rich soils. Independently of land use and the total amount of carbohydrates and TOC the relative distribution of the carbohydrate concentrations within the water-stable aggregates was the same for all analysed samples. It was found that 31% of the carbohydrate concentration was compromised in aggregates >2000 µm, 38% was found in aggregates 2000-630 µm, while the microaggreagtes (630-200 and 200-63) compromised 19 and 12% respectively. Glomalin in contrast, was much more equally distributed within the different aggregates and still displayed high concentrations in the microaggregates. This strongly indicates that glomalin plays a major role for the microaggregate formation in the analysed soils and thus for the stabilization of the organic matter.

**Tillage and soil organic C: digging deeper into the soil**

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Tillage has a strong influence on SOC dynamics and storage. While many studies have shown a net positive effect of NT on SOC stocks, others have shown no difference or even higher values under inversion tillage, especially when the whole soil profile is considered. The extent, significance, and factors controlling C sequestration at depth compared to the soil surface under various tillage practices are not well documented. We used a combination of published empirical field data and laboratory incubations to evaluate the contribution of factors that can explain the differential effects of tillage practices on soil C dynamics and storage throughout the soil profile. We investigated more specifically the influence of soil C saturation. As expected, reduction in tillage depth results in significant accumulation of C in the surface soil layer (0-10 cm). This accumulation is observed in the fine size particles in the case of unsaturated soils, and in the coarse particles in the case of C-saturated soils. On the other hand, the analysis of whole-soil profiles (0-60 cm) at a number of experimental sites mainly from temperate environments, shows that there is no significant effect of tillage practices on C stocks; the increase in C at the surface under no-till is compensated by greater C contents at the bottom of the plow layer. There are also indications of SOC accumulation below the plow layer in the tilled soils. Detailed particle size analysis showed that the organic C accumulating below the surface in the plowed soils is associated with particles <50 µm, particularly in fine-textured soils which show a low level of C saturation. We thus hypothesize that the saturation deficit can explain, at least partly, the accumulation of C in subsurface layers in plowed soils in these environments. The significance of soil C saturation in determining the impact of tillage on SOC storage relative to other determining factors such as micro-environmental conditions remains to be determined.

**Organic matter in the soil of pasture land with various intensity of use**

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Soil organic carbon may be an appropriate indicator in relation to soil quality. Organic matter in the soil has great production and non-production significance as it influences a whole range of soil characteristics. One of the other indicators of environment quality, in terms of the landscape, is diversity, including biodiversity of permanent grassland. In our research we have focused on the study of biodiversity of permanent grassland (pasture) in upland regions of the Czech Republic and on selected soil characteristics of these biotopes. A total of 44 such characteristics were studied and mutual correlation was proven among many of them. In subsequent processing of the results through cluster analysis and further evaluation we divided the grassland sites into three groups, from newly established grassland (16 plant species) to species-rich communities (33 species). From the characteristics showing the greatest correlation we select suitable criteria with which to evaluate individual sites in field conditions. In our research a great number of correlation points were found between the range of characteristics and the content of humus and total nitrogen. In non-parametric analysis of these results statistically significant differences were found between species-poor and species-rich plant communities in the content of carbon and nitrogen in the soil. The slightly higher quality of humus expressed as HA : FA under species rich vegetation is also not insignificant. At a depth of 0-20 cm a quantity of 58.9 tonnes of carbon per ha was recorded in species-poor vegetation and 106 tonnes of carbon per ha in species-rich vegetation. As well as increasing species diversity, the qualitative changes described here can be significant for carbon sequestration. This sequestration can be affected not only by the transformation of arable land to permanent grassland, but also extensification, e.g. within the scope of payments for organic farming. With differences between communities of around 40 tonnes per ha and with a transfer of 10% of permanent grassland in the Czech Republic to species-rich communities would achieve a sequestration of around 3.9 Mt carbon. If the transfer is implemented only on land with agroenvironmental payment (20% of vegetation) the carbon sequestration in these communities would be around 1.7 Mt.

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**Soil Organic Matter Pool Dynamics following Field Succession in Sumatra, Indonesia**

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Tropical forests in Sumatra, Indonesia are under high deforestation pressure, mainly due to their conversion into crop-land. Changes in soil organic matter pools during succession in deforested areas have been reported, but the magnitudes are inconsistent. Regional studies are needed to quantify the gains and losses of soil organic matter pools during land conversion in deforested areas. This information is important to explain the trend in soil carbon storage in each ecosystem during the process of natural restoration. This study compared soil organic carbon, nitrogen, particulate organic carbon, and macroaggregates in the surface 10 cm of forest and fallow fields. Fallow fields were covered with naturally occurring growth of Imperata cylindrica, Melastoma malabathricum, Wedelia trilobata, and Saccharum spontaneum. In general, after three years, all fallow fields had lower labile carbon and available inorganic nitrogen than forest soils, but among these fields, Wedelia trilobata provided the highest soil carbon and nitrogen. In forest soils, macroaggregates (> 250 µm) were predominant (89%), whereas Imperata cylindrica fields were 45%. The averaged losses of soil organic carbon and nitrogen from the conversion of forests to fallow fields were 55% for soil carbon and 67% for nitrogen, respectively.

**Socioeconomic and Environmental Factors that Influence Adoption of No-Till in the Great Plains**

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In the last few decades, many conservation practices have been introduced that provide a host of environmental benefits and contribute to long-term agricultural sustainability. One of those practices, conservation tillage, has been found to reduce soil erosion, improve soil structure, and increase soil organic matter in comparison with conventional methods. While adoption of no-till by farmers has increased, barriers still exist to widespread adoption. There are likely a variety of socioeconomic and environmental factors that prevent adoption and those factors may vary by region. Our objective was to use household farmer surveys and other economic, social and environmental data sources to determine which factors had the largest influence on adoption of no-till in the U.S. Great Plains. We used the Conservation Tillage Information Center (CTIC) adoption statistics to identify three regions for analysis; north-central Montana, central South Dakota and northeastern Colorado. Household surveys of farmers were conducted in 2-3 neighboring counties in each region for a total of 107 surveys. Participants were asked several questions about their socioeconomic condition and current and past management practices on their farms. Initial analyses indicate that farm structure, gross household income and environmental attitudes are important factors that affect farmer decisions to adopt no-till.

# Oral presentations

# Parallel Session 4:

# "SOM and Soil Depth: Controls on C and N Balance"

**SOM in deep soil horizons: what do we know about its participation in C and N cycles ?**

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Despite their low carbon content, most subsoil horizons contribute to more than half of the soil carbon stocks. Generally, carbon in deep soil horizons is characterised by a high contribution of stabilised carbon compounds with mean residence times of more than thousand years. The reasons for these long residence times are only partly understood. However, the contribution of deep soil organic matter to soils C and N cycles needs to be elucidated in view of enviromental change as well as high possibility to increase soil organic matter storage.Its presence close to the soil mineral phase makes a root origin of carbon in deep soil horizons very likely. However, a substantial contribution of sorbed dissolved organic matter compounds to deep soil organic matter stocks may not be ruled out, particularly because SOM in deep soil horizons were found to be composed of small molecules, most likely organic acids. These organic matter compounds are most likely stabilised by intimate interaction with the mineral phase. Fe and Al oxides were reported to be the main stabilising agents. Low C/N ratios as well as higher contributions of microbial derived carbon indicate that stabilised carbon in deep soil horizons is highly transformed, being depleted in energy-rich compounds. In a laboratory experiment decomposition of subsoil C with high residence times could be stimulated by the addition of labile carbon. Therefore, energy limitation was postulated as a possible reason for the high residence times of SOM in deep soil horizons. If this was true, every input of labile carbon compounds may lead to destabilisation of this organic matter. Recently, it was shown that stabilised carbon compounds in deep soil horizons are not homogenously distributed. Most likely due to preferential flow pathways and rooting behaviour by plants, labile plant derived compounds occur in close proximity to microbially transformed, stabilised compounds. This indicates that SOM with long and short residence times is horizontally stratified within the soil profile. Therefore, in deep soil horizons, spatial location may be extremely important for determining the participation of subsoil carbon in soil C and N cycles. The complexity of stabilisation and destabilisation processes operating in deep soil horizons as well as the heterogeneous nature of carbon distribution makes the modelisation of mean residence times an unresolved issue.

**Transformation of Soil Organic Matter by Fungi and their Extracellular Enzymes in Forest Soils is Controlled by Soil Depth and Fungal Community Composition**

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Hardwood and coniferous forests represent one the most important biomes in temperate zone. Forest soils accumulate significant amounts of carbon deposited annualy through litterfall and the accumulation is a prerequisite for the formation of soils with distinct litter and humus horizons. In hardwood forest soils, saprotrophic basidiomycetes and ascomycetes dominate the litter horizon while ectomycorrhizal species dominate in deeper soil. There is a sharp gradient of soil physical and biological properties including the amount of microbial biomass, organic carbon, humic material, soil respiration and the activity of extracellular enzymes participating in carbon transformation. All of these parameters decrease with soil depth reflecting the availability of nutrients. The presence of saprotrophic basidiomycetes in soils results in an increased activity of the ligninolytic enzymes Mn-peroxidase and laccase, polysaccharide hydrolases and chitinase. Isolated strains of saprotrophic cord-forming basidiomycetes (e.g. Hypholoma, Rhodocollybia, and Gymnopus, spp.) are able to mineralize significant part of lignin contained within litter and to form humic substances from lignin and other soil components. In a further, slower step, the same fungi continue in the mineralization of humic compounds. In vitro experiments demonstrated that Mn-peroxidase is the required enzyme for humic acid and lignin transformation by basidiomycetes while there is no contribution of laccase to this process. The potential to degrade and transform lignocellulose is, howerver, limited in situ when basidiomycetes interact with other members of soil biota. In the case of lignocellulose transformation, the competitors are mainly nonbasidiomycetous microfungi and certain soil bacteria, e.g. the Actinomycetes. Their contribution to litter transformation is obvious from the analyses of microbial community composition of litter in different stages of decay and by the fact that the fine chemical properties revealed by pyrolysis and polysaccharide analysis show a distinction between the biomass transformed by basidiomycetes alone and by the whole soil microbial community. The studies on opportunistic micromycetes from forest soils showed that simple carbon compounds are the most widely used substrate while they are unable to attack lignin and their abilities to decompose cellulose are limited. The decomposition of litter seems to be at least partly regulated by the chemical composition: the availability of $NH_3$ increases litter decomposition while high P content decreases lignin removal. The rate defining step for fungal litter decomposition is cellulose hydrolysis since the loss of litter mass closely correlates with cellobiohydrolase activity. Our results show that fungi are the drivers of litter decomposition and transformation in forest soils.

**Evaluation of some chemical and spectroscopic parameters during biodegradation of the soluble organic matter**

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Soluble organic matter (OM) is considered as one of the labile fractions of soil organic matter. Dynamics of this fraction have been suggested that have an important role in the biogeochemical cycles and C sequestration. This experiment was conducted to evaluate the impact of management and depth on the decomposition of SOM. Soil samples were collected from topsoil (0-20cm) and subsoil (60-80cm) from a sequence of land uses in Canterbury region, New Zealand. Soluble OM samples were extracted with 0.01M $CaCl_2$ and 0.5M hot $K_2SO_4$ followed by a 90 day incubation period. DOC, DON, $^{13}C$, and UV absorption were measured during the experiment. Samples were also analyzed by FTIR and electrophoresis approaches. The salt extractable OM showed higher content of C and N in all cases. The UV absorption increased along with a depletion in $^{13}C$ ratio (some samples) during the incubation period. This was attributed to an increase in content of the aromatic compounds as a result of the microbial transformation of the soluble OM. Application of the total ion chromatography (TIC) and electrophoresis approaches was not successful for detection of proteins in the soluble OM. Although affected by depth and vegetation, overall we observed an increase in aromaticity and a decrease in N containing compounds during the microbial degradation of the soluble OM.

**Large effects of land management on dissolved organic matter in surface layers of agricultural soils are attenuated at larger soil depth**

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Vertical leaching of dissolved organic matter (DOM) is an important factor controlling SOM dynamics in deeper soil layers. Reported mean annual DOM fluxes from surface soils (top 20 cm) vary from 10 to 130 kg DOC $ha^{-1}$ $y^{-1}$ in agricultural soils and from 10 to 850 kg DOC $ha^{-1}$ $y^{-1}$ in forests. Variation in soil properties, land management and hydrological conditions explain this wide range. However, it is generally unknown which mechanisms control release and transport of DOM. We studied the solubility and degradation of DOM in batch and column experiments. The results of these laboratory experiments were linked with those of a field trial, to interpret monitoring data of DOM leaching in an arable field subjected to 4 different land management treatments, i.e. conventional tillage (CT), reduced tillage (RT), waste water irrigation (WWI) and manure application (MA). Laboratory studies showed that amendment of plant residues or manure and drying-rewetting cycles increase soil solution DOC from 10-30 mg C/L at background to 250 mg C/L. These DOC peaks have a low specific UV absorbance (SUVA at 254 nm), are largely hydrophilic (fractionation, DAX-8-resin) and have degradation half lives ranging from a few hours to 3 weeks. Batch incubation data with $^{13}C$ labeled residues allowed calibrating a DOM model with two different DOM fractions originating from residues, biomass and SOM. Modeling data of unsaturated columns showed that the degradation rate of the hydrophilic fraction affect DOC peak heights (> 100 mg C/L) in leachates and that slow release of DOM from biomass or SOM explain decreasing DOC concentrations as pore water flow rate increased. In an agricultural luvisol, the soil solution percolating at 40 cm below soil surface was sampled using Passive Capillary Wick Samplers during three years. The DOC concentrations, DOC fluxes and the SUVA of the DOC were determined. The DOC concentrations ranged from 3 to 82 mg C/L and fluxes varied between 6 and 29 kg $ha^{-1}$ $y^{-1}$. The average DOC concentrations in soil solutions collected under MA were significantly but marginally larger than under other treatments (10 versus 8 mg C/L) and average DOC fluxes were larger under WWI than under other treatments (16 versus 12 kg $ha^{-1}$ $y^{-1}$). Annual DOC fluxes were mainly explained by water fluxes. Temporal DOC peaks were only observed at low water flow rates and this DOC typically had low SUVA values suggesting a labile C-source. Such DOM peaks are, therefore, unlikely to affect the SOM in deeper soil layers.

### Stabilisation of soil organic matter in complete soil profiles of semiarid steppe soils after grazing cessation

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Grazing is one of the most important factors that may reduce soil organic matter (SOM) stocks and subsequently deteriorate aggregate stability in grassland topsoils. Land use management and grazing reduction are assumed to mitigate these detrimental effects and sequester and stabilise additional atmospheric carbon. Deeper soil layers will also be affected but knowledge on quantity, quality and dynamics of SOM in deeper soil layers is scarce. The aim of this study was to evaluate the quantitative and qualitative effects of grazing cessation on SOM and the involved stabilisation mechanisms in complete soil profiles. We fractionated three horizons (0-10 cm, 10 cm-carbonate boundary, carbonate boundary-parent material) of four sandy steppe soils using a combined aggregate size, density and particle size fractionation procedure. Three different particulate organic matter (POM) and seven mineral-associated organic matter fractions were separated for each of three aggregate size classes (ASC; coarse = 2000-6300 µm, medium = 630-2000 µm and fine = <630 µm) in four differently grazed plots (different OM inputs due to different grazing intensities). Chemical composition of POM was analysed using solid-state $^{13}C$ NMR spectroscopy. Higher inputs of organic matter due to grazing cessation led to higher amounts of OC in coarse ASC and especially in POM fractions across all depth. These processes started in the topsoil and took more than 5 years to reach deeper soil horizons (>10 cm). After 25 years of grazing cessation, subsoils showed clearly higher POM amounts, too. No grazing-induced changes of SOM quantity were found in fine ASC and particle size fractions. Current carbon loading of fine particle size fractions was similar between differently grazed plots and decreased with depth, pointing towards free sequestration capacities. Despite these free capacities, no increase in current carbon loading after 25 years of grazing exclusion could be detected. It is supposed that either the particle size fractions are already saturated and empirical estimations overestimate sequestration potentials or that external factors (e.g. low soil moisture) delay the decomposition and incorporation of OM in particle size fractions. POM quality was comparable between different grazing intensities. POM is decomposed hierarchically from coarse to fine particles in all soil depths and grazing cessation has not affected the OM decomposition processes. Finally, the content of organic matter was increased in all horizons after more than 5 years of grazing cessation. In all horizons this surplus of OM was predominately sequestered in readily decomposable POM fractions and not stabilised in the long-term.

## Sensitivity of subsoil organic matter turnover to inputs of labile substrates

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Due to its old age and association with mineral surfaces, organic matter in subsoils is generally considered to be stable and therefore of little relevance for short- or even long-term C-cycling in soils and ecosystems. However, in Mediterranean soils irrigated with treated wastewater (TWW) for 10-35 years, subsoil C-pools below 50 cm were found to be depleted by 12 to 40 t $ha^{-1}$ compared to freshwater irrigated soils.

In short-term laboratory soil incubation experiments with disturbed sandy soil samples, SOM in subsoils was mineralized at a much higher rate than SOM in topsoils, although the mean residence time determined from $^{14}C$ data was much higher in the subsoils (1100 vs. 50 years). This shows that subsoil-SOM is potentially labile, if samples are homogenized and aerated. When $^{14}C$-labelled sugars or amino acids were added to the samples, the substrate induced respiration responded much quicker in subsoils from TWW irrigated plots, while SOM mineralization was more stimulated in subsoils from freshwater irrigated plots. The lack of "priming effects" in the TWW irrigated soils indicates that here microbial activity is not substrate limited due to the inputs of easily degradable TWW-borne soluble organic compounds. At the same time, these inputs apparently stimulate SOM mineralization to such a degree that substantial subsoil C-losses can be observed within a few years. Recently, the differential microbial activity in these subsoils was also found in enzyme activity patterns, thus indicating shifts in community structure.

Our data shows that subsoil stability is highly sensitive to physical disturbance and to inputs of easily degradable substrates. Sorptive stabilization or recalcitrance are therefore unlikely mechanisms responsible for the long residence times of subsoil SOM. Instead, we suggest that the spatial segregation of the sparse organic matter from the microbial consumers and the lack of easily degradable compounds are important factors controlling the accumulation of SOM in subsoils.

**Structural properties of dissolved organic carbon in deep horizons of an arable soil**

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The objective of this work is to quantity the DOC that percolates in deep horizons of an arable soil, and to characterize the structural properties of the main fractions. The study was conducted on the long term observatory for environmental research- biogeochemical cycles and biodiversity Lusignan site-France. DOC collected using lysimeter plates inserted to a depth of 105 cm was fractionated into 3 fractions using the two column array of XAD-8 and XAD-4 resins. The HPO (hydrophobic) fraction (i.e. humic substances) isolated from the XAD-8 resin, the TPH (Transphilic) fraction from the XAD-4 resin and the HPI (hydrophilic) fraction which corresponds to the DOC that does not adsorbed onto the two resins under the acid condition used (pH 2). DOM adsorbed onto the resins is recovered with a 75%/25% acetonitrile/water mixture and lyophilized. The hydrophilic fraction is purified according the protocol proposed by Aiken and Leenheer (1993). The isolated fractions were subjected to several characterization tools: UV/Vis, fluorescence EEM, HPSEC/UV/DOC, $^{13}$C NMR, $^{14}$C dating, FT-IR, pyrolysis, thermochemolysis and MSSV GC/MS. The DOC content ranged from 1 to 2.5 mg / L between winter and the middle of spring and then to 4-5 mg / L in summer time. For all isolated fractions HPSEC analyses indicated the predominance of low molecular structures with a low aromatic character. Fluorescence EEM confirmed the non-humic character of the DOM. $^{13}$C-NMR spectra showed that the aromatic character decreased from HPO to TPH, and HPI character. Molecular size follows the same trend. HPI DOM was found to be strongly enriched in carboxyl groups. The $^{14}$C concentration of the HPO fraction corresponds to an apparent calibrated age around AD 1500. For the same fraction isolated from the 0 - 30 cm horizon, the measured $^{14}$C concentration 131.9 pMC corresponds to that in the atmosphere around AD 1978. Significant input of terpenoid derived organic matter was confirmed in the HPO fraction of DOC, results supported by the data of $^{13}$C NMR, FT-IR and Micro Scale Sealed Vessel / pyrolysis GC / MS. Flash pyrolysis GC / MS chromatogram highlight the presence of phenol and alkyl phenols, generally attributed to structures polyhydroxyaromatic structures. Acetamide, a pyrolysis product of amino sugars constituents of microbial cell wall is also significantly present. The thermochimiolysis (TMAH)/GC/ MS confirmed the presence of hydroxy aromatic structures in the extracts; however, their precise origin (lignin, tannins ...) remains uncertain.

**Why is deep soil carbon old ? A modelling approach.**

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Despite having a lower carbon concentration than surface horizons, deep horizons play a major role in soil carbon storage. The vulnerability to climate and land-use changes of deep soil carbon is still poorly understood and many hypotheses are currently proposed to explain its dynamics. Vertical discretization of the carbon dynamic models may help for testing these hypotheses, taking the specific characteristics of deep soil horizons into account and integrating vertical inputs and transfers of carbon.

We vertically discretized the soil carbon module of the ORCHIDEE ecosystem model, which is derived from CENTURY. Carbon inputs within the soil were defined according to simulated root profile and litterfall. The model was tested and validated against several soil carbon profiles collected on various crop, grassland and forest soils from different French regions. Two mechanisms were tested and the associated parameters adjusted in order to satisfactory reproduced the carbon profiles with depth: 1) a migration of carbon down the profile and 2) a reduced turnover of soil carbon pools with depth due to reduced priming effect and different temperature and humidity controls. Both descriptions are able to explain the age increase of SOC with depth but they have different implications for the vulnerability of soil carbon storage in deep soil. These results and their implications for the global carbon cycle will be discussed.

**Towards explicit representation of the vertical soil organic matter profile and surface organic layers in soil carbon models**

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Most large scale soil organic matter (SOM) models describe SOM dynamics as a box without any representation of where in the vertical soil profile the organic carbon resides. However, evidence is increasing that topsoil and subsoil carbon cycling on long time scales are controlled by different mechanisms, which presumably respond differently to climate and vegetation change. Moreover, due to the strong non-linearity of the response of decomposition to temperature and moisture, soils with contrasting SOM profiles can respond very differently to short term variability of temperature and precipitation. Since bulk soil models are not able to capture these effects there is an increasing need for models that dynamically simulate the vertical SOM profile under different climates and vegetation, for adequate future prediction of soil $CO_2$ emissions.We have developed a SOM model that dynamically simulates the vertical profile of SOM, and above ground organic layers. The model simulates the organic layer and mineral soil as two connected reservoirs. Organic matter is transported from the organic layer into the mineral soil, and further downward by two mechanisms: dispersion and advection. Dispersion represents mixing processes such as bioturbation whereas advection accounts for downward movement of mobile fractions with water, such as dissolved organic matter and colloidal organic matter. Simulations for two temperate forests with contrasting SOM profiles demonstrate that the model is applicable for widely different conditions. The results suggest that topsoil organic matter is mostly derived from material transported downward by bioturbation, and input by root turnover, whereas deeper SOM pools are derived from mobile SOM fractions deposited at depth. However there is large uncertainty with respect to the comparative role of root turnover and the different transport mechanisms.Future work will include constraining the transport parameters for different soils and ecosystems based on measurements of soil fauna activity and lead isotope profiles as well as addition of depth specific stabilization processes such as energy limitation of microbes. The model will be the basis of improvement of land-surface schemes and dynamic vegetation models.

**Modelling the Depth Distribution of Soil Organic Carbon, in Relation to Land Use and Soil Type at the Regional Scale in Northern Belgium.**

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Monitoring the dynamics of soil organic carbon (SOC) stocks provides for the moment the most reliable regional estimates of $CO_2$ exchange between the soil and the atmosphere. As carbon stored in the subsoil is more stable than carbon stored in the topsoil, its vertical distribution is an essential element to integrate in regional assessments. Here we aim to model the dynamics of the vertical distribution of SOC over time including its spatial patterns for agricultural soils in northern Belgium. Therefore, a model describing the SOC distribution with depth was constructed and applied on different land use - soil type combinations. The results suggest that between 1960 and 2006 SOC content decreased significantly due to an increase in plough depth (1.02 ± 0.23 kg C $m^{-2}$ in the top 0.3 m of dry silt loam soils) and intensive soil drainage (3.99 ± 2.57 - 2.04 ± 2.08 kg C $m^{-2}$ in top 1 m of wet to extremely wet grassland). Furthermore, a small increase of SOC stock could be observed between 0.2 and 0.7 m depth under dry to moderately wet grasslands (i.e. 0.65 ± 1.39 - 2.59 ± 6.49 kg C $m^{-2}$ in the top 1 m). In order to obtain a single model, quantifying the three dimensional distribution of SOC in the study area, each parameter of the depth distribution model was expressed in relation to land use, and soil type variables. The results indicate that the influence of land use on SOC content is restricted to the topsoil, while soil type determines the SOC content throughout the profile. SOC content near the surface is higher in fine than in coarse textured soils and tends to increase with soil wetness under sand and silt textured soils. SOC near the bottom of the profile also increases with soil wetness, but only in fine textured soils. Under forest, SOC declines remarkably fast with depth, while high sand content seems to result in a rather slow decline of SOC with depth. Total amount of SOC stored in Flanders is calculated at 62.20 ± 0.72 Mt C for the top 0.3 m and at 103.19 ± 1.27 Mt C for the top 1 m.

**Three sources partitioning of microbial biomass and $CO_2$ efflux from soil to evaluate mechanisms of priming effects**

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The input of easily available organic substances in soil may strongly change the turnover of native soil organic matter (SOM), i.e. cause priming effects (PE). PE can be real: altered mineralization of SOM or apparent: increase of microbial C turnover not linked with changes of SOM decomposition. To investigate PE mechanisms, it is crucial to distinguish $CO_2$ produced from individual C pools. We studied priming effects induced by $^{14}C$ labeled glucose and N application in Ap of loamy Haplic Luvisol developed under C3 vegetation. Miscanthus x giganteus (Greef et Deu) – a perennial C4 plant – was grown for 12 years, and natural differences in the abundance of 13C between C4 and C3 plants were used to distinguish between old SOM (> 12 years) and new Miscanthus-derived C (< 12 years). Main source of $CO_2$ (86% of total $CO_2$) released from soil without glucose addition was from SOM younger than 12 years. Glucose application (with or without N) caused two positive PEs (during 1-7 and 30-55 days) with higher contribution of “old” C3-$CO_2$ (up to 60%) as compared to the soil without glucose addition. For the sources of C released by priming it was important that at the end of incubation (55 days) the contribution of “old” C to microbial biomass C increased (up to 36% of total) as compared to the control without glucose. Thus, real PE was observed not only in $CO_2$ but also in microbial biomass and became evident after complete utilization of applied $^{14}C$ glucose. This real PE was confirmed by microbial succession from r- to K-strategists as estimated by microbial growth rates in soil.

**SOM and Total Nitrogen Balance in Soils after Changes from Forest to Agriculture in Humid Subtropical Highlands of Thailand**

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More than 50 soil profiles in humid subtropical highlands located in the North of Thailand were studied to investigate the impact of cultivation on SOM and total nitrogen contents compared to that of currently native forest nearby. Field study and laboratory analyses were based on standard procedures with soils chosen being classified using Soil Taxonomy system. Results showed that most soils in agricultural areas still contained high organic SOM content in the Ap horizon ranging from 18.7-94.7 g $kg^{-1}$ while soils under native forests, mainly hill evergreen with some others such as secondary forest, coniferous forest and Liquidambar plantation, having similarly high amounts of SOM in the A layer varying from 26.3-85.5 g $kg^{-1}$. This illustrated that SOM conservation under crop production with the heavy addition of composts and animal manures on forest clearance areas have seemingly been successful, particularly those with terracing installed and under greenhouse on wide and flat terraces. Total nitrogen content of these soils ranged between 0.73-4.23 g $kg^{-1}$ in the former with the latter having the range of 0.13-2.65 g $kg^{-1}$. It was clear that SOM:total N ratio under cultivation was mostly greater than that under native forest. This was because of substantial amounts of N fertilization for crop production and naturally higher C:N ratio in native forest than in crop production area. In addition to that, nitrogen can be leached out from the soil surface of forest soils more easily than from the surface layer of cultivated soils, especially in the areas under greenhouse cover and some other areas with effective mulching using plastics and crop residues. Furthermore, erosion played no part since the forest lands have been converted for uses. It was shown by very thick surface layers of most soils and also by the classification units which almost all soils were classified as Palehumults and Haplohumults, indicating that OC content was still high even in the upper part of argillic horizon. Thus, it can be stated that agriculture with appropriate soil management and conservation in the humid subtropical highlands of Thailand, following land use conversion immeasurably in some areas, can store carbon within the soils to a great depth.

**Root-derived carbon and nitrogen turnover and stabilization in different soil fractions at major soil horizons**

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Recalcitrant nature of root tissues compared to aerial tissues (higher Lignin/N ratio of roots compared to aerial parts) and susceptibility to sorption of some root originated compounds on mineral surfaces supports the assumption that root originated carbon has stronger sequestration potential. The objective of this study was to determine the rate of incorporation of root material in different soil fractions at different soil depths. Litter bags were incubated at three different soil depths (30, 60 and 90 cm) containing $^{13}C$ and $^{15}N$ labeled wheat roots mixed with soil of respective depths. The application of $^{13}C$ and $^{15}N$ labeled root litter enables to study decomposition processes as well as the allocation of root-derived (rd) C and N in different soil fractions. These litter bags were extracted from the soil after six month interval for three consecutive years. Different forms of SOM were quantified by density fractionation in order to determine mineral-associated SOM, free particulate organic matter (f POM) and occluded particulate organic matter (o POM) followed by particle size fractionation to isolate OM fractions associated with different soil particles (<50, 50-200 and >200 µm). After first year of incubation, C and N mineralization was higher at surface soil horizon (at 30 cm depth) but after that it increased with depth and overall there was higher C and N mineralization in sub soil (at 60 and 90 cm depth). But rd C and N mineralization was always higher at 30 cm compared to other two depths of subsoil having similar rd C and N mineralization. At 30 cm depth, C and N of both fPOM and oPOM proportions were higher during incubation compared to other soil depths. During the early stage of decomposition (first 6 months), enrichment of rd C and N increased rapidly in the macroaggregates (>200 µm) in sub soil but decreased thereafter. There was also higher increase in proportion of rd C and N in 50-200 and <50 µm in subsoil horizons compared to surface horizon. In conclusion, higher rd C and N distribution in 50-200 and <50 µm stable aggregates in subsoil results in the storage and stabilization of C and N from residues. This stabilization in subsoil may be due to organo-mineral complex formations but at surface soil, it was mainly due to physical protection in water-stable aggregates.

# Oral presentations

# Parallel Session 5:

# “Soil C Quantification for GHG Accounting”

**Quantifying Soil Organic C Stock Changes for GHG Inventories: Approaches, Uncertainties and Future Challenges**

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Estimating changes in soil organic C (SOC) stocks has been the focus of much research during the past few decades, particularly in relation to evaluating land use and management impacts on the carbon cycle. Moreover, there has been considerable interest in adopting land use and management practices that mitigate emissions of greenhouse gases, including C sequestration in soils. Different methods can be used for quantifying SOC stock changes, which the Intergovernmental Panel on Climate Change has grouped into three tiers. The methods range from simple equations with default data in the lowest tier to more complicated approaches employing process-based models and/or measurement networks in the highest tier. The intermediate approaches use simple equations that are informed by measurements or model analyses. In general, the precision and even accuracy of the approaches tends to increase with the more sophisticated approaches. For example, the U.S. inventory for SOC stock changes in agricultural lands has been advanced over the past decade from the intermediate approach to a process-based method using the Century model. The estimated change in C using the simple equation was 13.5 Tg C $yr^{-1}$ and the process-based method produced a result of 17.5 Tg C $yr^{-1}$. The uncertainty declined from +37%/-40% with the simple equation to ±16% with the process-based model. Even with the development of more advanced methods, there are still challenges for the research community and improvements to be made in these methods. For example, new findings will need to be incorporated into the analyses from studies such as the temperature dependence of soil organic matter decomposition, erosion and deposition effects on carbon exchange with the atmosphere, influences of land use and management deeper in the soil profile, black carbon potential for C sequestration, and priming effect on decomposition. Incorporating the latest methods should reduce uncertainty and improve estimation for greenhouse gas inventories. Furthermore, it is likely that interdisciplinary studies will engage the soil science community to provide the latest in modeling approaches for applications ranging from economic analyses of C sequestration to climate change assessments. Policy makers and carbon trading forums will look to the scientific community for robust methods to account for SOC stock changes in soils and address uncertainties. Without this support, it seems unlikely that soil C sequestration will play a major role in mitigation efforts, or may not accomplish the expected mitigation levels.

**Drivers of soil C sequestration in European grasslands inferred from flux measurements**

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Within the framework of the CarboEurope IP project, we analyzed C fluxes from 21 grassland and 7 wetland European sites over the 2002-2007 time period. There was no drained organic soil in the data set. All sites were equipped for eddy flux measurements and measured soil (SOC content) and vegetation state variables, as well as management practices (e.g. imports and exports of organic C). Methane emissions from soils and enteric fermentation of grazing ruminants were measured on a subset of sites (5 wetland sites and 5 grassland sites). Carbon (DOC/DIC) leaching was measured at three sites. C in animal products was estimated from intake at grazing (Soussana and Tallec, 2009). The grassland and wetland sites displayed a mean annual Net Biome Productivity (NBP) by 91 ± 18 g C $m^{-2}$ $yr^{-1}$ (n=106 site years, mean ± s.e) indicating C removal from the atmosphere, in good agreement with a previous study with 9 sites (Soussana et al., 2007). Three sites out of 28 had a negative mean annual NBP, indicating an average carbon source to the atmosphere. In order to better understand and upscale these results, two contrasted models were used: the Pasture Simulation Model (PASIM) (Riedo et al., 1998, Vuichard et al., 2007), which includes the CENTURY soil model, and a simple 5-compartments C cycle model with few parameters which was forced by measured daily gross primary productivity (GPP). Both models were parameterised from site specific measurements and initialized either at equilibrium or through an optimization procedure. When PASIM was initialized at equilibrium, simulated GPP was significantly correlated without bias to site means. However, simulated ecosystem respiration (Reco) was on average lower than - and uncorrelated - to site means. Initial SOC compartments were then initialized by fitting simulated to measured ecosystem respiration using an analytical (matrix inversion) procedure. Optimized initial SOC contents were not significantly different (P>0.95) from measured (0-60 cm) SOC contents. However, the slow C pool had unrealistically low values at sites with low N availability. The simple C cycle model was optimized independently for each site by fitting: i) initial SOC to measured site means, and ii) three parameters (humification coefficient, turnover rate of the slow compartment, stabilization rate) to daily Reco and annual NBP. The fitted model predicted accurately daily Reco and annual NBP across sites. Optimized parameter values indicated that: humification coefficient increases (P<0.05) with precipitation to evapotranspiration ratio; turnover rate of the slow pool declines with N balance (P<0.05) and stabilisation rate increases with loam fraction (P<0.01). These results are discussed in relation to the priming effect (Fontaine et al., 2007) and to the need of revising standard soil models in order to better reflect the role of nutrients deficiency on soil C turnover.

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**Dealing With Uncertainties in Extrapolating SOC Data for Regional Inventories**

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Sequential soil organic carbon (SOC) inventories are the most frequently used approach to monitor exchanges of $CO_2$ between the soil and the atmosphere and as such recommended in greenhouse gas reporting. Detection of the small changes in SOC over periods of less than 10 years still remains difficult due to the large spatial variability in SOC. Here we aim to assess the uncertainties of different methods of spatial integration of SOC data, illustrate the impacts on the efficiency of monitoring programmes and present an alternative method of data acquisition using hyperspectral sensors. The main techniques used to extrapolate point values of SOC to larger areas are either geostatistical techniques or attribution of point values to stratified units usually by land use, soil type and/or climate. Geostatistical techniques require a high sample density and are therefore restricted to smaller or rather homogeneous areas. Attribution of SOC data to homogeneous areas can either be done based on the location of the sample point or by using empirical models. The latter technique has been applied to northern Belgium based on a historical sampling campaign containing 7000 soil profiles (a density of 1 profile per 2 $km^2$). The empirical model proved to be rather accurate (80 % of the units had errors between 2 and 7%), but the large spatial variability of SOC within the units resulted in a RMSE of the prediction of c. 30 % of the SOC stock. Where such large number of SOC data are not available, repeated sampling of 128 profiles within four units in southern Belgium, allowed us to quantify the variability in SOC stock and its components (C concentration, bulk density, stoniness and soil depth) in function of scale. The RMSE within the same field amounted to 13 % of the SOC stock, while the RMSE for different fields within the same units was 30%. The minimum detectable difference (MDD) for this stratified sampling is still rather large (0.8 kg C $m^{-2}$).Although the precision of hyperspectral techniques in detecting SOC is still somewhat lower than using chemical analysis (3-6 vs 2 g C $kg^{-1}$), its application as proximal sensor on an aircraft has demonstrated that the SOC content in the plough layer can vary by a factor two. The application of these techniques to SOC inventories could reduce the MDD significantly by using a very large number of SOC values from the pixels in each field.

**The importance of bulk density independent sampling for soil C quantification.**

Stewart Wuest

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Use of the soil surface as a guide for measuring depth results in inconsistent soil samples. Not only is the surface hard to define precisely and subject to biases between tools and operators, it changes in elevation as bulk density fluctuates due to moisture, frost, tillage, traffic and other variables. This means samples taken at different times or by different people or with different tools will sample to slightly different points in the soil profile. Even worse, a built-in bias occurs when treatments with greater bulk density are sampled to a deeper point in the soil profile than treatments with lesser surface bulk density. Not being able to ensure that samples are taken to the same point in the soil profile makes it impossible to accurately compare changes over time or differences between treatments. With a modest change in technique, soil samples can be taken that are independent of bulk density and also not dependent on the accuracy of determination of the soil surface. This is done by measuring the dry mass of each sample, and expressing depth in terms of mass of dry soil per unit area instead of linear depth from the surface. After sample processing, an equivalent mass-depth can be calculated for all soil types, treatments, and sample dates. This is done by interpolating the values for each measured soil constituent using the nearest points to the chosen equivalent mass depth. It has been demonstrated by several researchers that this method is able to correct for known biases and sometimes makes substantial differences in conclusions drawn from both quantitative and qualitative measurements. Most researchers find these concepts to be new and somewhat confusing, so this presentation will focus on photos, diagrams, and principles to guide the listeners to a basic understanding of the problem and its solution.

**Modeling Carbon Seqeustration in Home Lawns**

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Soil organic carbon (SOC) sequestration and the impact of carbon cycling in urban soils are themes of increasing interest. There are 80 million U.S. single family detached homes comprising of 6.4 million ha of lawns with an average size lawn of 0.08 ha. The potential of SOC sequestration for U.S. home lawns is determined from the SOC rates of turfgrass and grasslands. Net SOC sequestration in lawn soils is estimated using a mathematical model derived from typical homeowner lawn maintenance practices. The average SOC accumulation rate for U.S. lawns is 80.0 kg C $lawn^{-1}$ $yr^{-1}$. Additional C accumulation resulted from fertilizer and irrigation management. Hidden C costs (HCC) of typical lawn management practices include mowing, irrigating, fertilizing, and pesticide application. The net SOC sequestration is assessed by subtracting the HCC from gross SOC sequestered. Lawn maintenance practices range from low to high management. Low management or minimal input (MI) includes mowing only, with a net SOC sequestration rate of 63.5 – 69.7 kg C $lawn^{-1}$ $yr^{-1}$. Do-It-Yourself (DIY) management by homowners is 106.9 – 122.4 kg C $lawn^{-1}$ $yr^{-1}$. High management is based on industry-standard best management practices (BMPs) and had a net SOC sequestration rate of 84.5 – 141.8 kg C $lawn^{-1}$ $yr^{-1}$. Results support the conclusion that lawns are a net sink for atmospheric CO2 under all evaluated levels of management practices with a national technical potential ranging from 63.5 – 141.8 kg C $lawn^{-1}$ $yr^{-1}$.

## Quantifying Carbon Change in Canadian Cropland for Greenhouse Gas Reporting

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*Agriculture and Agri-Food Canada*

The United Nations Framework Convention on Climate Change and the Kyoto Protocol to that Convention require that countries calculate national inventories of their greenhouse gas emissions. The accounting methodology for cropland used by Canada corresponds to Tier II under Guidance from the Inter-governmental Panel on Climate Change (IPCC).

Areas of land-use change (LUC) or land management change (LMC) for which carbon (C) change were derived from relational databases of land use and management. Breaking of native grassland to cropland and clearing of forest for cropland were the two types of LUC considered. Included LMC were change in tillage practice (no-till, reduced tillage, and full tillage), change in summerfallow frequency, and change in the proportion of perennial to annual crops. A factor of C change per unit area is applied to each area of LUC and LMC to derive total C change. The factors are derived using the Century model of soil organic carbon (SOC) from the difference between predicted SOC without any LUC or LMC and the SOC with the LUC or LMC of interest. Because there was a rich set of data available for LUC and the LMC of fallow reduction, the magnitude of SOC change for these was scaled to these empirical data. For other LMC, the magnitude of SOC change was predicted from the Century simulations. The change in SOC was fit to the equation: dC = dCmax [1-exp(-kt)] where dC is the factor of C change t years after the LUC or LMC, dCmax is the total expected SOC change, k is a rate constant (1/yr), and t is the time since the LUC or LMC (yr). The factor of SOC change for the inventory year was derived from this equation. When excluding the C impact of loss of woody biomass from clearing of forest for cropland, in 1990, Canadian cropland was estimated to have a net increase of SOC of 0.3±0.5 Tg C. By 2007, the net C increase had grown to 3.4±0.7 Tg. The SOC increases arose primarily from reduction in summerfallow and reduction in tillage. These C sinks occur almost exclusively in the Canadian Prairies (Great Plains) while many other areas of Canada are losing SOC from conversion of pasture and hayland to annual crop production.

The highest contribution to total uncertainty was associated with SOC change from conversions between annual crops and perennial forage crops.

**Measuring Carbon Dynamics in Field Soils Using Soil Spectral Reflectance: Prediction of Maize Root Density and Soil Carbon Content**

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The patterns of carbon (C) sequestration in soils are highly correlated to plant root density and root turnover times. Deeper root systems have the potential to sequester carbon deeper in the soil profile where root turnover times can be slower. Plants with deeper, denser root systems will also be in demand to recapture nitrate that would have leached past shallower root systems. Deeper plant roots may also increase water use efficiency by optimising the use of subsoil water and minimizing irrigation frequency. To exploit these opportunities crop cultivars that express deeper and denser rooting characteristics will need to be evaluated in field trials. Our research reports the development of a soil coring technique that can predict maize root density and soil carbon content from the soil`s visible and near-infrared (Vis-NIR) spectral reflectance. Soil cores (18 x 600 mm depth by 46 mm diameter) were collected from two sites within a paddock of 90 day old silage maize. At one site the soil was dominantly Kairanga silt loam and at the second site a Kairanga fine sandy loam (Recent/Orthic Gley Soils). At each site, three replicate soil cores were taken at 0, 15 and 30 cm distance from the maize stem towards the centre of the 60cm row. A soil core was sectioned at 5 depths (7.5, 15, 30, 45, and 60 cm) and at each depth the soil reflectance spectra was acquired from the freshly cut surface using an ASD Field SpecPro spectroradiometer and a purpose built soil reflectance probe. A 1.5 mm soil slice was taken at this surface to obtain root mass (using wet sieve laboratory root measurement) and total soil C and N (using LECO) reference data. Root densities decreased with depth and distance from plant and were lower in the silt loam, which had the higher total C and N contents. Calibration models developed using partial least squares regression (PLSR) between the first derivative of soil reflectance and the reference data were able to accurately predict the soil profile root density ($R^2$ cross-validation 0.83; RPD 2.42) and C ($R^2$ cross-validation 0.86; RPD 2.66) and N (R2 cross-validation 0.81; RPD 2.32) distribution patterns. Soil carbon can be predicted using wavelengths different to those used for root density prediction, indicating independent prediction between soil organic matter and root content. The advantages of using this methodology for measuring the spatial distribution of root systems and soil organic carbon are discussed.

**The effect of forest management on soil carbon stocks**

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Soil organic carbon (SOC) stocks are assumed to be sensitive to forest management and site conditions. In the frame of the German Biodiversity Exploratories initiative the relation between forest management and the magnitude of SOC was studied. This study was conducted in the Hainich region in Thuringia/Germany with a total of 500 sampling points along a forest management gradient which covers unmanaged forest, selection forest and age class forests. At each sampling point site variables (e.g. inclination, exposition, soil horizons, texture, soil type) were recorded. The forest floor was sampled by means of a metal frame and the mineral soil with a soil column cylinder auger to obtain undisturbed samples at six depth increments. After sample preparation the OC concentration was determined and the OC stocks were calculated. The C stocks under different landuse intensities,humus types and soil types have been compared with a two-way Anova. The results of the first 100 sampling points pointed out that the OC stock in the forest floor was significantly higher under unmanaged and selection forest (0.8 and 0.7 kg $m^{-2}$) than under age class forest (0.4-0.5 kg $m^{-2}$). In contrast, the OC stocks in the mineral soil were not significantly affected by landuse intensity. However, the Anova showed that the OC stocks of the major soil types (Luvisols and Cambisols) were significantly different ($p<0.0001$). Cambisols contained the highest OC stocks within all depth increments. Effects of forest management intensity on C stocks in the mineral soil were not detectable with a sample size of n=90. A higher number of soil samples (n=500) will enhance the propability to find significant effects of forest management intensity, particularly in the topsoil. Additionally, the light fraction of soil organic matter (SOM) was isolated from 83 A horizon samples to proof the hypothesis if the labile fraction of SOM is more sensitive to forest management than total OC stocks. To our surprise preliminary results showed that the heavy fraction of soil organic matter in A horizons seems to be more sensitive to management than the light fraction.

## Spatial application of DNDC biogeochemistry model and its potentiality for estimating GHG emissions from Italian agricultural areas

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Agriculture is responsible of the 10-12% of the total Green House Gases (GHGs) emissions (IPCC), in particular accounting for about 60% of global anthropogenic N2O emissions in 2005. However uncertainty of GHG inventories are still high, since biogeochemical cycles are strongly influenced by climatic and environmental conditions and also dependent on local agricultural practices. To improve GHG balance in cropland, higher order methods (Tier 3) are recommended as, for example, model applications at territorial level previously tested in representative pieces of land. With the aim of improving the national GHG inventory in Italy, a GIS-Model integration was performed. DNDC biogeochemical model was chosen (due to its ability in simulating C and N cycles and the corresponding GHG - $CO_2$, $CH_4$ and $N_2O$) and tested against measured data coming from eddy-covariance stations and soil flux chambers belonging to Carbon-Italy network. As first approach, model results were compared with net ecosystem exchange (NEE) values, evidencing the good behaviour of the model in mimic the real C balance. Then DNDC was run for the entire country considering a land use cover grid of 1 x 1 km (CAPRI - JRC), only simulating the area covered by maize in each cell. Soil and meteorological data were provided by IBIMET and SPIDE database. First results showed average higher and more variable heterotrophic respiration values in the northern with respect to the rest of the country, during the growing season. However due to the higher yields and hence C input, this cropping system seemed to be a weak C sink in the north, evidencing instead net biome productivity (NBP) close to 0 in almost central and south Italy. Preliminary promising results for the C balance evidenced the potentiality of this tool in the GHG inventories, that could be further improved implementing more detailed management practices, simulating other crops and the $N_2O$ emissions.

**The National Cooperative Soil Survey and Soil Organic Carbon Inventories**

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The National Cooperative Soil Survey (NCSS) of private lands in the US is nearing completion and data from this inventory are available in publically accessible databases. These include the NCSS Soil Characterization Database for analytical data and corresponding pedon descriptions and the STATSGO2 and SSURGO databases that contain spatial data and estimated tabular attributes at two different levels of generalization. The objectives of this paper are to describe these databases, their limitations, and plans for enhancing soil survey data. The NCSS Soil Characterization Database contains data and descriptions for about 30,000 pedons in the US. The incorporation of additional data from university laboratories across the country will roughly double this number. Included in the database are properties needed to inventory soil organic C stocks, namely horizon thickness, organic C content, bulk density, and rock fragment content to a soil depth of 1.5 to 2 m. Similar estimated data are available in the SSURGO and STATSGO2 databases. These estimates are derived for individual map unit components based on measured values and/or estimates from analytical data for similar soils in the region. Lack of information that reflects property variation associated with land use and management is recognized as a major shortcoming of these databases and efforts are underway to rectify this issue. The SSURGO database includes low, high, and representative values for each property to represent the dominant land use condition and the property range encountered within the soil survey area. Land use at the time of sampling is commonly identified in pedon descriptions in the databases, but terminology differences and data base structure complicate stratification of the pedon data by land use. Improved accessibility of this land use information is currently under evaluation. In addition, the NCSS is initiating a program to systematically collect data for dynamic or use-dependent soil properties. This inventory addresses extensive benchmark soils and will include sufficient replication to allow statistical evaluation of property differences among steady-state soil-land use combinations. The dynamic soil property data will become part of the NCSS Soil Characterization database, will be extended to similar soils, and used to update SSURGO and STATSGO2 map unit component attributes. A suite of values that reflect differences due to land use and management will be provided for selected dynamic soil properties. Existing data can be downloaded from http://ssldata.nrcs.usda.gov and http://soildatamart.nrcs.usda.gov

**Simulating SOM dynamics and denitrification-nitrification processes with the EPIC model**

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The EPIC (Environmental Policy Integrated Climate) model is a comprehensive terrestrial ecosystem model capable of simulating many biophysical and biogeochemical processes of managed ecosystems. Using weather, soil, landscape, and management information, EPIC can simulate many ecosystem processes including crop yields, net primary productivity, soil erosion, and the balance of water, carbon, and nutrients. APEX (Agricultural Policy Environmental Extender), the watershed version of EPIC, can simulate and integrate all these processes in multiple fields or subareas within small or large watersheds. The objective of this paper is to describe the latest advances incorporated in EPIC / APEX to simulate coupled carbon and nitrogen processes in managed ecosystems. First, we will describe the carbon and nitrogen models with particular reference to decomposition, erosion, denitrification, and nitrification processes. Second, we will provide examples of model testing and application regarding these processes. We will conclude by elaborating on research directions towards enhancing EPIC / APEX capabilities for simulating carbon cycling and trace gas processes.

**Estimation of carbon cycling in croplands using SiBcrop model**

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SiBcrop is a modified version of the Simple Biosphere model (SiB), a widely used fine-resolution land surface model. The major differences in SiBcrop include the crop-specific phenology and physiology scheme within SiBcrop (against the phenology based on remotely sensed NDVI in SiB) and better parameterization and representation of carbon cycling in croplands. The performance of SiBcrop has been evaluated by testing it against the site specific observed data at several Ameriflux eddy covariance flux tower sites with a variety of crops. SiBcrop has been coupled with the regional Atmospheric Modeling System (RAMS, a model developed at Colorado State University) for predicting regional scale carbon and other fluxes, and the predicted fluxes have been evaluated against the observations. Sub-hourly carbon exchanges which include net ecosystem exchange and its components (photosynthesis and respiration) predicted by SiBcrop have also been able to capture the interannual variability observed in the field based on the changes in weather and crop characteristics. The yields estimated by SiBcrop for major crops (corn, soybean, and wheat) have been compared against the site-specific and NASS (National Agricultural Statistics Service) based yield estimates. SiBcrop still utilizes the simple mechanism used by SiB in estimating ground respiration. We have planned to modify this by utilizing the ability of SiBcrop to produce carbon inputs to soil (in terms of residue/litter) from different plant pools and a simple soil carbon decomposition scheme.

## Comparison of COMET-VR and SCI as Carbon Assessment Tools

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Both the Soil Conditioning Index (SCI) and COMET-VR are carbon assessment tools used by the USDA-NRCS to estimate conservation management effects, including soil organic carbon (SOC) dynamics. However, the two tools have never been compared. We used a regression of SCI scores to carbon change from long term studies to quantify SOC from SCI ratings for comparison to COMET-VR. Management scenarios included: three tillage systems; no-till (NT), mulch-till (MT), and conventional-till (CT); five textural classes along a textural gradient; and two typical crop rotations at 9 locations per region for a total of 540 scenarios. Crop rotations for the eastern U.S were: corn (*Zea mays* L.)-soybean [*Glycine max* (L.) Merr.] (C-S); and corn-soybean-winter wheat (*Triticum aestivum* L.) (C-S-W) without irrigation. Rotations for the western states were: winter wheat-potato (*Solanun tuberosum* L.) (W-P) and winter wheat-four-year alfalfa (*Medicago sativa*, L.) (W-4yA) with irrigation. Both models predicted significant tillage effects ($p<0.0001$) with ranking NT>MT>CT without net SOC loss under NT for any location. COMET-VR predicted significant SOC losses at 6 of 9 locations under MT and at all eastern locations under CT. Conversely SCI predicted SOC loss at 1 of 9 locations under MT and 5 of 9 eastern locations under CT. For the western U.S., COMET-VR predicted SOC loss at 3 of 9 locations for MT and at all 9 locations under CT. Predicted SOC was significantly different by tillage for the western states, without any net SOC loss probably due high biomass from irrigation. Both models predicted significant (p„T0.0073) rotation effects on SOC at some locations. For the eastern U.S., SCI predicted higher SOC at 8 of 9 locations for the C-S-W rotation compared to C-S as opposed to 5 of 9 for COMET-VR. Among the western states, COMET-VR predicted significantly higher SOC for the W-P at 6 of 9 locations compared with W-4yA, while SCI predicted significantly higher SOC for W-4yA at 7 of 9 locations compared to W-P. Texture significantly (p„T0.05) affected SOC but not along a textural gradient. SCI predicted significantly higher SOC in finer textured clay loam soils, while COMET-VR predicted significantly higher SOC in the coarse textured sandy loams contrary to expectations. Overall, COMET-VR SOC estimates were more conservative than SCI. Similarities in model outcomes for tillage effects, differences in magnitude of predicted SOC levels and inconsistent trends between rotations and among textures indicate the need for continued evaluation and validation of both models.

# Oral presentations

# Parallel Session 6:

# "SOM: Global and Regional Perspectives"

## An Overview of Soil, Carbon, and Climate Change

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The earth`s soils are major depositories of carbon, in the forms of fresh organic residues, humus, and mineral carbonates. The organic carbon in soils alone constitutes a reserve that is at least three times greater than the amount contained in the atmosphere. Moreover, soil organic matter is exceedingly labile: It may be augmented by judicious soil and vegetation management but may decompose and release greenhouse gases ($CO_2$, $CH_4$, $N_2O$) if mismanaged. Appropriate management of organic matter in soils may enhance their fertility and thus may help to absorb carbon from the atmosphere via green plants and store, i.e., sequester, it in the soil. Carbon sequestration in soils can therefore contribute significantly to the global effort to mitigate the greenhouse effect, while enhancing soil productivity. However, because soils of different regions vary greatly in their properties and in their existing and possible modes of management, no universal prescriptions can fit all circumstances. Rather, the soils of each region and type must be regarded in terms of its own characteristics and its contribution, and potential response, to anticipated climate change. Soil carbon sequestration provides a mechanism to ameliorate agricultural soils in developing countries, since when denuded and cultivated, soils are subjected to rapid organic-matter decomposition without replenishment. Particularly vulnerable are cultivated and overgrazed soils in the humid tropics, where decomposition tends to be very rapid and where bared topsoil tends to erode by intense downpours during rainy seasons and by winds during dry spells. Even more vulnerable are organic soils of bogs and marshes. A major goal is to reverse loss of vegetative cover and of organic matter from soils and the ensuing structural degradation, fertility depletion, and accelerated erosion. An important task at present is to develop effective mechanisms to enhance soil carbon sequestration in practice. Toward that end, various economic and policy mechanisms have been proposed. We shall provide a review of the proposed alternatives, and suggestions for policies appropriate for developed and developing countries.

**Land-Use Induced Dynamics of Soil Organic Matter and Nitrogen in Mountain Soils of South Ecuador**

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In the mountain rainforest region of the South Ecuadorian Andes natural forests often have been converted to pastures by slash-and-burn. With advanced pasture age the pasture grass (Setaria sphacelata) is replaced more and more by the tropical bracken (Pteridium arachnoideum) leading to the abandonment of this unproductive pastures. Subsequently a successional vegetation develops on the former pasture sites. Along this land-use gradient (natural forest, 17 and 50 year old pastures, abandoned pasture, succession) the dynamics of soil organic matter (SOM) and nitrogen in the soils were investigated. Furthermore, plots of a recently established pasture fertilisation experiment (treatments: urea, rockphosphate and urea + rockphosphate) have been included in the study. To track the effects of urea on SOC and N mineralisation in pasture soils in more detail, incubation experiments with the addition of $^{14}C$- or $^{15}N$-labelled urea have been carried out. The study sites were located close to the Estacion CientÃfica San Francisco, about halfway between the provincial capitals Loja and Zamora, in the Cordillera Real, an eastern range of the South Ecuadorian Andes at about 2000 m above sea level. The mean annual air temperature is 15.3°C with an average annual rainfall of 2176 mm. The stocks of SOC were significantly highest in the 50 year old pasture top soil (0-10 cm). In contrast, stocks of total N were elevated in both (young and old) pasture soils compared to forest, abandoned pasture and succession. Thus, the C/N ratio significantly changed along the land-use gradient: appearing narrowest in the 17 year old pasture and widest in the soil under successional vegetation. The stocks of microbial biomass carbon and nitrogen were significantly highest in the young followed by the old pasture soil. In the laboratory experiment, with $^{14}C$- and $^{15}N$-labelled urea fertilisation of the 17 year old and the abandoned pasture soil, it has been shown that urea accelerated the mineralisation of SOM directly after addition up to 17 % compared to the non-fertilised control. Urea fertilisation induced a shift in the microbial community composition towards a relative lower abundance of PLFA marker characteristic of Gram positive bacteria and a higher one of those typical of Gram negative bacteria and fungi. This shift was positively correlated with the increase in $NH_4$, $NO_3$ and DON availability. The principal component analysis of PLFA data indicated that also the structure of the microbial community was at least significantly different between the 17 year old and the abandoned pasture.

**The carbon balance of European croplands: a trans-European, cross-site, multi model simulation study**

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Croplands cover approximately 45% of Europe (EU25) and play a significant role in the overall carbon budget the continent. However, the estimation of the carbon balance is still uncertain due to a lack of data to parameterize models to simulate the complex interplay of management and environmental conditions. The CarboEurope IP (CEU) cropland eddy covariance network represents for the first time data on a gradient of environmental conditions and representative management practices. Here, we present a multi-site model comparison for four ecosystem models namely the DeNitrification DeComposition model (DNDC), the coupled vegetation-crop model ORCHIDEE-STICS, the CERES-EGC model and the Soil Plant Atmosphere model (SPA). The models represent a crosscut of model species that are currently used to analyse the carbon dynamics of croplands. The DNDC model is a general site to regional scale model with a focus on nitrogen and carbon biogeochemistry simulating crops on a daily time step. CERES-EGC requires daily rain, mean air temperature and Penman potential evapo-transpiration as forcing variables to simulate cropland carbon dynamics daily time step. ORCHIDEE-STICS is a coupled model between a dynamic global vegetation and a process-oriented crop model surface $CO_2$, water vapour and heat fluxes on a half hourly time step. The last model in the comparison is Soil Plant Atmosphere model (SPA). It is a process-based model that simulates ecosystem photosynthesis and water balance at a 30 minute time step. We compare the accuracy of the models in predicting net ecosystem exchange (NEE), gross primary production (GPP), ecosystem respiration (Reco) as well as actual evapo-transpiration (ETa) for winter wheat and maize derived from eddy covariance measurements on five sites of the CEU network. The sites cover a gradient of environmental conditions in Europe from the eastern part of Germany (T=9.6ºC; P=501.0mm), Switzerland (T=9.0ºC; P=1100 mm) to the central and southern part of France (T=12.9ºC; P=700mm). The models are all able to simulate mean daily GPP, with correlation coefficient (r) values between 0.70 to 0.95 for all sites when compared to measurements. The simulation results for mean daily ETa and Reco are less satisfying with ranges of r below 0.20 to 0.90 respectively 0.30 to 0.95. The resulting simulation of daily NEE is satisfying in some cases, but in others the models fail due to a mismatch in the timing of peak GPP and peak respiration. In general model performance is clearly site specific and a function of management, crop and environmental conditions.

**Opportunities and barriers for the estimation and prediction of soil carbon at State and catchment scales in New South Wales, Australia.**

Brian Wilson[1], Subhadip Ghosh[2], Paul Kristiansen[2], Phoebe Barnes[2], Dacre King[1]

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Implementation of the the New South Wales Soil Condition Monitoring Program began in 2008/9. The program aims to assess a range of soil condition indicators but among these, soil carbon is considered to be the most important. Data from the program, gathered from more than 800 sites, across an area exceeding 800,000 $km^2$, provide a unique opportunity to examine patterns and trends in soil carbon status across a wide range of climatic zones, soil types and land-uses. Here we explore this extensive, systematically collected soil carbon dataset. Examination of spatial variability has allowed the assessment of the precision and confidence of soil carbon estimates at site and regional scales and limitations in such estimates. Analysis of the depth distribution of soil carbon points to predictable profile partitioning of soil carbon across climate/soil-type/land-use combinations. Through analysis of this dataset, we present a potential rapid, efficient method for the estimation of soil carbon for carbon accounting at Catchment and State scales along with limitations and barriers to this approach.

**Effects of historic forest management on carbon stores in soils in the Hainich-Dün Region, Central Germany**

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Based on the increasing understanding of the role of land-use history in present biogeochemical cycles this study deals with the question, how much current carbon pools on forest sites are influenced not only by the present ecological conditions and land-use, but also by anthropogenic interventions in the past. Historical management practices like clearing and agricultural use of forest surfaces, coppice with standards or high forest management may still have an effect on the current state of forest soils. The overall objectives of this study were: i) to reconstruct the history of forest management in forest ecosystems during the last 150-200 years in the Hainich-Dün region, the northern part of Thuringia/Germany ii) to quantify the soil organic carbon (SOC) storage in forest soils with different land-use history (historical coppice with standards versus historical selection systems, historical old forest versus former agricultural used forest versus present cropland) ii) to determine the SOC storage in density fractions (mineral-associated-SOM, occluded particulate organic matter and free particulate organic matter). The forest history of the Hainich-Dün region was influenced over centuries by several ownerships, which caused a mosaic of different forest management in the 18th and 19th century in this region. The forests of the Kurfürstentum Mainz and the free imperial city Mühlhausen were mainly used as coppiced with standards. The formerly selection system forest were in possession of old monasteries and forestal cooperative societies (Laubgenossenschaften). The Prussians convert all coppices with standards into age class forest and afforested agricultural used land during the 19th century. Based on these information soil investigations to quantify the effects of different management history on present carbon stocks were done. First results show no effects of historic forest management on present carbon stocks. SOC stocks were not significant different between beech shelterwood forest which were use formerly as coppice with standards and as selection system. SOC stocks in present cropland soils were smaller than in the forest soils but no significant differences in SOC stocks were found between historical old forest and former agricultural used forest (afforested 120 years ago). First results of the density fractionation show an increase of SOC storage after afforestation of agricultural land (comparison between 120 years old afforestation and present cropland), but this accumulated carbon is as free particulate organic matter available. The analysis of the density fractionations are still in progress and the results are expected by the End of May 2009.

**SOM - global and regional perspectives: a regulatory compartment of GHG levels in the atmosphere**

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The interactions of land use, management and environment create a varied picture of SOM dynamics across the globe. Globally, the amount of organic matter in soils, commonly represented by the mass of carbon, is estimated to be about 1500 Pg C (1 Pg C = 10^15 g carbon) in the top 1 m of soil, which is three times the amount present in the vegetation and twice the amount found in the atmosphere. The amount of carbon stored in soil is determined by the balance of two biotic processes - ”the productivity of terrestrial vegetation and the decomposition of organic matter. Each of these processes has strong physical and biological controlling factors. These include climate; soil chemical, physical, and biological properties; and vegetation composition. This presentation will include both an integrative view of global patterns on the distribution and trends in SOM as well as research in South America, specially in Brazil, focusing the impact of land use change and management practices on SOM. Land use change, mainly for previous agricultural practices, has often decreased in soil organic carbon (SOC) stocks due to enhanced mineralization of soil organic matter (mainly to $CO_2$). A significant fraction of the ~32% increase in atmospheric $CO_2$ over the last 150 years stems from the breakdown of soil organic matter after forests and grasslands were cleared for farming. This process increases greenhouse gas concentrations in the atmosphere, exacerbating global warming. Conversely, adoption of best management practices, such as conservation tillage, can partly reverse the process - they are aimed at increasing the input of organic matter to the soil and/or decreasing the rates at which soil organic matter decomposes. This mechanism has been called soil carbon sequestration and can be defined as the net balance of all greenhouse gases (e.g., $CO_2$, $CH_4$ and $N_2O$), expressed in C-$CO_2$ equivalents or $CO_2$ equivalents, computing all emission sources and sinks at the soil-plant-atmosphere interface. It must be noted that $CO_2$ fluxes are evaluated trough C stock changes in the different compartments and $CH_4$ and $N_2O$ fluxes directly measured, or estimated with the best available estimates. Finally, this presentation will also present the potential effects on SOM due to the cultivation of biofuel crops in Brazil.

**Impact of land use variation on soil C change in different agricultural soils in NW New South Wales, Australia**

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Soils are an important reservoir of terrestrial carbon (C) and can be a source or sink of atmospheric C depending upon management practices. There is increasing international interest in quantifying the magnitude and resilience of this sink. Land-use change can affect C storage and turnover in soils by altering the soil environment. This can also have a profound impact on the sustainability of farming systems and C sequestration or C losses from soil. Change in land use typically results in different rates of erosion, aggregate formation, biological activity and drainage, which will have a significant impact on soil organic carbon (SOC) accumulation. Differing land uses have variable impact on SOC pool and fluxes. For example, decline in SOC under cropping or grazing can be attributed to reduced inputs of organic matter, increased decomposability of crop residues, and tillage effects that decrease the amount of physical protection to decomposition.

A system of paired plots have been established in three major soil types (basalt, metasediment and granite) across north-western New South Wales, Australia, through state wide soil monitoring program in order to determine the direction and magnitude of soil C changes associated with major land use change i.e. cropping, native pasture, improved pasture and woodland. Ten random samples were collected from a 25 x 25 m plots at four different depths (to 30 cm) from each land-use which were in close proximity having identical soil type, slope, aspect and elevation. Total soil organic carbon in the surface 10 cm decreased in the order of woodland > native pasture > improved pasture > cropping soils for all three soil types. However, the site variation was large and changes in surface total soil carbon was not significantly different between improved pasture and cropped soils.

**The effect of precipitation and land use on carbon pool dynamics in Inner Mongolia, China**

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An understanding of soil carbon dynamics is essential for predicting terrestrial responses to climate change and land use interactions. Grasslands play a significant role in the global carbon cycle, and numerous studies have attempted to describe the main drivers of SOC in grasslands. However, these studies often treat SOC as homogenous, investigate one influencing variable, and examine only one region. This study examined the response of different soil carbon pools to precipitation, land use, and soil texture across the Northeast China Precipitation Transect in Inner Mongolia, China. Northwest China has a long history of grassland conversion to cultivated fields, and is predicted to see some of the largest effects of climate change in the world. Soils sampled from the transect were sieved and separated into coarse and fine particulate organic matter (POM) fractions which were analyzed for organic carbon content. SOC increased along the precipitation gradient, and the highest variation was explained by ecosystem type, soil texture, and land use. Labile SOC was the most sensitive to both precipitation and cultivation, and the proportion of stable carbon in total SOC significantly increased with increasing precipitation. Stable C showed no relationship to cultivation intensity, except in the sites with the longest cultivation history. The heterogeneous response of different carbon pools to precipitation and land use may be important when predicting responses of SOC dynamics to climate change.

**Differential Impacts of Grazing and Fire on Central U.S. Grasslands C and N Balance Under Current and Projected Climate and Atmospheric $CO_2$**

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A simulation experiment was conducted to evaluate the long-term (10-100 years) influence of grazing and fire on system carbon storage, productivity, and trace gas fluxes at 6 sites in the central U.S. grasslands. Using the DayCent ecosystem model and VEMAP climate and soils information, we simulated the separate and combined impacts of 4 grazing intensities (ungrazed, light - 20% removal, moderate – 35% removal, and heavy – 50% removal), 5 fire frequencies (unburned and fires occurring every 1, 2, 3, or 4 years), 3 climate scenarios (current, CCC, Hadley), and 2 levels of $CO_2$ (ambient and 100 year ramp to 2x $CO_2$). In general, total system carbon storage dropped under heavy grazing regardless of fire regime, climate, or $CO_2$ status. Light grazing stimulated carbon storage relative to baseline conditions in most cases at all sites. Moderate grazing (baseline management) showed little impact on system C storage over 100 years. In all cases, eliminating grazing led to increased C storage. As one would expect, increasing fire frequency led to reduced carbon storage at all sites. This impact was least pronounced at the Fort Keogh in the northern Great Plains. Forage production did not respond as consistently to fire frequency. Annual fire increased production at all sites except for the CPER (shortgrass) site. Biannual fire enhanced production everywhere except for Konza (tallgrass) and Hays (mixed grass). Fire every 3 years enhanced forage production at all sites. Fire every fourth year reduced production relative to baseline management everywhere but Jornada (southern desert grassland). As would be expected, climate change and $CO_2$ had strong impacts on these generalized patterns due to differences in available moisture. Grazing reduced $N_2O$ production at all sites. Using this information, it is possible to optimize fire and grazing management for maximum forage production, system C storage, and minimum $N_2O$ production for each grassland region.

## Grazing Effects on Net Global Warming Potential in Mixed Grass Prairie

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Quantification of global warming potential (GWP) for grassland ecosystems is critically important given their vast geographical extent and inherent capacity to affect the global carbon cycle. Contributions of grassland ecosystems to net GWP, however, are largely unknown. In this study, we sought to quantify GWP for two long-term grazing management systems located within a mixed grass biome in south central North Dakota (46.77 N, 100.92 W). Grazing management systems included moderately grazed pasture (MGP; 2.6 ha/steer) and heavily grazed pasture (HGP; 0.9 ha/steer), both of which were established on native vegetation in 1916. Factors evaluated for their contribution to GWP included, 1) change in soil organic carbon (SOC) through utilization of archived soil samples, 2) flux of methane and nitrous oxide over the three year period using static chamber methodology, and 3) literature-derived estimates of methane production for enteric fermentation. Analysis of SOC over a 44 yr period indicated both pastures to be significant soil C sinks, with a mean sequestration rate of 0.40 ± 0.29 Mg C/ha/yr. Cumulative fluxes of methane and nitrous oxide over the measurement period were minor, and not different between pastures. Due to differences in stocking rate, methane production from enteric fermentation was nearly three-fold greater in HGP than MGP. Summation of factors contributing to net GWP indicated both pastures to be net sinks of greenhouse gases to the soil, underscoring the value of grazed, mixed grass prairie to reduce atmospheric radiative forcing.

**Cropland conversion to grassland: increasing or decreasing soil organic carbon?**

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Conversion of cropland to permanent grassland is often expected to sequester atmospheric $CO_2$ and to increase soil organic carbon stocks (SOC). We investigated this possibility under realistic management conditions. We compared the development of the C balance and SOC stocks of intensively (high N-input and frequent cutting) and extensively (no N input, infrequent cutting) managed grassland after conversion from an arable rotation. The study was carried out at a site is in the lowlands of Switzerland with a temperate climate and a soil classified as Eutri-Stagnic Cambisol. The C balance was assessed by measuring C fluxes in and out of the ecosystem including net $CO_2$ exchange by eddy flux measurements, organic fertilizer C input, and harvest C output. SOC stocks (0-45 cm depth) were quantified at the beginning (2001) and at the end (2006) of a 5-year observational period. An equivalent soil mass of 500 kg $m^{-2}$ was sampled. Results showed very similar SOC stocks in 2001 of 13.3 (+/- 0.6) and 13.7 (+/- 0.9) kg C $m^{-2}$ for the intensive and extensive field, respectively. Over the 5-year period, the observed mean annual increase of 0.04 kg C $m^{-2}$ $yr^{-1}$ for the intensive field was small and not significant, whereas for the extensive field a significant decrease of 0.22 kg C $m^{-2}$ $yr^{-1}$ was found, amounting to 1.1 kg C $m^{-2}$ $yr^{-1}$ over the five years. The second approach (flux budget) also indicated a generally positive C balance (C accumulation) for the intensive field and a negative balance (C loss) for the extensive field, with substantial inter-annual variations in relation to growing season length and precipitation. While both stock and flux measurements revealed significant differences between management types, the flux measurements indicated significant gains to the intensive management whereas the stock approach suggested significant losses due to extensive management. Absolute values for the C balance differed between the two assessments, but they revealed a consistent difference of about 0.25 kg C $m^{-2}$ $yr^{-1}$ between management systems, which also appeared in simulations with the mechanistic grassland model PROGRASS. It can be concluded that without continuous nitrogen input, the conversion from arable rotation to permanent grassland may cause a considerable loss of SOC due to increased soil organic matter decomposition.

# Oral presentations

## Plenary Session:

## "Development in SOM Characterization Methods: What Do They Tell Us About SOM Dynamics?"

**SOM and soil architecture: developments in characterization methods**

Ingrid Kögel-Knabner[1], Katja Heister[1], Carsten Mueller[1], Jürg Prietzel[1], Kai U. Totsche[2]

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The heterogeneous distribution of the nutrient and energy sources leads to the formation of a complex architecture of soil, with diverse zones of biological and chemical (re)activity. Soil can thus be considered as a dynamic and hierarchically organized system of various organic and inorganic constituents and organisms, the spatial structure of which defines a large, complex and heterogeneous biogeochemical interface. Although the research in this area is one of the most rapidly growing and competitive fields of soil science, in particular the interplay and the interdependencies of the multitude of biochemical and biophysical processes still await unravelling. A major step forward was achieved by combined efforts of soil mineralogical, organic chemical and microbial research approaches, with increasing evidence of the important influence of soil biota in the formation of organo-mineral assemblages. Thus, the need for using appropriate in-situ techniques that do not only allow visualization, but also give information on the chemical structures or at least elemental composition is evident. Already established techniques are facing their limits when studying reactive spots in soils. Synchrotron-based Near Edge X-ray Absorption Fine Structure (NEXAFS) (or X-ray Absorption Near Edge Structure (XANES)) spectroscopy have provided a substantial step forward in the characterization of organic C, N, S and other elements and its distribution in soils at the submicron scale. Atomic force microscopy (AFM) is used to map interface morphology as well as to measure force-distance-characteristics at molecular resolution. While the former reveals information on surface area and topography as well as spatially resolved surface roughness, the latter provides information on local surface material properties such as elasticity, hardness, friction, charge densities and heterogeneity and can be used to measure directly tip-surface interaction forces with special consideration of adhesive, capillary and magnetic forces as well as “chemical” forces employing modified tips. The technique of nano-scale secondary ion mass spectrometry (NanoSIMS) with its ability to analyze simultaneously several elements or isotopes with high sensitivity and resolution introduces a new analytical window for soil biogeochemical research at the submicron scale. The NanoSIMS technology combines submicron scale imaging with in situ chemical and isotopic data, thereby enhancing our ability to locate the association of elements in soil structural components.

**On the use of physical fractionation methods to isolate the labile portion of soil organic matter**

Denis Curtin, Mike Beare, Catherine Scott

*NZ Institute for Plant & Food Reseach, Christchurch, New Zealand*

Physical fractionation methods are widely used to isolate labile pools of soil organic matter (SOM). However, there is ambiguity in the literature regarding the relative merits of density and size-based fractionation. Another concern is that the choice of density and size is often based on arbitrary criteria (e.g., a density of 1.7 g/ml is widely used because it is near the maximum achievable using sodium iodide. The aim of this research was to improve our understanding of the inter-relations between density and size-based SOM fractions in order to provide a rational basis for selection of fractionation methods. We separated a New Zealand pasture soil (Wakanui silt loam; 0-15 cm depth; total C = 29 g/kg) into size (>50, 20-50, 5-20, and <5 µm) fractions following ultrasonic dispersion. The >50, 20-50, and 5-20 µm fractions were subjected to a sequential separation using sodium polytungstate solutions with progressively increasing density (1.7, 2.0, 2.2, and 2.4 g/ml). Although the sand (>50 µm)-associated organic matter (commonly called particulate organic matter, POM) is regarded as free (not mineral associated), only about one-third of it was separated at a density of 1.7 g/ml and a density of 2.4 g/ml was required for complete recovery. Most of the organic matter in the 20-50 and 5-20 µm fractions was recovered using the density sequence, but the proportion of low density material declined as particle size decreased (at a density of 1.7 g/ml, recovery of C in the >50, 20-50, and 5-20 µm fractions was 33, 17, and 11%, respectively). The C content of the isolated material (light fraction) was inversely related to solution density (~400 g C/kg at a density of 1.7 g/ml, decreasing to ~ 80 g/kg at 2.4 g/ml). The light fraction had a significant mineral content in all cases, but especially at higher density. The results indicate that the POM is likely to be an organo-mineral complex, rather than free organic matter. Further, POM is heterogeneous and parts of it (the low C component) may be relatively stable. Use of solutions with density of 1.7 g/ml or lower may seriously underestimate labile SOM. Further work is needed to determine the optimum density for separation of labile organic matter.

**Photodissolution of Soil Organic Matter**

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Tens of percent of particulate organic carbon (POC) in marine sediments were shown recently to dissolve after irradiation by sunlight – a process termed photodissolution. We thus tested a variety of A-horizon soils, including tilled and un-tilled examples, for susceptibility to photodissolution. Time course experiments showed that 8-28% of soil POC photodissolved largely to dissolved organic carbon after 96h of irradiation, under immersed conditions. Experiments that varied the water content of soils showed that reaction extent decreases by about four-fold for air-dry soils, with field-moist states showing intermediate reactivity. Reflectance data suggest that the enhancement by water is due to chemical and not optical reasons. Particulate organic nitrogen also photodissolves, largely to dissolved organic nitrogen and partly to ammonium. Exposure time of field soils to sunlight depends on factors such as photic zone depth and soil mixing rates; rough estimates imply that significant fractions of soil POC could be photodissolved on decadal time scales. This reaction may have contributed to historical organic matter losses associated with agriculture, and management regimes that minimize surface water and exposure of subsurface soils to sun may improve long-term sustainability of soil organic matter.

**Effect of Extraction Temperature on the Composition and Biodegradability of Water-Extractable Soil Organic Matter**

Mike Beare[1], Denis Curtin[1], Martin Chantigny[2], Tina Harrison-Kirk[1], Catherine Scott[1]

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Water-extractable organic matter (WEOM) is considered to be a labile fraction of soil organic matter (SOM). Cold (20-25ºC) and hot water (70-80ºC) extraction methods have been used to recover WEOM; however, the influence of extraction temperature on the amount, biochemical composition and biodegradability of WEOM is largely unknown. Twenty mineral soils from New Zealand and eastern Canada, representing different land uses and cropping histories, were collected (0-15 cm) and extracted with water at temperatures ranging from 20 to 80ºC. The water extracts were analysed for dissolved organic C and organic- and mineral N, as well as pH, and inorganic cations (Ca, Mg, K, Na, Mn) and anions (Cl, sulphate, phosphate, bicarbonate). Biochemical characterisation was carried out to determine amounts of phenolic-C, hexoses, pentoses and ninhydrin-reactive N in the water extracts. The biodegradability of the organic matter extracted in water was determined using a 42-day bioassay (20ºC) with repeated analysis of CO2 production. In all cases, the amounts of WEOM recovered increased exponentially as water temperature increased. Averaged across all soils, water-extractable C doubled between 20 and 50ºC (from 124 to 245 mg/kg) whereas, over the next 30ºC increment (50 to 80ºC), it tripled from 245 to 732 mg/kg. At 80ºC, between 1.1 and 3.7% of total soil C was extracted. The WEOM was influenced by management history, with grassland soils having more WEOM than arable and forest soils at any given temperature. WEOM was highly biodegradable in all cases with 10 to 20% mineralized after one week of incubation at 20ºC, and more than 60% mineralized after 42 d. Contrary to expectation, the biodegradability of WEOM tended to increase with increasing extraction temperature. There was no evidence that heating to 80ºC changed the biodegradability of cold (20ºC) WEOM. Polysaccharides were preferentially solubilized as extraction temperature increased. The amount of hexoses, pentoses, phenols and ninhydrin-reactive N compounds all tended to increase with increasing extraction temperature. Hexoses and pentoses accounted for an average of 33% of C extracted in water at 80ºC compared to only 19% at ºC. In summary, our results show that hot water extracts easily degradable organic matter.

**Changes in Mid-infrared Spectral Properties of Soil Fractions During Incubation**

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We carried out Mid-infrared (MidIR) spectral interpretation of fractionated fresh and incubated agricultural soils to determine the relationships between change in dynamics of the fractions during long-term incubation and their functional groups in soil organic matter (SOM). Soils cores from four long-term sites under continuous corn in the US Corn Belt were obtained from 0-20, 25-50, and 50-80 cm depth. The samples were then taken to the laboratory and analyzed at time zero, 440 d and 800 d of laboratory incubation. At each sampling time, the soils were processed to obtain the light fraction (LF), particulate organic matter (POM), silt, and clay-sized fractions. Time zero samples were also acidified to obtain decalcified soils. The dried and ground samples were scanned as neat samples in diffuse reflectance mode from 400 to 4000 wavenumbers (wn). Principal components analysis (PCA) of the MidIR spectra showed that for all 4 sites, shallow soils had different spectral properties from deeper soil samples. Acidification of the soils also changed the spectral properties of the soils across several sites, with the effects more pronounced on deeper samples. The PCA analysis indicates that the whole soil, POM, LF, silt and clay all have different spectral properties, with POM and silt being the most similar to each other, while the whole soil, LF and clay formed distinct and separate clusters. Incubation had a stronger effect on the spectral properties of the clay and LF than on other fractions. While clay sized OM accounts for the largest portion of SOM (36-68% of the total in these soils), the LF lost proportionally more C than the rest of the fractions during incubation, possibly because the LF includes the labile plant residues and microbial biomass. The differences due to incubation in clay and LF spectra were more pronounced after 800 d of incubation than after 440 d. PCA Loadings show that incubation resulted in different spectral changes in the LF than the clay sized fraction. Spectral subtraction shows that the bands that declined in the LF during incubation are within a broad region from 1243-1730 wn, while bands at 1151 and 578 wn increased in LF during incubation. These spectral regions may indicate labile and resistant C, although further analyses of spectral changes in other fractions are needed.

**Modeling Saturation and Protection Mechanisms of Soil Organic Matter**

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A new soil organic matter (SOM) model explicitly including protection mechanisms and the potential saturation of soil organic carbon (SOC), in which the pools have been defined functionally, rather than kinetically, is presented. Over the past few decades, simulation models of SOM have been used quite extensively to investigate the effects of tillage management, land use changes, changing climatic scenarios, and soil texture on SOM decomposition and storage. It has recently been suggested that models composed of functionally defined pools may better represent SOM dynamics as these pools are defined by physical and chemical fractionation schemes, rather than the decomposition kinetics (usually first-order) of each pool. In this exercise, we have attempted to "model the measureable", a phrase that encompasses our overall strategy. The SATURN model is defined by soil organic carbon pools, loosely grouped into aggregated and non-aggregated pools. This model also incorporates a new theory of potential SOC saturation and modern theories of soil aggregation and the physical and chemical protection provided therein. We have completed both qualitative and quantitative assessments of model behavior against a suite of long-term agroecosystem experiments that include differences in tillage management, crop rotations, climate and other site-specific characteristics.

### High Spatial Variability of Soil Organic Matter Detected by Synchrotron-Based Spectroscopy

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The complexity of soil organic matter has created challenges for its characterization and linking behavior to organic matter forms. Only recently, soil organic matter was described as a complex mixture of smaller molecules rather than a complex macromolecular structure. An analysis of bulk chemical properties still neglects, however, the importance of the spatial organization of organic matter. In the past decades, great advances have been made to separate organic matter according to its location in soil. For example, organic matter outside aggregates was contrasted with that residing inside stable microaggregates or bound to mineral surfaces. These methods have provided the first insight into the mechanism of soil organic matter changes. Recent advances in focusing techniques afforded the opportunity to use x-ray and infra-red methods for mapping of chemical forms at even higher high spatial resolution of 0.03-7 micrometers. Synchrotron radiation is needed to achieve a sufficiently high flux rate to image low elemental concentrations at this small scale. Particularly near-edge x-ray fine structure (NEXAFS) spectroscopy is suitable for mapping both elemental contents and functional group chemistry at spatial resolution of currently 30 nm. NEXAFS spectroscopy demonstrated that functional group composition of organic carbon was very similar between different forest soils, but highly variable on a small scale of 50 nm within intact microaggregates. In addition, no region within the studied microaggregates bore the chemical signature of the carbon of the entire soil. This finding highlights the importance of recognizing the spatial variability of organic matter forms for understanding processes such as organic matter stabilization and destabilization. While organic matter rich in aliphatic and carboxyl and carboxamide functional groups were distributed along pore structures, aromatic carbon forms were rather clustered. Challenges associated with such high spatial observations are the scaling to pedon or field levels, and merging such findings with observations of dynamic change in organic matter properties.

**Organic Matter in Sandy Cropland Soils Studied by Combined Density Fractionation and Pyrolysis Field Ionization Mass Spectroscopy**

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Sandy cropland soils in North-Western Europe were found to contain unusually high organic carbon (OC) levels and a link with their land-use history has been suggested in previous research. The clay size fractions of a group of such sandy cropland soils with historical heathland land-use had nearly double OC contents (on average 19.9% OC) compared to a reference group of permanent cropland soils (on average 10.9 %OC). Given these very high OC loadings we hypothesized OM-OM interactions to be involved as an OM stabilization mechanism in the cultivated heathlands next to mineral-binding. To further our knowledge herein we separated the clay fraction into a heavy (>2.2 g $cm^{-3}$) and a light (1.6-2.2 g $cm^{-3}$) fraction, presumed to contain differing proportions of mineral bound OM. Temperature resolved Pyrolysis Field Ionization (Py-FIMS) was used for molecular level characterization and to assess the thermal stability of OM components. For the sand, silt, <2.2 g $cm^{-3}$ clay and >2.2 g $cm^{-3}$ clay fractions the ratios of OC in soils with historical heathland use over OC in the soils without were 0.5, 1.3, 1.3 and 2.0, respectively. The higher contribution of the >2.2 g cm-3 clay OC to soil OC in the cultivated heathlands points to the stability of this fraction. Py-FIMS spectra revealed: 1Â° higher ion intensities in both clay fractions of masses related to lipids, sterols and a lower thermostability in the cultivated heathlands compared to the permanent croplands, and enrichment of alkylaromatics and heterocyclic N-containing compounds in the latter; 2Â° strong similarities between the mass spectra and thermograms of the two clay density fractions; 3Â° the >2.2 g $cm^{-3}$ clay fraction was relatively enriched in N-containing compounds (both heterocyclic compounds as well as peptides) and relatively poorer in medium to long-chained lipids. We conclude that the OM of the permanent croplands clearly has a more decomposed character. Accumulations of lipids and sterols, logically linked to historical land-use, appear to be stabilized in the cultivated heathland group. Second, in spite of the limited success in separating distinct soil OM fractions by density, higher ion intensity proportions of marker signals of organic N compounds in the heavy fraction confirm their preferential mineral binding, in line with a layering model of OM-mineral conformations. Finally, lipids and sterols enriched in the light clay fractions of the cultivated heathland soils may point to their stabilization either through OM-OM sterical entrapment or in clay sized particulate OM.

**Carbon turnover from diverse microbial groups in temperate and tropical forest soils**

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Microorganisms represent an important source of actively cycling carbon (C) in terrestrial ecosystems, yet little is known of the fate or stability of microbial C in soils or the relative importance of microbial biochemistry as a factor influencing C stabilization. This project utilized $^{13}C$ stable isotope labeled microorganisms including fungi, bacteria gram +, bacteria gram -, and actinomycetes as substrates in a reciprocal transplant experiment in a temperate forest in the Sierra Nevada and a tropical forest in Puerto Rico. Microbes were isolated from each site, grown with $^{13}C$ media, autoclaved and, lypholyzed and added back to soils at each site. The temperate and tropical soils were sampled over a 3 and 2 year period, respectively. Microbial C turnover was significantly faster at the tropical site as compared with the temperate site, as was expected. Results indicate that the decomposition of microbial C stabilized at the temperate site at about 35% of initial input C after 12 months, while in Puerto Rico decomposition does not to begin to stabilize until about 16 months at less than 10% of initial input C. For the temperate site, there were slight differences among microbial groups in the initial stage of C turnover, but over time treatment differences declined and the amount of microbial C stabilized was similar among microbial groups. For the tropical site, the treatments behaved more similarly and did not exhibit substantial differences in C turnover. Similarly, there were initial differences in the amount of C recovered within the native microbial biomass pool and as dissolved organic carbon, but these differences declined over time. Physical fractionation of soil indicate differences between sites in the partitioning of microbial C among light fraction (LF), occluded fraction (OF), and mineral fraction (MF). While the temperate site retained a substantial portion of input microbial in the light fraction and mineral fraction, the tropical site retained substantially more of the treatments within the mineral fraction. These results also correspond to the overall C pool sizes for the two sites among fractions. Recovery within the OF was significantly less than LF and MF for both sites, but exhibits a slower turnover rate relative to the LF and MF. Compound-specific turnover of input microbial residues associated with biomarkers from pyrolysis-gas chromatography-mass spectrometry-isotope ratio mass spectrometry (Py-GC-MS-IRMS) for the two sites will be discussed.

**Fate of lignins in soils: a review**

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Lignins are amongst the most studied macromolecules in natural environments. They constitute an important parameter in many soil-plant models (CENTURY, RothC) and appeared determinant for the estimation of the soil organic matter pool-size and its stabilization. The aim of this paper was to review the current knowledge about quantity, composition and turnover of lignins in soils and to identify parameters determining lignin residence time. Despite the large number of methods existing to study lignins, their fate in soils is almost exclusively evaluated using alkaline CuO oxidation. The CuO oxidation products released by this method allow to obtain limited quantitative information (amounts of V, S and C monomers) on lignin content and various qualitative information (S/V, C/V, (Ad/Al)V,S) on lignin composition and degree of decomposition. In soils, the lignin content generally decreases with soil depth and with decreasing size of the granulometric fractions, whereas its level of degradation increases concomitantly. A meta-analysis showed that their presence appears to be related to various environmental parameters, such as clay contents, land-use and climate (MAT). Our analysis of the literature data also suggests the accumulation and stabilization of a part of lignins in soils. Lignin dynamic appears to be a function of land-use and vegetation, lignin contribution to SOM being higher in agricultural than in forest soils, but with high variation for each land-use type. Finally, lignin turnover in soils seems to be faster than that of total SOC. Two pools of lignins were suggested: one pool of non-degraded lignins with the faster turnover and one pool of stabilized lignins with lower turnover. The pool sizes seem to be variable for different soil types and the mechanisms behind different degradation behaviour still need to be elucidated.

**Separation of Mineral Associated Organic Matter From Arable and Forest Topsoils by Sequentially Combined Physical and Chemical Steps of Fractionation**

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Land use and soil mineralogy strongly affect the ability of soils to sequester organic carbon and their potential to mitigate the greenhouse effect. This study is aimed to clarify long-term impacts of land use (i.e., arable, forest) and soil mineralogy on composition and stability of soil organic matter associated with soil minerals. Seven soil types different in mineralogy (Albic and Haplic Luvisol, Colluvic and Haplic Regosol , Haplic and Vertic Cambisol, Haplic Stagnosol) were selected within Germany. Samples were taken from topsoils at deciduous forest and adjacent arable sites that are continuously used for more than 100 years. We sequentially separated particulate and water soluble organic matter from the samples of the Ap and Ah horizons. The organic particles were separated by (i) an electrostatic attraction procedure to obtain coarse organic particles and (ii) a density fractionation in water combined with ultrasonic energy to obtain organic particles occluded in macro- and micro-aggregates. Further the water soluble organic matter was extracted. From the remaining solid residue the Na-pyrophosphate soluble organic matter fractions (OM(PY)), representing mineral associated organic matter, were extracted and characterized by FTIR spectroscopy and $^{14}C$ analysis. For the arable topsoils (pH 6.7-7.5) multiple regression analyses indicate a strong influence of clay, oxalate soluble Al and pyrophosphate soluble Mg on the content of organic carbon separated with OM(PY) weighted with its C=O content. The $^{14}C$ values of OM(PY) are strongly related to the independent variables: (i) specific mineral surface area, (ii) relative C=O group content in OM(PY) and (iii) soil pH. Such strong relation suggest an increase in OM(PY) stability with increasing interactions between OM(PY) and soil mineral surfaces via cation bridging. For the forest topsoils (pH < 5) a similar relation is found if the specific mineral surface area is not considered by multiple regression analysis. This finding and a higher pyrophosphate soluble organic carbon content suggest that in forest topsoils cations like Fe are mainly used to cross-link the OM(PY) components. However, cross-linking is assumed to be less effective for OM stabilization as compared to cation bridging with mineral surfaces which is reflected by $^{14}C$ data indicating the OM(PY) from forest topsoils to be less stable than that from arable ones.

# Oral presentations

# Plenary Session:

# “SOM and SOM Research in 2030”

**SOM research in 2030: what scientists then might ask of us now**

Henry H. Janzen

*Agriculture and Agri-Food Canada*

The biosphere is changing abruptly, mostly because of human influences. By force of our growing numbers and greater technological strength, we exert ever more pressure on our ecosystems: we ask for more food and fuel, wider habitat for us and for wildlife, greater conservation of species and the many hidden services by which our lands sustain us. At the same time, many resources – arable soil, fresh water, clean energy, biodiversity – are dwindling, creating an ecological squeeze. Further adding to uncertainty is the prospect of changing climate, which may make vulnerable, not only ecosystems, but also some of our past concepts and assumed understanding. Many of the challenges facing us in coming decades hinge on two factors: the way we manage our lands, and the way we manage carbon. At the intersection of these is soil organic matter, a large and dynamic repository of carbon, which we will need to know and manage better. In this paper, I review briefly the ecosystem services furnished by soil organic matter, and ponder some questions that might arise in coming decades, as these services are stressed more and more. These examples, then, lead us to ask: what anticipatory explorations might we undertake now to best help our successors, a generation away, as they confront the challenges and opportunities of their changing world.

# Posters

# Session 1:

# “Climate and Soil Dynamics”

**PS1_1**

### Soil carbon in subsurface horizons: evidence for decadally cycling C pool in deeper soils

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Soils play a key role in the global carbon (C) cycle as the largest C reservoir in terrestrial ecosystems; they can potentially act as both a source and a sink of C. Most studies on soil C dynamics and its response to climate changes have focused on the top surface horizons (A horizons) where higher C concentrations and greater microbial activity are usually found. In contrast, the quality and dynamics of C in the underlying subsurface horizons has received little attention and accordingly remains poorly understood although the horizons can store more C than the surface horizons. Here, we hypothesized that radiocarbon ($^{14}C$) signature of deep soil C would change significantly between the period of 1992 to 2005 if a significant component of the deep soil C cycles on decadal timescales. We applied a density fractionation method followed by the $^{14}C$ measurements to a set of soil profiles collected in both years from the Sierra Nevada elevational transect in central California. In 1992, the maximum storage of soil C below the A horizon was found both in the low-density (LF: <2.0 g $cm^{-3}$) and high-density (HF: >2.0 g cm-3) fractions at mid-elevation where the highest clay content and aboveground litter input are observed. Low density carbon accounted for about a half of the C at all depths and at all elevations dominated by forest vegetation. However, unlike LF-C in typical surface horizons, the LF-C in subsurface horizons was significantly depleted in $^{14}C$, and showed sometimes older $^{14}C$ age than the HF-C that is considered to be strongly associated with mineral particles. The results suggest that soil mineralogy and/or chemical nature of the LF-C, rather than the climate, exert strong controls on quantity and quality of the deep soil C. We found that $^{14}C$ signatures of both LF-C and HF-C fractions increased from 1992 to 2005 in most subsurface horizons in all elevations, providing clear evidence of the incorporation of soil organic matter enriched in bomb-$^{14}C$ into the deep soil C pools. These increases are difficult to explain without invoking significant (>10 years) time lags between C fixation and input into the LF and HF fractions. One mechanism for this would be long-lived roots, or significant time lags between root inputs and incorporation into measured fractions. However, the increases, despite overall old $^{14}C$ values, suggests that the deep soil C consists of rapidly as well as slowly cycling C, and thus the size of decadally cycling C pool in soils may be larger than expected from studies of the A horizon alone.

**PS1_2**

## Evaluation of soil carbon stocks in different native and cultivated areas in Southern Peru

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Carbon accumulation and sequestration in the Peruvian's soils (from lowlands to highlands) - as in most Andean Latin countries included in Biome B - are scarcely documented. The altitude and orography of this mountain chain produces changes in the temperature, rainfall and humidity patterns, which have direct effect on soil development. Rainforests are found at the windward east hillside while the leeward west hillside is a desert. With the aim to determine soil carbon stocks according to soil classes, altitude, temperature gradient, climatic parameters, crop classes and native vegetation, as related to global warming, soils from main cropping systems in 5 contrasting Peruvian agroecologies within a 1,000 km transect, were sampled. These soils were sampled, in triplicates, from the arid Pacific coast, passing through the Andean high plateau, and down to the Amazonian rainforest. Five layers samples from 0 to 30 cm depths were taken and processed for total carbon analysis in duplicates. Carbon contents (CC, in g $kg^{-1}$) and Carbon stocks (CS, Mg $ha^{-1}$) were estimated in each layer and throughout the entire profile. Using a linear additive model for a nested sampling scheme, CC and CS were compared, among cropping systems within agroecologies and among agroecologies, using MANOVA and orthogonal contrasts. Overall, the soils in the Amazonian site (134 Mg $ha^{-1}$) presented higher ($P>0.05$) CC than all the other agroecosystems. It also presented, together with dry valleys, the highest ($P>0.05$) CS (83 Mg $ha^{-1}$). It is noteworthy that well managed coffee plantations in the Amazon and alfalfa under irrigation in the dry valleys can present as much CS as primary rainforests. The dry lowlands showed the lowest values (CC: 51 g $kg^{-1}$; CS: 40 Mg $ha^{-1}$). This can be due to typical problems found in dry soils such as compactness, fire, wrong tillage practices, and the lack of water. Our results also showed that soil organic carbon increased with elevation in the arid environments, and when CS was analyzed as a function of altitude for different agroecologies, within the same texture class, a linear relationship ($r \sim 0.8$) was obtained, which confirms some observations found in the literature. In the high plateau low CC (68 g $kg^{-1}$) and CS (47 Mg $ha^{-1}$) were estimated. The texture in these soils were different from the others agroecologies and thus non-comparable.

**PS1_3**

## Soil C storage under simulated climate change is mediated by plant functional type

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We conducted a 6-year experiment combining Free-Air $CO_2$ Enrichment (FACE, 550 ppm) and warming (+2°C) with careful soil sampling under patches of C3- and C4-dominated vegetation to evaluate the role of functional type (FT) on FACE and warming induced changes in soil organic matter (SOM) accumulation in native Australian grassland. In this system, competitive interactions appear to favor C4 over C3 species under FACE and warming. We used physical fractionation and long-term incubation to assess SOM pool sizes and decomposition rates. SOM-C was higher under C4 than C3 vegetation, but only at ambient $CO_2$. The presence of C4 vegetation accelerated SOM decomposition in response to FACE and warming, suggesting species-specific differences in priming. Decomposition rates were lower with warming, possibly because higher root N reduced microbial demand for older N-rich SOM. This research suggests that if C4 vegetation becomes dominant in future climates, SOM storage may be compromised.

**PS1_4**

**A Response to environmental change in soil extra cellular enzyme profiles – A Proteomic Perspective**

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This study aims to monitor the dynamic changes in extra cellular enzyme profiles in response to environmental changes. Soil mainly peat is estimated to contain 1580 Gt of the world's carbon. Global soil stores hold enough carbon to triple the atmospheric concentration of $CO_2$. It is well known that extra cellular enzymes are the main driver in the decomposition of soil carbon which is eventually released to the atmosphere as $CO_2$. An upward trend in dissolved organic carbon (DOC) concentration has trigged concerns that the soil carbon store has been mobilized. A clear cause has not yet been established. What is certain is that DOC increases must stem from increased net production in the ecosystems or in leaching of DOC from them? Central to increased net production in DOC are proteins in the form of enzymes which are involved in the biochemical decomposition of carbon. This study aimed at understanding extra cellular processes in a new and potentially more exact way than methods applied to date. Until recently, extra cellular enzyme activity in peat has only been measured as potential activity by using enzyme assays. Proteomics using mass spectrometry has the potential to measure insitu –activity, post-translational modifications and to identify the source organisms responsible for this activity. Schultz et al 2005 has already shown that proteins can be detected as a component of DOC using *MALDI –TOF and *LC-MS and 2D Gel electrophoresis. This poster will present the findings from an experiment where the enzyme profile of peat soil samples under different sulphate concentrations is established by using mass spectrometry based proteomics.

*LC-MS = Liquid Chromatography – mass spectrometry

*MALDI-TOF =Matrix- assisted laser desorption /ionization – time of flight

**PS1_5**

## Contemporary evidence for soil carbon loss under different crop management systems and never tilled grassland

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Temporal changes in soil carbon (C) content vary as a result of complex interactions among different factors including climate, historical (baseline) soil C levels, soil texture, and agricultural management practices. The objectives of this study are, first, to estimate the changes in soil total C contents that occurred in the past 18-21 years in soils under agricultural management and in never-tilled grassland in southwest Michigan, USA; second, to explore the relationships between these changes and soil properties such as baseline C levels and soil texture; and third, to simulate C changes using a system approach model (SALUS). The data were collected from two long-term experiments located at Long Term Ecological Research (LTER) site and established in 1986 and 1988, respectively. Geo-referenced samples were collected from both experiments prior to establishment and then were resampled in 2006-2007. The studied agricultural treatments were conventional chisel plowed management with and without nitrogen (N) fertilization, conventional no-till management with and without N fertilization, and organic chisel plowed management with cover crops. Since 1986, a loss of -17.3 Mg/ha total C occurred in never-tilled grassland soil. Losses were observed under chisel plowed management with the largest loss of -4.5 Mg/ha observed in chisel-plowed system without N fertilization. Changes in C content tended to be negatively related to baseline C levels. In no-till, changes in C were positively related to silt + clay contents. In summary, compared to 1980s total soil C in the studied area was either lost in conventionally tilled and never-tilled systems or was only maintained at the 1980s levels by the conservational management systems. SALUS predictions of soil C changes were in excellent agreement with the observed data for most of the agricultural treatments and for the never-tilled soil.

**PS1_6**

# Microbial growth and enzyme activities induced by available substrates at elevated $CO_2$

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Increased belowground carbon (C) translocation by plant roots at elevated $CO_2$ can cause a shift in the structure and activity of soil microbial community. This shift depends on allocation of microorganisms in macro- and microaggregates because of spatial differences in C availability. Previous investigations of the effects of elevated $CO_2$ that focused on total soil organic C or total microbial C showed contradictorily results: increase, decrease or no changes. We evaluated the effect of elevated $CO_2$ on microbial growth and enzyme activities in three $CO_2$ enrichment experiments: two FACE systems on agricultural fields (Hohenheim and Braunschweig in Germany) and on intensively managed forest at the Biosphere 2 Laboratory (B2L) in Oracle, AZ. Microbial biomass C, specific growth rate, and growing microbial biomass were estimated by the kinetics of $CO_2$ emission from bulk soil and aggregates (>2, 0.25-2.00, <0.25 mm) amended with glucose and nutrients and/or yeast extract. Activities of hydrolytic enzymes (b-glucosidase, chitinase, phosphatase and sulphatase) were measured in soil with and without glucose addition. For B2L and both FACE systems, up to 58% higher specific growth rate were observed under elevated versus ambient $CO_2$, varying for site, plant species and N fertilization. This characteristic increased linearly with atmospheric $CO_2$ concentration at all three sites showing that elevated $CO_2$ affects microbial community in the rhizosphere. After adding glucose, the increase of enzyme activities under elevated $CO_2$ was 1.2-1.9-fold higher than the increase under ambient $CO_2$.The specific growth rates increased with decreasing aggregate size and especially under elevated $CO_2$. Based on these observations, we conclude that elevated $CO_2$ stimulated the r-selected microorganisms, especially in soil small microaggregates (<0.25 mm). Enzyme activity in glucose amended soil increased under elevated $CO_2$, especially in large microaggregates (0.25-2 mm). The stimulation was particularly pronounced for chitinase, indicating a higher contribution of fungi to litter decomposition under elevated $CO_2$. We conclude that higher release of available organics by roots at elevated $CO_2$ affected microbial community functioning, but not the total content of microbial biomass. Fast-growing r-selected species were stimulated by elevated $CO_2$ in small microaggregates, while activity of hydrolytic enzymes (probably connected with fungal abundance) was more pronounced in large microaggregates. Such an increase of fast-growing microorganisms and activity of hydrolases indicates acceleration of available C mineralization in soil. This acceleration of decomposition may counterbalance the additional C input by roots in soils at elevated atmospheric $CO_2$.

**PS1_7**

## Evolution of Mineral-OM associations with changes in amount and temporal distribution of rainfall

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For California, the Canadian/CGCM1 and Hadley/HadCM2 climate models project shift in rainfall amount and timing over the next 100 years. Both models agree on likely increase in amount of future rainfall, but disagree on whether the anticipated increase in rainfall will occur as additional winter rain or result in extension of the rainy season into late spring and early summer months. Here, we present results from a field rainfall addition experiment that was setup to test the effects of increased amount of rainfall (20% over ambient) and timing (increased rainfall in the rainy season = winter addition, or increased rainfall during late spring and early summer = spring addition treatment). Specifically, we present results on stock of soil organic carbon (SOC); changes in amount and biochemical composition of free light soil organic matter (SOM) fraction (fLF, $<1.7 g/cm^3$); association of SOM storage with Fe and Al oxides in soil. We found that the two treatments, winter vs. spring addition, have different effects on carbon (C) storage and association of SOM with iron and aluminum oxides. Extension of the rainy season into late spring and summer months results in up to 50% increase in total SOC and 20-40% increase in the fraction of C that is stored as fLF, which was not observed in the winter treatment. Increase of rainfall amount during the already wet rainy season leads to important changes in relationship of organic C with soil mineral that are critical for SOM stabilization. More than 35% of the variability in soil C storage in the control and spring treatments is explained by dithionite extractable (crystalline) Fe, compared to <0.01% in the winter treatment plot. Similarly, more than 26% and 41% of the variability in C storage is explained by poorly crystalline Fe and Al oxides in the control and spring treatments, respectively, compared to <5% in the winter treatment plots. Our results suggest that rapid shifts in rainfall patterns could have significant implications for not just total soil C storage, but also mechanisms of its stabilization.

**PS1_8**

## Temperature-driven shifts in soil microbial communities are consistent across a temperature gradient

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Our research indicates that the temperature sensitivity of soil organic matter (OM) decomposition increases with decreasing soil OM lability. Thus, as temperature increases the rate of decomposition also increases due to metabolism of more recalcitrant OM rather than by increasing the decomposition rate of labile material. An important corollary hypothesis is that the abundance of microbes able to decompose more recalcitrant OM increases with increasing temperature. To test this hypothesis, we collected soils from two locations with mean annual temperatures of 5 and 13 ºC, respectively. Soils from cultivated and native sites were incubated at 5, 15 or 25 ºC for 60 or 150 days and then the temperature raised 10 ºC. Microbial community composition was assessed using fatty acid profiling before, 30 and 60 days after the temperature bump. We found consistent changes in the lipid profiles of the soil microbial community in response to temperature despite differing community structure among the soils. Although this in part may signal a membrane response within individual cells, it most likely represents a community shift due to the large number of fatty acids included in the discriminant model. The separation among temperature treatments was largely driven by changes in the bacterial community, specifically increased relative abundance of iso- and 10-methyl branched fatty acids indicative of gram positive bacteria. Actinobacteria responded positively to the higher temperature bump and their diverse catabolic abilities may signal degradation of more recalcitrant OM such as lignin. Results from this research will provide insight into soil OM stability under pressures from global warming. Furthermore, it will direct future research on microbial adaptations to global temperature change.

**PS1_9**

## Bayesian calibration of DayCent model to quantify parameter uncertainty and its effects on soil carbon dynamics

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The amount of carbon dioxide emitted by human activity that remains in the atmosphere is controlled by carbon cycle processes on the land and in the ocean. To evaluate the source or sink strength of $CO_2$ emissions or removals requires a capacity to predict $CO_2$ in relation to environmental conditions and land use change. Biophysical models simulating the dynamics of carbon and nitrogen have a unique potential to explore these relationships, but are fraught with high uncertainties in their parameters due to their variations over time and space. A sound and feasible methodology to characterize current and predictive uncertainties in dynamic carbon models is crucial for the design of efficient carbon management strategies. In this study, we demonstrated such a methodology by performing a Bayesian calibration of the DayCent model utilising data from a grassland site (Oensingen, Switzerland, latt: 47.29, long: 7.73) to estimate and reduce the uncertainties associated with the key carbon cycle parameters. Bayesian calibration combines prior information about the parameters and measured data on model output variables, to obtain a revised (posterior) probability distribution for the parameters. Prior to Bayesian calibration, we subjected all the uncertain parameters to elementary effects sensitivity analysis. This method allowed us to find a list of uncertain parameters to which the model is most sensitive. The model performed much better after calibration of these parameters than with default parameterisation. Posterior distributions for carbon cycle parameters were narrowed down, thus decreasing parameter uncertainty. More work is needed to investigate regional patterns of parameter distributions by applying the method to several data rich sites.

**PS1_10**

## Will Elevated Atmospheric Carbon Dioxide Change Soil Carbon Stocks in Tilled Corn-Soybean Rotation Agroecosystems of the U.S. Midwest?

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The capability of agricultural soils to serve as significant C sinks that can help offset rising atmospheric $CO_2$ concentrations is uncertain. The potential for storing additional C in U.S. Midwest soils is large because long-term cultivation has depleted the substantial soil organic matter (SOM) stocks that once existed in the native grassland and forest ecosystems of the region. Yet, it is unclear if responses of rowcrop agroecosystems to rising atmospheric $CO_2$ will alter residue inputs or decomposition rates sufficiently to cause a net change in soil C stocks. In central Illinois, free-air $CO_2$ enrichment (FACE) technology was used to investigate the effects of elevated $CO_2$ on soil C pools in a tilled corn-soybean rotation system. After 5 and 6 y of $CO_2$ enrichment (following soybean and corn, respectively), we investigated the distribution of C among soil fractions believed to vary in their ability to protect SOM from rapid decomposition. None of the isolated soil C pools, nor the bulk soil C, showed any significant differences between the ambient- and elevated-$CO_2$ treatments. Comparisons to pretreatment soils suggest that overall the site has lost soil C from unprotected pools regardless of $CO_2$ treatment since the experiment's inception. Soil C in microaggregate-protected pools remained unchanged throughout the study. These findings suggest that tillage and other management practices employed during the experiment have had a greater effect on soil C than the $CO_2$ treatments. Apparently, the disturbance associated with tillage, coupled with the high fertility of the site, have precluded any significant soil C response to the increased C inputs resulting from atmospheric $CO_2$ enrichment.

**PS1_11**

# Driving Forces of Soil Organic Matter Accumulation in Rice-Wheat Rotation Agroecosystem Under Elevated Atmospheric $pCO_2$

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Soil organic matter accumulation in farmland is not only vital for the maintenance of soil productivity, but also for the mitigation of global warming. Rice-wheat rotation agroecosystem is one of the predominant agroecosystems. In this experiment, FACE (free air $CO_2$ enrichment) technology was used to investigate the soil organic matter dynamics at 2 $CO_2$ concentration (ambient and ambient +200 $\mu mol \bullet mol^{-1}$), 2 nitrogen levels (low nitrogen–150 kg $ha^{-1}$; Normal nitrogen –250 kg $ha^{-1}$), and four soil managements. The four soil managements are fallow (without any plants), rice and wheat plantation without residue amendmendment (after rice and wheat harvested, rice-wheat root and straw were removed) (0 res); rice and wheat plantation with root and 50% harvested rice and wheat straw amendment on the area basis (0.5 res); and rice and wheat plantation with root and 150% harvested rice and wheat straw amendment (1.5 res). Results showed that elevated atmospheric $pCO_2$ enhanced rice biomass carbon uptake by 15.3% and 10%, and wheat by 20.6% and 15 .9% at normal nitrogen and low nitrogen for four 4 seasons average, respectively. Nitrogen content decreased by 14.2% for wheat straw and 15% for rice straw at normal nitrogen level at elevated atmospheric $pCO_2$, but the influence of enriched $CO_2$ on carbon content was minimal. After 4 yrs $CO_2$ fumigation, soil organic matter increased by 0.56%, 1.42%, 2.31%, and 6.00% at low nitrogen level, and 0.37%, 4.18%, 9.53% and 6.28% at fallow, 0 res, 0.5 res and 1.5 res treatment, respectively. The difference of decompostion rate of wheat (rice) straw between ambient CO2 and enriched CO2 was negligible. The transformation rates of straw carbon to soil organic carbon were 18.7%, 20.7%, 21.6%, and 20.9% at ALN (ambient $CO_2$-low nitrogen), FLN (enriched $CO_2$-low nitrogen), ANN (ambient $CO_2$-normal nitrogen), FNN (enriched $CO_2$-normal nitrogen), respectively. Soil microbial biomass C and activities of dehydrogenase, FDA hydrolysis, �-glucosidase, invertase, urease, amidase and arylsulphatase increased with straw amendment. The enzymes mentioned above responded to elevated $CO_2$ significantly at NN treatment. Soil enzyme activities were linearly correlated with C input, and the response rate of these enzymes to C input at FACE was slightly lower than at ambient treatment. These results indicated that the soil would serve as a carbon pool at future elevated $CO_2$, and soil carbon increase was mainly due to the biomass C production enhancement.

**PS1_12**

## Does warming release older soil carbon?

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Soil is a large reservoir of terrestrial carbon (C), which has the potential to act as a positive feedback to global warming by releasing more $CO_2$ to the atmosphere as temperatures increase. It is well known that warming increases the decomposition rate of new soil organic matter, but the amount of old soil carbon released by warming is a subject of current debate. Incubation of soils from the Free Air $CO_2$ Enrichment (FACE) sites provides a unique opportunity to study the effects of warming on belowground carbon cycling. Soils from FACE experimental ecosystem are depleted in both $^{13}C$ and $^{14}C$ due to decade-long addition of fossil-derived $CO_2$, making young (FACE-labeled C, < 10 y) and old (pre-FACE fumigation, >10 y) soil carbon easily distinguished by their isotope signatures. Here we use incubation and isotope measurements from FACE soils to test whether warming affects older (more recalcitrant) soil organic matter (SOM) differently than young (labile) SOM. Similarly, a nitrogen (N) fertilization experiment at the site allows to test the effect of nitrogen deposition on the age of carbon respired.

Soils from $CO_2$- and N- elevated and control plots at the Duke FACE site near Durham, North Carolina were incubated in the laboratory at three temperatures (site mean annual temperature, +10ºC, +20ºC). Respiratory fluxes of $CO_2$ were determined periodically, and measured for delta $^{13}C$ and delta 14C content. Respiratory fluxes increased with warming, but the proportion of flux from the > 10 y and < 10 y pools was about equal under all temperature treatments, and stayed relatively constant in time. Warming appears to promote a rapid, transient loss of soil carbon from both fast and slow cycling pools, as demonstrated by similar drops in the fluxes of old carbon between the first and last radiocarbon measurements. Along with lower flux rates, the delta $^{13}C$ of $CO_2$ respired in the nitrogen treatment is enriched relative to the control. This observation, plus the lower fluxes observed under nitrogen fertilization may indicate differences in the quantity, source, and delta $^{13}C$ of inputs.

**PS1_13**

### The Role of Photo-Degradation in Litter Decomposition

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Several field experiments have concluded that photo-degradation contributes to the carbon cycle. However, it is not known how large its global role is. It is also not known to what extent photo-degradation acts on its own and to what extent it acts by making the litter more degradable. We analysed the potential global importance of photo-degradation in the carbon cycle. Radiation reaching ground level was calculated based on total incident radiation and leaf area index and published values for weight loss per radiation energy. Results indicate that photo-degradation is of great importance in the carbon cycle in semi-arid and dry grassland areas, but also in some arctic regions. Photo-degradation needs to be taken into account when modelling the carbon cycle in these areas. However, the role of photo-degradation in the total global carbon cycle is rather small, estimated at 1.4 % of global NPP. In the experimental part dry litter was exposed to light including UV light for almost 10 months, and then incubated with soil and moisture. The results show that the light exposure leads to a small, but significant weight loss and significantly larger $CO_2$ production during the following incubation. We conclude that photo-degradation acts in tandem with microbial degradation. The pattern of nitrogen release was not intensively studied in this experiment, but the data suggests that nitrogen may be released quickly from the exposed litter.

**PS1_14**

## Effect of Litter Quality on Organic Matter Composition of Earthworm Casts

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Earthworms contribute to decomposition and stabilization of organic matter (OM) in soil. The digestion during intestinal passage inside worms may lead to a change in the composition of OM. The Fourier Transform infrared spectroscopy (FTIR) can be used to characterize the OM composition in form of hydrophobic (A) and hydrophilic (B) functional groups (i.e., A/B- ratio). It is largely unknown whether the type of litter the earthworm is feeding affects the OM composition in casts. The objective was to compare the composition of OM within casts of the primary decomposer lumbricus terrestris with that of corresponding litter samples. Litter from 10 different plant species including leaves of birch, beech, oak, spruce, pear, mustard and wheat straw (3 replicates) was offered separately to L. terrestris in microcosms containing a Luvisol soil. The OM composition of casts, collected from the soil surface after 4-weeks, and of litter was analyzed with FTIR (DRIFT technique). The A/B ratio of casts was generally increased as compared to that of the soil. For most litter types, the A/B ratio of cast was relatively similar except for casts from birch (Betula pendula) and pear (Pyrus communis) where the hydrophobic group contents strongly increased (i.e., 3-times higher A/B ratio as compared to wheat (Triticum aestivum) or beech (Fagus sylvatica) casts. The higher A/B ratios seem to be related to the relative higher C/N ratios in the casts from Betula pendula and Pyrus communis feeding experiments. The assumption that worm casts may enrich hydrophobic OM components could be verified only partly. The results indicate that digestion of litter by the worm may change OM composition. However particulate and soluble OM fractions in the earthworm casts could have contributed to such differentiation.

**PS1_15**

## Soil fertility, mineral nitrogen and microbial biomass in upland soils of the Central Amazon under different plant covers

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Amazon is the largest State of Brazil and major area of the State is covered by a largest tropical rainforest of the world. Most soils of the Amazon region soils are characterized as acidic and infertile. When the Amazon forest land is cleared for agricultural use by burning the vegetation, the efficient nutrient recycling mechanism are disrupted. However, nutrient contents in the deforested burn land increased temporarily. The objective of this study was to evaluate the soil fertility, mineral nitrogen and microbial activity of carbon (C), nitrogen (N) and phosphorus (P) resulting from the replacement of the primary forest with pasture (Brachiaria brizantha), commercial plantations of rubber (Hevea spp.), cupuaçu (Theobroma grandiflorum), and citrus trees (Citrus sinensis) cultivated in Xanthic Ferralsol and secondary forest under Acrisols Dystric Nitosols. The results showed that ammonium-N predominates in the 0-10 cm soil depth both in primary forest and areas with secondary forest, citrus plantation and pasture. There was no increase in soil fertility with management of the cultivated areas under secondary forest, but in the pasture there was a significant increase in the stock of organic C and total N and high C/N ratios, the inverse of what occurred with the carbon of the microbial biomass. The primary forest had the highest values of C and P of the microbial biomass and the lowest me<x>tabolic quotient. Of the successions studied, the rubber trees were the plant cover with the smallest changes in terms of quality of the organic matter in the soil.

**PS1_16**

## Soil Carbon and Nitrogen Dynamics in a Deciduous Forest Exposed to Ten Years of Atmospheric $CO_2$ Enrichment

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The impact of atmospheric $CO_2$ enrichment on soil organic matter (SOM) dynamics and stocks will depend on the interplay between plant responses, the soil's capability to protect and stabilize SOM against decomposition, and nutrient availability. Information on C and N allocation to functionally meaningful SOM pools and their dynamics can improve our understanding of soil responses and facilitate predictions of the potential for long-term stabilization. At the free-air $CO_2$ enrichment (FACE) experiment on a sweetgum plantation in Oak Ridge, Tennessee, we are using (1) repeated sampling over time, (2) the isotopic tracer provided by the depleted 13C signature of the fossil fuel source of $CO_2$ used for fumigation, and (3) physical fractionation procedures to determine the fate and dynamics of FACE-derived detritus inputs to SOM. Samples collected in years 0, 3, 5, 8, and 10 of the experiment were fractionated to separate particulate organic matter (POM) and silt- and clay-sized fractions occluded in stable microaggregates from their more readily dispersible counterparts. In this aggrading system, significant linear increases in bulk soil C and N occurred in the surface 5 cm of both ambient and elevated $CO_2$ treatments during the first 10 years of the experiment, but the rates of C and N accrual doubled in response to $CO_2$ enrichment -- with no treatment differences in C:N ratio. "New" FACE-derived C accounted for the 10-year increase in bulk soil C and replaced 18.5% of the "old" pretreatment C. Coarse POM (>250 microns; outside microaggregates) remained relatively constant throughout the experiment with a 5-year mean residence time. The difference in C and N accrual between elevated and ambient treatments occurred mostly in fine POM (both microaggregate-occluded and non-microaggregated) and in silt-sized particles. Initially, the silt-sized fraction accrued C and N at a faster rate inside microaggregates than outside. In years 8 and 10, however, destabilization of microaggregates (likely due to prolonged drought) led to significant loss of C and N from microaggregated silt-sized fractions and a gain in the more readily dispersed silt-sized pool. Old C made up a greater proportion of transferred pool, suggesting that turnover of aged microaggregates was hastened by the drought conditions. Beyond the $CO_2$ treatment responses, the dynamic changes in this system -- coupled with the isotopic tracer -- will contribute to improved mechanistic understanding and quantitation of the processes involved in soil C cycling and stabilization required by SOM simulation models.

**PS1_17**

## Dry/wet cycles effects on carbon and nitrogen dynamics in soils of differing textures and organic matter contents

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Previous studies have reported both enhanced and reduced C and N cycling when soils of different compositions are exposed to repeated wet/dry cycles. The factors that determine the different responses are poorly understood. The objective of this study was to determine the effects of different textures and organic matter levels on the C and N dynamics resulting from repeated drying and rewetting cycles. Soil samples were collected from 6 paddocks on each of two soil types with contrasting textures (silt loam & clay loam) to produce an OM gradient for each. The soils (bulk density = 1.1 g $cm^{-3}$) were incubated aerobically for 92 d. The experiment consisted of three phases: 1) Pre-incubation phase (14 d at field capacity [FC, -0.01 MPa]), 2) Treatment phase (treatments as described below) and 3) Recovery phase (soils returned to FC, 18 d). Three constant moisture and two dry/wet cycle treatments were imposed during the treatment phase:

1) Continuously wet (WW) – soil maintained at FC (-0.01 MPa),
2) Medium dry (MD) – soil adjusted to 120% of wilting point (WP, -1.5 MPa),
3) Very dry (VD) – soil adjusted to 80% WP,
4) Medium dry/wet (MDW) – oscillating between 120% WP and FC,
5) Very dry/wet (VDW) - oscillating between 80% WP and FC,

The dry/wet treatments (MDW and VDW) included three 20 d cycles each consisting of 16 d drying, rapid rewetting and 4 days at FC. Dry treatments were dried down and incubated in their dry states for duration of the treatment phase. Drying was achieved using silica gel, allowing continuous measurement of $CO_2$ (IRGA) and $N_2O$ (GC) during the experiment. At the end of each phase soils were analysed for mineral N (Min N), and cold water (CWEC) and hot water (HWEC) extractable C. Overall, cumulative C mineralised, HWEC and CWEC were positively related to the initial SOM (%C) content and there was little evidence of a texture effect. The textural classes also had similar responses to the dry/rewet treatments, with the dry treatments (MD, VD) having the highest contents of CEWC and HWEC, particularly at the end of the treatment phase, and the lowest C mineralisation. In contrast, there were large differences in Min N availability and $N_2O$ emissions between the two soil textures. In the silt loam soils Min N increased with C content and decreased with drying intensity and $N_2O$ emissions remained very low. In contrast there was a poor relationship between Min N and C content in the clay loam soils, but $N_2O$ emissions were markedly increased during the dry/wet cycles (MDW, VDW).

**PS1_18**

## Biochemical controls on soil organic carbon saturation: assessment of lignin, cutin, and suberin contributions to fractionated carbon pools

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Agricultural soils have the potential to act as net carbon sinks through land management practices that improve soil organic carbon (SOC) sequestration. This mitigating response to climate change is nonetheless limited by the maximum carbon sequestration potential of soils. Recent studies have confirmed that SOC responds asymptotically, indicating that SOC does saturate in whole soils and soil physical fractions with increased carbon input.

Biochemical characterization of whole soils along a soil carbon saturation gradient was employed to further explore the mechanisms of carbon stabilization and saturation with increased carbon input. Soils from a long-term agricultural experiment in Lethbridge, Alberta, where soil carbon saturation has been observed with increased carbon input through manure applications, were analyzed for the content of plant-derived compounds, specifically lignin, cutin, and suberin. Preliminary data from gas chromatography-mass spectrometry (GC-MS) quantification of soil cupric oxide oxidation products demonstrate increasing whole soil lignin, cutin, and suberin contents on a per carbon weight basis with increasing SOC saturation. The acid:aldehyde and syringyl:vanilyl ratio of lignin phenols, which positively correlate with increased lignin decomposition, decreased in the whole soils with increased SOC input. These initial findings indicate that with increasing SOC saturation, partly transformed litter inputs represent a larger proportion of total SOC, as accumulation exceeds decomposition. Coupled with the observed decrease in SOC sequestration efficiency with increased SOC saturation at the Lethbridge experiment, we hypothesize that this result also reflects decreased stabilization of transformed plant-derived compounds in more stable, fractionated soil pools that offer physical and chemical SOC protection. Continued work will examine fractionated SOC pools to determine the differential responses of SOC protective mechanisms on detrital compounds with increasing carbon saturation.

**PS1_19**

## Arbuscular mycorrhizal fungi and glomalin enhance carbon sequestration in organic farming systems

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Soils may be able to mitigate the increase in atmospheric carbon dioxide by sequestering carbon, but agricultural soils are often a net source. The Rodale Institute's Farming Systems Trial® (FST) was initiated in 1981 to develop economically competitive organic farming systems. In this trial, carbon levels in the organically farmed soils rose to 2.5% while those of the conventionally farmed soil remained at 2.0% 22 years after the treatments were established. In the 1990's, significantly higher populations of arbuscular mycorrhizal [AM] fungi were present in organic vs. conventionally farmed soil. AM fungi are symbiotic soil fungi which assist the host plant by taking up mineral nutrients and water from the soil and helping the plant resist pathogens. AM fungi also produce glomalin, a glycoprotein that i) stabilizes soil aggregates, ii) is resistant to degradation, and iii) may be a significant portion of soil organic carbon. In 2006, a three year study was initiated to analyze soil samples collected at six depths (0-5, 5-10, 10-20, 20-30, 30-60, and 60-80 cm) in conventional, organic legume-based, and organic manure-based treatments. Each sample was tested for soil carbon and soil organic matter concentrations, spore populations, and total AM propagules using the MPN bioassay. In addition, soil samples were dry sieved to separate three aggregate size classes (1-2, 0.25-1, and 0.053-0.25 mm) which were weighed and analyzed for percentage of water stable aggregates and glomalin-related soil protein (GRSP) concentration. Finally, the GRSP extract was analyzed to estimate carbon content in this fraction. In 2007 and 2008, spore and propagule data followed trends similar to analyses in the 1990's. Preliminary GRSP values in 2007 and 2008 were about twice as high as those in 2006, but in all years, the data followed similar patterns with higher values in the organic treatments compared to the conventional treatment. Carbon content in the GRSP extracts indicate this fraction to be a carbon storage sink. All AM parameters (i.e. spore populations, propagule number, and glomalin concentration) and soil C values declined with increasing depth. Results from this study indicate organic farming systems have the potential to enhance carbon sequestration through the beneficial relationship between AM fungi, glomalin, and plant host production.

**PS1_20**

## Control of vertical soil temperature and moisture on temporal variation of soil carbon dioxide production and emission

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Efflux of carbon dioxide ($CO_2$) from soil is a critical component of the global carbon (C) budget. Magnitude of soil $CO_2$ production and efflux to the atmosphere are spatially and temporally variable and depend on several soil processes and properties. Determining how deep soil layers control fluxes of $CO_2$ at the soil surface can potentially account for the variation in soil $CO_2$ efflux. In this study, we aimed to elucidate C dynamics through the whole soil profile and its direct influence on surface $CO_2$ fluxes at hourly time scales. A field experiment with three replicated plots was set up on Reiff very fine sandy loam soil derived from non-marine alluvial parent material. In each plot, the changes in soil temperature, air pressure, moisture and $CO_2$ concentrations were monitored at depths of 15, 30, 50, 70 and 90 cm in the soil profile. At each of these locations, soil surface $CO_2$ efflux was measured hourly. Here, we present data from January 2009, during which air temperature fluctuated between 0ºC and 19ºC and water filled pore space was between 36-70 percent. The effect of soil temperature and moisture on $CO_2$ production was determined by using least-squares linear regression of soil $CO_2$ concentration with soil temperature and moisture over time. Slopes generated from the linear regressions represented the magnitude of how soil $CO_2$ production at depths is sensitive to the changes in temperature and/or moisture. Generally, our results showed that soil profile $CO_2$ production was negatively correlated with soil moisture and positively correlated with soil temperature. Soil $CO_2$ production in deeper layers was more sensitive to changes in both temperature and moisture than in the above layers.

# Posters

## Session 2:

## "Development in SOM Characterization Methods: What Do They Tell Us About SOM Dynamics?"

**PS2_1**

## Use of Near Infrared Reflectance Spectroscopy (NIRS) to Determine the Indicator of Residual Organic C in Soil (IROC) and RothC Model Pools of Exogenous Organic Matters

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The use of Exogenous Organic Matter (EOM) in croplands can contribute to increase soil organic matter (SOM) content and improve soil fertility. Several tools can be used to evaluate the potential C incorporation in soils after EOM application: (i) IROC, indicator of residual organic C, corresponding to the proportion of residual C from EOM incorporated into SOM (ii) multi-compartment models such as RothC simulating the long term C evolution in soil. The indicator IROC is calculated from the proportion of EOM C mineralized after 3 days of incubation and from biochemical fractions determined by laboratory measurements which are rather costly, time consuming and generating polluting wastes. The C dynamic models are poorly parameterized for the use of EOM. There is a need to find more effective methods to either determine the IROC or the RothC model pools for a large variety of EOMs. Near Infrared Reflectance Spectroscopy (NIRS) has been shown to be a suitable and promising method to predict various characteristics in soils or for EOMs. The objective of the study was to assess the potential use of NIRS to determine for 441 EOMs of various origins the IROC indicator and RothC model pools. The indicator IROC was correctly predicted using NIRS, with fairly good RÂ² and RPD (ratio of standard deviation of the reference data to standard error of cross-validation or standard error of prediction) for the both calibration and validation subsets (RÂ²=0.87 and 0.79, RPD=2.6 and 2.1, respectively). The proportions of EOM carbon into RothC pools DPM (labile), RPM (resistant) and HUM (humified) were calculated by fitting RothC to C mineralization kinetics measured during 91-days laboratory incubations. RothC was well adjusted to incubations data (mean RÂ²=0.98, mean RMSE=2.6, n=441). The DPM pool and IROC were highly negatively correlated (r=-0.88). The prediction of DPM pools using NIRS was promising with RÂ²=0.85 and 0.67 and RPD=2.4 and 1.7 for the calibration and validation subsets, respectively. The results obtained show that NIRS can be used as a rapid and inexpensive method to determine the IROC indicator and to estimate the RothC DPM pools fitted to laboratory incubations data.

**PS2_2**

## Comparison of two methods for the study of lignin in soils: the CuO oxidation method and the 'Milled Wall Enzymatic Lignin' isolation method

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In soils, to study the fate of lignins the most commonly applied method is the alkaline CuO oxidation, releasing lignin-derived phenolic products (VSC monomers and dimers) (Kögel et Bochter, 1985). However, the amount of native lignins represented by the VSC compounds is not known and is probably limited since the CuO oxidation only cleaves aryl ether bonds but does not completely depolymerize the macromolecule (Otto and Simpson, 2006). The objective of this study is to use an isolation method named 'Milled Wall Enzymatic Lignin' (MWEL – Pew, 1957, Lapierre et al., 1986) to obtain access to a gigger part of the macromolecule and to evaluate its use for the study of lignin dynamics in soils. In a C3/C4 chronosequence, soil and plant lignins were isolated following the MWEL procedure in various plots cultivated in wheat (C3) or maize (C4) since 3, 6 and 9 years. Before lignin isolation from soils, about 300 g of sample were demineralised using 10 % hydrofluoric acid. Lignin derived products (VSC) were also isolated from the same samples with the CuO oxidation method. The $^{13}C$ isotopic signature was measured on the CuO oxidation products and on the MWEL by gas chromatography or elementary analysis combined to an isotope ratio mass spectrometer (GC-C-/EA-IRMS). Characterization of lignin purity was performed by the combination of pyrolysis-gas chromatography/mass spectrometry (py-GC-MS) and solid-state NMR spectroscopy. In soils, the amount of lignins and VSC monomers isolated using the MWEL and CuO procedures are in the same range (0.10 to 0.35 mg OC g-1 soil). The $\delta^{13}C$ values measured on the bulk soil for the MWEL lignins (-30 to -26‰) are similar to those measured with the CuO method (-33 to -25‰). For the plants, similar results were obtained with the two methods. This suggests the efficiency of the MWEL method for the study of lignins in soils. Moreover, py-GC-MS and NMR spectoscopy showed that the lignin isolation is more efficient from soils than from plants, the isolated lignins being less contaminated by polysaccharides (Dignac et al., 2008). To conclude, the method MWEL can be used in combination with the CuO method to characterize the lignins in soils, estimate their dynamic in situ using isotopic method and increase our knowledge about lignin degradation and stabilization processes.

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**PS2_3**

**Structural investigation of organic matter in physical soil fractions from two broadleaf forests by High Resolution Magic Angle Spinning NMR**

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1H HR MAS NMR is a powerful technique that allows examination of the chemical and physical properties of heterogeneous and polydisperse macromolecular systems such as soil organic matter (SOM). SOM plays a major role in the fate, transport, and bioavailability of organic and inorganic components and its dynamics depends on its chemical composition as well as physical protection mechanisms within soil fractions. Soil pH seems to be a variable that affects the rate and processes of SOM decomposition by influencing microbial activity, hydrolysis and protonation. Protonation regulates many soil processes such as solubilisation and complexation which controls sorption and desorption of organic C on mineral surfaces. Despite its documented importance as factor influencing SOM transformation, and despite the high frequency of acid soil in forest ecosystems, the effect of pH on SOM dynamics has been studied rather little. In the present study 1H HR/MAS NMR is applied to SOM extracted from two forest soils differing mainly in pH. The acid site (Geescroft) and the calcareous site (Broadbalk) are both temperate deciduous woodlands at Rothamsted Research, UK. The two soils were physically fractionated according to the procedure of Sohi et al (2001). SOM in three fractions for each site was investigated: free light fraction (FLF), intra-aggreagte light fraction (IALF) and fine silt and clay (S+C). Together these fractions represented 70-80% of the total SOM in the soils and the organic C content was above the threshold value of 3%, needed to obtain good signal/noise ratios in NMR spectra. $^{2}$-D $^{1}$H-$^{1}$H homo-correlation spectroscopy (COSY), $^{1}$H-$^{13}$C heteronuclear single quantum coherence (HSQC) and $^{1}$-D experiments were assessed for both a qualitative and a quantitative analysis of SOM in the three fractions. For both sites the S/N (signal to noise) ratio is higher for FLF-SOM and IALF-SOM than for S+C-SOM fractions, in agreement with the lower carbon concentration in S+C-SOM. Amino acid residues, peptides and carbohydrates are the prevalent species and 6 typical chemical shift regions can be identified in each sample. The S+C-SOM fractions of both sites show strongly decomposed material compared to FLF and IALF, confirmed by the presence of sharp peaks at specific positions. The smaller content of aromatic groups in Geescroft extracts compared to Broadbalk suggests that the effect of acid pH influences degradation processes.

**PS2_4**

## Chemical and Physical Stability of SOM Following Planting of Forest on Native Prairie

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Both mineral interactions and chemical complexity affect the stability of soil C. The Nebraska National Forest at Halsey provides a unique opportunity to investigate both mechanisms of storage. Planted with eastern red cedar and ponderosa pine on native C3/C4 prairie, the forest provides a $^{13}C$ signal to calculate the C dynamics and the ~96% sand at this site should make it more amenable to the measurement of chemical interactions. The cedar soil accumulated SOC above that of the native prairie. The $^{13}C$ analysis showed 50% losses of the total native prairie C under pines but greater than 80% retention under cedars. We determined physical SOM composition by separating the soil into >250 μm (POM), 250-53 μm, (floccules equivalent to micro aggregates) and <53 μm fractions (silt and clay associated materials). The amount of the >250 μm size fractions of the 0 to 5cm layer of the forested soils were twice that of the prairie and retained 20 to 30% of the prairie SOC. The 250-53 μm fraction was the largest in all soils comprising ~50% of the SOC of which 44-47% was prairie-C. The <53 μm represented ~8% of the SOC and was the oldest fraction. The difference between pine and cedar increased with depth. At 15 to 30 cm, the >250 μm fraction contained 3% (pine) to 9% (cedar) of the SOC. The 53-250 μm fraction again predominated at this depth and retained 88% prairie C in the cedar soil. The <53 μm fraction of the cedar contained 100% of its original prairie C and had a higher C content indicating the accumulation of a small amount of root C and little decomposition of the prairie C. We used py-MBMS to determine the chemical differences between soils and litter from the three vegetation types. Differences were found in all comparisons. Pine and cedar soils contained more long chain C aliphatics and aromatics. Specific M/Z peaks that were responsible for greatest difference were 114 representative of proteinaceous- glycine, M/Z 73 and 144, representative of cellulose and found in much higher concentration in the litter than soil, M/Z 85, high in prairie litter, M/Z 180, a phenol common in prairie litter but not in prairie soil, M/Z 298, 300 and 368, lipids found in both soils and litter. Flocculation mechanisms in the absence of clays are not known but help preserve SOC. We found evidence of both physical and chemical stabilization of SOC following planting trees on native prairie.

**PS2_5**

## Quantification of organic matter bound to iron and aluminum: selective dissolution techniques coupled with dissolved nitrogen analysis

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Iron and aluminum can stabilize organic matter (OM) via organo-metal complexation and sorption on metal oxides. Yet little information is available on the amounts of this metal-bound OM in field soils, because selective extraction methods often use carbon-based compounds. We previously developed the dithionite extraction technique to be free of organic-complexation agents, to quantify the organic carbon sorptively associated with reducible iron oxides. Here we examine an alternate approach to assessing OM in selective extractions. Mineral-associated OM in soil has a relatively narrow range of C:N ratio and organic N accounts of most of N in the soils that contain little 2:1 clays. We therefore assessed soil organic matter in various metal oxide fractions by focusing on N dissolved upon selective dissolution of metal oxides and organo-metal complexes, using dithionite-citrate, ascorbate-citrate, and pyrophosphate. We examined a range of soils including podzolic and volcanic soils. Of total soil N, the strongly reducing dithionite-citrate extraction dissolved >50% from a spodic horizon sample, roughly 20-50% from two volcanic soils, and 20-40% from two weathered tropical soils. For the non-tropical soils rich in poorly-crystalline oxides, the ascorbate-citrate extraction dissolved significantly less Fe (by 50-90%) than the dithionite-citrate extraction while Al dissolution was similar. The amounts of soluble N were similar between the two extractions except for the volcanic soils where the ascorbate-citrate dissolved less N by 20-30%. The difference between dithionite-citrate- and ascorbate-citrate-soluble N may be attributable to the N bound to allophane and crystalline iron oxides because ascorbate-citrate is considered to selectively dissolve ferrihydrite and organo-metal complexes. The amounts of ascorbate-citrate-extractable Fe and Al were similar to those extractable by pyrophosphate, suggesting that ascorbate-citrate mainly dissolved organo-metal complexes in the studied soil samples. Focus on organic nitrogen thus confirms the importance of these phases for OM storage, and appears useful to quantify the OM associated with different soil inorganic constituents that are selectively dissolved by carbon-containing extractants.

**PS2_6**

# Thermal and Spectroscopic Analyses Applied to the Study of Different Molecular Size Humic Acids

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The structural characterization of humic acids (HAs) is a focal point in understanding and establishing a relationship between their structure and biological properties. However, the complexity of HAs seriously limits the application of a single analytical technique. For a better understanding of HAs role in the environment, it is necessary to develop methods which can provide a complete characterization of HA structure. Humic acid extracted from the A horizon of a Chernozem (Boroll, USDA Soil Taxonomy) soil and their fractions (A, B and C+D) with different molecular size (MS) obtained by coupling size exclusion chromatography and polyacrylamide gel electrophoresis (SEC-PAGE) were investigated using thermal (TG-DTA), spectroscopic (DRIFT) and isotopic (delta $^{13}C$) analyses. Moreover, the molecular structure of the high temperature stable fraction (residues obtained by stopping the heating of the sample in TG-DTA apparatus at 400°C) was studied by DRIFT spectroscopy. The highest MS fraction (A) were characterized by the highest contents of aliphatic, carboxyl groups, carbohydrates and amino acids than the B and C+D fractions. Instead, the C+D fraction, that was 36% of HA (w/w), seems to be characterized by a higher content in aromatic compounds, in particular in benzoic derivatives, than the other fractions. A shift of delta 13C to more negative values was observed in the lowest MS fractions (B and C+D). The aromatic structure of A and B residues seems to be more complex than that of C+D residue.

**PS2_7**

## Thermal analysis applied to litter decomposition studies

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Litter decomposition depends on both environmental factors and litter quality which is difficult to define because it continuously changes as decomposition proceeds. Litter components mainly affecting the decomposition process are cellulose and lignin. Their determination through chemical methods is laborious and time consuming and requires, as a first step, the extraction of the cell walls. As a possible alternative to classical methods to study litter decomposition, we used the thermogravimetric (TG) and differential thermal analysis (DTA) to follow the decomposition of two forest litters differing in plant age. This technique without any sample pre-treatment allows a quali-quantitative characterization of organic compounds on the basis of their different thermostability. Both litter samples and their cell walls were analyzed by TG-DTA. On these samples C isotope ($^{13}C$) ratio was also measured. In both forests the TG-DTA profile of litter samples was characterized by three exothermic reactions (Exo1, Exo2 and Exo3). Exo1 (about 340 ºC) is related to the mass loss of thermo labile compounds, such as carbohydrates, hemicellulose, cellulose. These substances accounted for 70% and 68% of total organic matter of young and old forest litter, respectively, and were partly degraded during the studied period. Exo2, which temperature was about 465ºC in the young and 440 ºC in the old forest litter, is the recalcitrant one due to the decomposition of lignin and other aromatic compounds. Their content ranged from 26% to 29% of total organic matter in the young and old forest litter and was also partly degraded during decomposition. Exo3, the third extra recalcitrant reaction at around 515 ºC is due to degradation of more complex aromatic structures such as waxes. These substances accounted for about 3% of total organic matter in both litters and constantly increased as decomposition proceeded. TG-DTA curves of litter cell walls showed the disappearance of Exo3, and the shift of Exo1 and Exo2 towards lower temperature compared to the whole litter suggesting that the cell walls extraction procedure causes a structural modification. Moreover, the shift of cell walls delta $^{13}C$ towards less negative values compared to the whole litters suggests that these substances were $^{13}C$-depleted.

**PS2_8**

## FT-IR Quantification of Aliphatic and Carboxyl Groups in Soil Humic Fractions

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Aliphatic and carboxyl groups are two important components in soil humic fractions. Absorbance bands in the ranges of 3020-2800 cm-1 (band A) and 1720-1600 cm-1 (band B) in Fourier Transform Infrared (FT-IR) spectra have been attributed to aliphatic and carboxyl groups, respectively. We prepared mobile humic acid (MHA) and recalcitrant calcium humate (CaHA) from 10 soils collected from six states in the USA. FT-IR spectra of these humic fractions were collected. Absorption bands of the original and ash-corrected FT-IR spectra were quantified using absorption height and area. High correlation observed between the original and ash-corrected spectra indicated that ash correction is not necessary. The correlation between height and area exceeded 0.946 ($p < 0.001$), indicating that both band height and area measurements are acceptable for semi-quantification of FT-IR spectra. This work demonstrated that FT-IR measurement may provide a simple and fast method for semi-quantifying these two functional groups of humic acid fractions.

**PS2_9**

## Can mineral specific surface area predict soil carbon stabilization capacity?

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Soils represent an important potential sink for atmospheric $CO_2$ through the actions of various stabilization mechanisms. Sorption of soil carbon to soil mineral surfaces is one of these major mechanisms. Soil mineral types will influence soil carbon sequestration due to the specific organo-mineral interactions. While previously published evidence indicates that soils have a limited capacity to stabilize organic matter, determining the stabilization capacity (and thus the saturation deficit) for a given soil remains a significant challenge. In this study, we address to what extent soil carbon stabilization is controlled by soil mineral surface area as a function of carbon inputs. Soil samples were collected from agricultural fields with long-term cultivation and manure input (0, 60 and 180 Mg/ha/yr) treatments, and from adjacent areas of native vegetation. In a previous study, these soils were physically fractionated to isolate easily dispersed silt and clay, and soil organic carbon (SOC) was determined for each fraction. In the current study, mineral surface area was measured by BET-N2 method before and after removing organic matter, and soil minerals will be identified by X-ray diffractometry. Previously, a close positive relationship has been found between SOC concentrations and mineral specific surface area. Organic C loadings of 0.5-1.0 g C/m$^2$ are frequently observed for soils and sediments, suggesting a zone of maximal carbon stabilization. We propose a conceptual model of carbon stabilization by soil minerals consisting of three zones. Minerals are initially under-saturated with respect to organic carbon. As carbon inputs to soil increase, carbon loadings of soil minerals will increase until the mineral surface is saturated and maximal stabilization occurs. Subsequent carbon inputs will accumulate in less stable fractions, such as particulate organic matter in aggregates or more loosely bound materials. Additional experiments (e.g., laboratory incubations) are planned to test SOM stability in each of these zones.

**PS2_10**

## Characteristics of Humic Substances in Long-Term Biosolid Reclaimed Soils

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Biosolids, produced from wastewater treatment plants, are considered as nutrient/organic matter-rich material to reclaim soil chemical and physical properties in degraded land, such as strip-mining places. The purpose of this study is to understand the characteristics of humic substances in the soil after long term biosolid application at Futon County, Illinois. Ratios of inorganic phosphorus (Pi) increased with the amount of biosolid application and NaOH-Pi existed as primary form. The composition of P was changed with the application period of biosolid. The soils stopped receiving biosolid for 25 years were with similar P composition to the soils never receiving biosolid, quite different from the soils receiving biosolid in recent years. Labile forms (KCl-Pi, $NaHCO_3$-Pi and NaOH-Pi) transformed into recalcitrant forms ($NaHCO_3$-Po, NaOH-Po, HCl-Pi and Residual-P) in the application period, which might be associated with the consumption of labile forms through microbial activities and plant uptake. Humic (HA) and fulvic acids (FA) increased with application rate, but they were not correlated with the duration after stopping dumping biosolid. Humification index, on basis of FA/HA, showed no correlation with application rate and period. The results suggest that biosolid can been transformed and stabilized as soil humic substances in a few years.

**PS2_11**

### Turnover dynamics of polycyclic aromatic hydrocarbons in soil fractions

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An understanding of turnover of soil organic matter is vital for the modelling of the global carbon budget. It is also important in the understanding of the fate of organic pollutants in soils which are intimately associated with the organic carbon fraction of soils. From such studies models can be constructed which will enable the prediction of the availability of these pollutants for ingestion by soil dwelling biota and man and inform risk assessments of contaminated sites.

Soils were incubated over a 512 day period with six polycyclic aromatic hydrocarbons and plant material from maize a C4 plant i.e. enriched with $^{13}C$. The soils were harvested at 1, 2, 4, 8, 16, 32, 64, 128, 256 and 512 days. The PAH and $^{13}C$ content of particulate organic matter, 2 mm, 212 μm, 53 μm, 25 μm, fine silt and clay fractions. The PAH and $^{13}C$ transferred between the different soil fractions in parallel and rapidly moved from the finer to the coarser fractions. For example within 8 days the fine silt fraction contained 60% of the total naphthalene added, this transferred to the fine clay fraction over the next 48 days such that both contained c. 45% of the total. The approach not only aides our understanding of the pollutant 'aging' process, but also provides an additional tool to investigate the carbon turnover dynamics of soils by using known pollutants as chemical probes.

**PS2_12**

## Applications of synchrotron-based X-ray spectromicroscopy techniques for understanding the spatial distribution and interactions of organic C, low-Z elements, and other metal ions in intact orgnomineral assemblages

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Soil represents the largest reservoir of terrestrial organic C. The Kyoto Protocol stresses the need for a fundamental understanding of basic soil biological, chemical, and physical processes that control C stabilization, and release from soils. Yet, the spatial arrangements, the underlying biogeochemical mechanisms for the long-term stabilization of C, the interactions between organic C and other elements involved in the stabilization process and the potential for the various soil types to sequester C remains unknown. The current conceptual soil organic C turnover models built on destructive macroscopic analytical approaches are not fully process-orientated and usually fail to provide explicit molecular-level information about micro- and nano-scale spatial features of organomineral assemblages to help bridge the gap between multi-scale processes. Therefore, understanding impacts of human interventions on soil health and quality, and the soils responses to climate change remains largely empirical. This presentation will provide an overview some of the efforts made by our group to identify and fingerprint the functional group composition of organic matter, and discuss the potentials of some of the novel non-destructive high resolution micro- and nano-scale X-ray microscopy (STXM) and near-edge X-ray absorption fine structure (NEXAFS) spectroscopy (at a spatial resolution ranging from 500 to 50 nm scale) approaches to obtain first-hand process-oriented biogeochemical evidence about: (i) the in situ spatial arrangement of minerals, metal-ions and other architectural features of organomineral assemblages at microscopic and sub-microscopic level, and (ii) element-specific (both low Z and other metal ions) information about local structural and compositional environments of neighboring atoms and surficial interactions, micro- and nano-scale spatial heterogeneity and other molecular-level features of organomineral assemblages.

**PS2_13**

## Cropping Effects on the Physical and Chemical Makeup of Soil Organic Matter and its Dynamics

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Agricultural soils encompass an important portion of the global terrestrial C pool, with the conversion of native vegetation to agriculture causing significant reductions in soil organic carbon (SOC) levels of most soils and the intensity of cultivation being capable of causing significant differences in SOC sequestration. To examine changes in SOC characteristics with land use, we utilized grassland and deciduous forest sites where the native vegetation had been converted to agriculture for a century and subjected to long-term conventional tillage and no-till treatments. The change in soil organic matter dynamics and composition that occurred with cultivation was determined by measuring shifts in C3/C4 content in long-term soil incubations and size fractions, along with chemical characterizations of these soils. The grassland site lost 54-58% of the native soil C during 100 years of cultivation and the deciduous forest site lost 77-80% of the native soil C after drainage and cultivation yet retained more SOC than the grassland. The grassland soil lost 10-20% of its SOC during incubation with complex rate curves depending on the original SOC content. The forested site lost only 4-5% of the amount of SOC respired with incubation. Both sites were positively related to the amount of C in the light fraction even though this fraction did not account for most of the $CO_2$ evolved in incubation. The proportion of native C in the POM tended to be lower (22-28%) than that of the LF (38-40%) with the exception of the grassland-NT where it was only 16-17% in both fractions showing that this treatment preserved recent wheat C. The fine clay, coarse clay and silt fractions contained mostly native C (~60%) in the forested site and up to 94% in intensely tilled grassland. All fractions contained native SOC with the mean residence time in the LF and POM being lower than in the clay fractions where it approached 500yr. We used pyrolysis molecular beam mass spectrometry, with quantitative standardization, to characterize the chemical differences is the soil organic matter.

**PS2_14**

## Partitioning and Composition of $^{15}N$ Labelled Beech Litter in Different Organic Pools in a Clay-Rich Forest Soil


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The mineralisation of soil organic matter (SOM) provides the main source for plant available N in forest soils and depends on litter composition, turnover rates as well as the soil type. Especially clay-rich soils contain a significant proportion of particulate organic matter occluded in aggregates (oPOM) that is not readily available for microbial decomposition. Thus, the aim of this work is to study the partitioning and composition of organic N (ON) in different labile and stabile organic pools of a beech stand soil using stabile isotopes and fractionation methods in order to improve our understanding on SON dynamics in forest soils. The experiment was carried out in a beech forest standing on a Rendzic Leptosol in SW-Germany. The soil is characterized by high contents of clay (>70%) and high pH values (~7). On three selected plots litter was removed and replaced by $^{15}N$ labelled beech litter in April 2008. Top soil and litter layer were then sampled in May, June and September 2008 and the soil samples were fractionated using polytungstate solution and ultrasonication to separate free POM (fPOM) and oPOM fractions. Bulk soil, POM fractions and litter samples were then analyzed for $^{15}N$, OC and N concentrations. Acid hydrolysis was applied to the samples to analyze Î±-amino N contents and CPMAS $^{13}C$ NMR spectroscopy gave information on SOM composition. The present results show an enrichment of $^{15}N$ particularly in the fPOM fraction of the soil at the beginning of the experiment, while an enrichment in the oPOM fraction is visible only 4 month later. CPMAS $^{13}C$ NMR spectra and results from the hydrolysis reveal differences in chemical composition of these fractions and thus different functions with regard to SON partitioning and turnover.  The application of a combined isotopic analysis and soil fractionation method was very suitable to elucidate OM pools that differ in function and turnover within this study and thus providing relevant information on SOM dynamics in the investigated soil.

**PS2_15**

## Mobile Humic Acids and Recalcitrant Calcium Humate in Eight US Soils

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Both excitation-emission matrix (EEM) fluorescence spectroscopy and solid state $C\text{-}^{13}$ nuclear magnetic resonance (NMR) spectroscopy have been applied for studying soil organic matter (SOM), but rarely have both techniques been employed together. We analyzed the fluorescence features of water extractable organic matter (WEOM), mobile humic aicds (MHA) and recalcitrant calcium humates (CaHA) prepared from eight US soils. EEM analysis revealed a four-component model, where component 1 was "fulvic like" and components 2 and 3 were "humic like". The abundance of the relatively unknown component 4 was highest in WEOM samples, confirming our previous hypothesis that this compnent could be a water-soluble fraction of soil organic matter. Statistic analysis revealed that Component 4 and 1 WEOM and MHA were negativly correlated at $P<0.05$, and Compnent 1 and 2 in MHA and CaHA were negatively correlated at $P<0.001$. All eight MHA and five CaHA samples were further analyzed by $C\text{-}^{13}$ CP/TOSS with dipolar dephasing. Statistic analysis o fthe $C\text{-}^{13}$ NMR spectra indicated that the two peaks at 0-50 (alkyls) and 50-60 ppm (OCH3 and NCH) were negatively correlated to the peaks at 108-145 (aromatics), 145-161 (aromatic C-O) and 162-190 ppm (N-C=O and COO) at P,0.05. FUrthermore, the two peaks at 0-50 and 50-60 ppm were postively correlated to fluorophore componet 4, but the two peaks at 145-162 and 162-190 ppm negatively correlated to fluorophore component 4, both at $P<0.05$. THis research indicates that combining both spectroscopic techniques enhances structural information for more fully characterizing soil organic matter.

**PS2_16**

# Application of X-ray Tomography for Quantification of the Soil Pore Structure and Visualization of Soil Organic Matter

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Protection of Soil Organic Matter Soil organic matter (SOM) determines soil fertility and soil quality and plays an important role in the global carbon cycle. Hypotheses to explain the protection of SOM against microbial degradation include chemical recalcitrance and physical protection of OM. Recent advances have stressed the importance of soil structure as a factor in SOM dynamics. Many studies have attempted to tackle the complex interaction between SOM and the soil matrix by using measurements of soil aggregates as surrogates of the soil structure. But in reality, the undisturbed soil profile exists as a continuous convoluted pore, bounded by solids and not as a bed of aggregates [1]. X-ray computed tompography The application of X-ray computed tomography (CT), a technique that generates cross-sectional images of an object by computer software from multiple X-ray scans, enables the visualization of the soil pore space in three dimensions. The very few studies applying CT scanning in soil science have attained spatial resolutions of several µm [2]. The UGent centre for X-ray Tomography (UGCT) has developed a CT scanner which is capable of providing the highest spatial resolutions in CT scans attainable at the present, i.e. about 0,4 Âµm. Application of this equipment for visualization of the soil structure will provide unique data on the 3D soil pore distribution which could enable us to relate the soil structure to SOM dynamics. The objective of this research is to investigate the potential of X-ray CT for the visualization of the pore space and ultimately the automated visualization of SOM.

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**PS2_17**

## Thermal Analysis as a Method for Evaluation of Soils and Soil Organic Matter

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Thermal analysis of soils and soil organic matter (SOM) has many applications to characterize stability and quantity of energy and assessment of thermodynamic characteristics. Samples are placed in a furnace and heated under a controlled atmosphere (under both oxidative and anoxic carrier gas conditions) at a specified rate. Analysis consists of a heating cycle(s) where heat flow into/out of the sample is measured over time and compared to an empty reference crucible via thermocouple and microbalance of mass loss. Under an oxidative atmosphere (air) the soil materials we have tested show more resolution than under an inert atmosphere (argon). Mass loss can be tracked for discrete temperature ranges and used to quantify SOM pools and associated ash contents. Thermograms can be qualitatively analyzed for SOM stability characteristics, heat flow values of the exothermic reactions, and evolved gas makeup for reactions across the analytical temperature range via coupled spectroscopy (FTIR and IRMS). Calculated second derivatives of thermal traces can be used to identify fine differences between samples; this approach has been used to compare denuded and revegetated whole soils and soils influenced by different vegetation types on a common soil but limited effort has been given to quantifying composts, soils of varying types and management conditions and dissolved organic carbon (DOC) with a goal of unifying assessments of natural organic materials. Our data for municipal yard waste composts, across a time series from fresh inputs to humified finished product, shows distinct changes in stability patterns with the low temperature/aliphatic C pool (~350 degrees C) dominant early in the composting process and a shift to a higher temperature/aromatic C pool (~550 degrees C) in more humified products. Preliminary analysis of DOC (native and DOC flocced with various me<x>tal coagulants) and coniferous forest soils under varying management treatment show patterns of varying stability under different treatments. Future efforts will include isolating mineral influences in whole soil samples, quantifying differences in thermograms based on statistical methods that compare data distributions and expanding sample analysis to include composts, DOC and soils of widely varying starting materials and stages of development.

**PS2_18**

## Application of Differential Scanning Calorimetry to Determine Enthaplic Character of Composts, Dissolved Organic Carbon (DOC), and Soils

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Analysis of polymeric materials with differential scanning calorimetry provides the quantitative resolution to detect heat associated with phase transformations, energy status (endothermic or exothermic conditions) and enthalpy for thermal reactions across a thermogram. These metrics are valuable to assess the status of a material for specific reactions and for comparison of entire thermal profiles across a variety of natural polymers. Currently two key exothermic reactions due to organic matter have been repeatedly measured in soil materials: a low temperature region (~350 degrees C) associated with nominally labile aliphatic compounds and lower molecular weight fragments and a higher temperature region (~550 degrees C) associated with nominally recalcitrant aromatic compounds and mineral stabilized C. Working with municipal yard waste composts, whole soils, and flocs of metal coagulants with wetland-derived DOC, we hope to characterize enthalpic values for major reactions and develop relationships with other chemical properties (organic C content, C/N values, delta $^{13}$C values, etc.) across these varied natural organic materials. Employing C mass coupled with enthalpic values will facilitate greater understanding of the C cycle based on energetic inputs (reduced chemical energy from photosynthesis) and stabilization of both C mass and associated chemical bond energy based on units that easily cross ecosystem boundaries (Joules). Enthalpy determination of soil materials is novel and will provide insight into natural organic materials based on thermal stability parameters that are reproducible and provide rich detail to compare treatments, stages of development or different native ecosystems.

# Posters

# Session 3:

# “Nitrogen and SOM Dynamics”

**PS3_1**

## Sequential Density Fractionation across Soils of Contrasting Mineralogy: Evidence for both Microbial- and Mineral-Controlled Soil Organic Matter Stabilization

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Sequential density fractionation (SDF) separated soil particles into light predominantly mineral-free organic matter vs. increasingly heavy organo-mineral particles in four soils of widely differing mineralogy. With increasing particle density C concentration decreased, implying that the soil organic matter (OM) accumulations were thinner. With thinner accumulations we saw evidence for both an increase in $^{14}$C-based mean residence time (MRT) of the OM and a shift from plant to microbial origin. Evidence for the latter included: 1) a decrease in C/N, 2) a decrease in lignin phenols and an increase in their oxidation state, and 3) an increase in $\delta^{13}$C and $\delta^{15}$N. Although bulk-soil OM levels varied substantially across the four soils, trends in OM composition and MRT across the density fractions were similar. In the intermediate density fractions (~1.8-2.6 g cm-3), most of the reactive sites available for interaction with organic molecules were provided by aluminosilicate clays, and OM characteristics were consistent with a layered mode of OM accumulation. With increasing density (lower OM loading) within this range, OM showed evidence of an increasingly microbial origin. We hypothesize that this microbially derived OM was young at the time of attachment to the mineral surfaces but that it persisted due to both binding with mineral surfaces and protection beneath layers of younger, less microbially processed C. As a result of these processes, the OM increased in MRT, oxidation state, and degree of microbial processing in the sequentially denser intermediate fractions. Thus mineral surface chemistry is assumed to play little role in determining OM composition in these intermediate fractions. As the separation density was increased beyond ~2.6 g cm-3, mineralogy shifted markedly: aluminosilicate clays gave way first to light primary minerals including quartz, then at even higher densities to various Fe-bearing primary minerals. Correspondingly, we observed a marked drop in $\delta^{15}$N, a weaker decrease in extent of microbial processing of lignin phenols, and some evidence of a rise in C/N ratio. At the same time, however, $^{14}$C-based MRT time continued its increase. The increase in MRT, despite decreases in degree of microbial alteration, suggests that mineral surface composition (especially Fe concentration) plays a strong role in determining OM composition across these two densest fractions.

**PS3_2**

## Comparison of organic carbon dynamics on the forest floors during an early humification stage between coniferous and broad-leaved forests in Japan

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The understanding of soil organic matter (SOM) dynamics in terrestrial ecosystems are of great importance because soils are the largest pool of terrestrial organic carbons so any future climatic disturbances have a possibility of greatly affecting them. We have previously reported organic carbon accumulation processes on the forest floor during an early humification stage in broad-leaved natural forest in Japan (Ono et al. 2009). In that report, however, forest floor dynamics in a coniferous forest had not been discussed although coniferous plantations account for half of the forest area in Japan. Organic composition of coniferous litter differs markedly with that of broad-leaved litter. Therefore it is necessary to quantitatively clarify the organic carbon dynamics on the forest floor in coniferous forests.

In the present study, we conducted a litterbag experiment and monitored solid-state $^{13}C$ NMR for phased-humified coniferous litters at two sites (Japanese cedar (Cryptomeria japonica) and cypress (Chamaecyparis obtusa) plantations) in the northern Kanto District, Japan. Then, we determined the carbon compositional changes of humified litters, quantified the mass changes of respective carbon components on the forest floor in coniferous forests, and compared the result obtained in the present study with that of a broad-leaved forest, which has already been reported by Ono et al. (2009).

The present study clarifies decomposability of organic carbons on the forest floor during an early humification stage in coniferous plantations. Decomposability of organic carbons the same tendency between cedar and cypress forests, but differed remarkably with those in a broad-leaved natural forest. Difference of organic carbon dynamics between coniferous and broad-leaved forests might be caused by the differences of litter quality and mass loss rate of each carbon component by tree species.

**PS3_3**

## Decomposing litter mixtures - a model

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In nature, different substrates do not always decompose separately; often they decompose together in a mixture. The decomposition rate of a mixture can be non-additive, i.e. the rate of the mixture can be faster or slower than the average rate of the two separate substrates. How can we model this? Suppose we have two substrates, which decompose at different rates and have different nitrogen concentrations. One possible mechanism by which the two substrates can interact is that the decomposer efficiency, i.e. the amount of incorporated carbon per unit of uptaken carbon, changes in response to the common inorganic nitrogen pool in the surrounding environment. When would a mixture decompose faster than the two substrates separately? Our model shows that a mixture of two substrates decomposes faster than the two substrates separately when the substrate of the higher quality also mineralises nitrogen fastest. A comparison between model predictions and observations will be presented at the symposium.

**PS3_4**

## Agricultural management practices and dynamics of C in a long-term field experiment followed by isotopic and thermal analysis

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Long-term field experiments are crucial for studing the effects of different management practices on organic C storage capacity of agricultural soils. One of the most important pools of soil organic C (SOC) is that of the humic substances and in particular of humic acids (HA-http//ihss.gatech.edu/ihss2) that are complex macromolecules modified from plant compounds or newly synthesized during decomposition, that accumulate in soil. Because of their resistance to microbial degradation, they represent a crucial component of SOC where C tends to be stored for long periods and an important reservoir of nutrients. In the long-term field experiment at the Cadriano farm (Bologna University) different fertilization treatments have been compared for over thirty years on a continuous-wheat (used as a reference field) and a continuous-maize cropping. These two plant species have different C isotope composition because the C3 and C4 photosynthetic pathways differently fractionate against the heavier isotope of $CO_2$-C, therefore the isotopic approach was used to quantify the C3 and C4-derived C in soil. In particular three fertilization treatments were compared: no fertilization (control) mineral fertilization and organic amendment, and the content of old C3 and new C4-derived C in soil and in the humic acids (HA) was determined. Moreover a structural characterization of HA was carried out with thermogravimetric (TG) and differential thermal analysis (DTA). After 36 years of continuous maize cropping the old C3-derived C similarly decreased in spite of the treatments. The new C4-derived C constantly increased with all the treatments, significant higher amounts compared the control were measured with the mineral, and even more with the organic treatment. In the HA the amount of C3-derived C decreased over the studied period in the control and in the mineral treatment, whereas it increased with the organic treatment. The amount of C4-derived C in the HA linearly increased over the studied period in all the treatments with the higher values measured for the mineral and organic one. TG-DTA data showed that the 36 years organic amendment caused in the HA an increase in aromatic compounds compared to the control and the mineral treatment.

**PS3_5**

## Moisture and vegetation controls on soil organic carbon and total nitrogen accumulation in restored grasslands

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Revitalization of degraded landscapes may provide sinks for rising atmospheric $CO_2$, especially in reconstructed prairies where substantial belowground productivity is coupled with large soil organic carbon (SOC) deficits after many decades of cultivation. The restoration process also provides opportunities to study the often elusive factors that regulate soil processes. Although the precise mechanisms that govern the rate of SOC accrual are unclear, factors such as soil moisture or vegetation type may influence the net accrual rate by affecting the balance between organic matter inputs and decomposition. These factors and the way they affect SOC are susceptible to modification by climate change. A resampling approach was used to assess the control that soil moisture and plant community type each exert on SOC and total nitrogen (TN) accumulation in restored prairies. Five plots that varied in drainage were sampled at least four times over two decades to assess SOC, TN, and C4- and C3-derived C. We found that higher long-term soil moisture, characterized by low soil magnetic susceptibility, promoted SOC and TN accrual, with twice the SOC and three times the TN gain in the seasonally saturated prairies compared to mesic prairies. Vegetation also influenced SOC and TN recovery, as accrual was faster in the prairies compared to C3-only grassland, and C4-derived C accrual correlated strongly to total SOC accrual but C3-C did not. High SOC accumulation at the surface (0-10 cm) combined with losses at depth (10-20 cm) suggested these soils are recovering the highly stratified profiles typical of remnant prairies. Our results suggest that C4 inputs combined with moist soil are more effective at restoring SOC and TN stocks than better drained soils or C3-dominated inputs. The future performance of C-sequestration in restored grasslands of North America must account for projected climatic changes on C4-plant productivity and soil moisture.

**PS3_6**

## Eeffct of Ammonum, Nitrate and Phosphate Fertilization in Microbial Carbon and FDAH Activity on a High Organic Matter Andisol

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We have studied the effect of increasing mineral N and P fertilization doses on the microbial biomass carbon (MBC) and soil fluorescein diacetate hydrolysis (FDAH) activity. The FDAH activity represents a broad range of mineralization enzymes (proteases, lipases and esterases) and it is a measurement of the soil microbial activity (1). For this study, we used an Andisol with low pH (4,2), high Al saturation (22.33%), low Olsen P concentration (1.7 mg/kg) and high organic mater content (18%). Soil samples were collected at 0-20 cm depth and incubated with different P and N doses for 30 days at 20ï¿½C and 50% constant water content (w/w). Ammonium (as ammonium sulfate) or nitrate (as and potassium nitrate) were applied at doses ranging from 0 to 200 mg N/kg. Phosphate fertilization was applied as potassium phosphate at rates ranging from 0 to 400 mgP/kg. Microbial biomass C was assayed by the fumigation-extraction method(2), and FDAH activity was measured spectrophotometrically at 490 nm (3). Relative FDAH activity (rFDAH) was calculated as FDAH activity per unit of microbial C.

The results indicated that ammonium treatments strongly increased MBC at all the N doses applied, reaching over 100% of increase at 150 mgN/kg. By contrast, there was not significant effect of nitrate on MBC at N doses up to 150 mgN/kg, but the application of 200 mgN/kg increased MBC by 40%. Nitrogen treatments did not show significant effect on FDAH activity, and therefore rFDAH values were significantly reduced by ammonium treatments. Phosphorus fertilization strongly increased MBC, and slightly raised FDAH activity. Relative FDAH activity steadily decreased under P fertilization. Although ammonium treatments decreased soil pH and P treatments increased it, both treatments had a similar impact on MBC and rFDAH. This fact suggests that MBC and rFDAH activity may be pH independent in the short term. The positive effect of P fertilization on the evaluated biological parameters was attributed to the linear increase of P availability from 1.7 to 20 P mg/kg. In conclusion, N and P fertilization strongly affected the size and behavior of the microbial community, which may have implications on the soil organic matter (SOM) dynamics related to agricultural practices.

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**PS3_7**

## Effect of long-term fertilization on soil organic carbon accumulation and microbial community structure in rice paddy soil

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The effect of long-term fertilization on soil organic carbon (SOC) accumulation, and soil biological properties in the plough layer in a rice paddy soil in southern Korea were investigated in relation to the continuous application of chemical fertilizers (NPK), straw based compost (Compost), combination these two (NPK + Compost) for more than 40 years: NPK (N/P/K = 120/34.9/66.7 kg ha$^{1}$ yr$^{1}$ during 1967-1972 and 150/43.7/83.3 kg ha$^{1}$ yr$^{1}$ from 1973 to present), Compost (10 Mg ha$^{1}$ yr$^{1}$), a combination of NPK + Compost, and no fertilization (control). Fertilization significantly improved rice productivity, and the combined long-term fertilization of chemical and compost amendment was more effective on increasing rice productivity and soil nutrient balance than single compost or chemical fertilizer application. Continuous compost application increased the total SOC concentration in plough layers. In contrast, inorganic or no fertilization markedly decreased SOC concentration resulting to a deterioration of soil physical health. Most of the SOC was the organo-mineral fraction (<0.053 mm size), accounting for over 70% of total SOC. Macro-aggregate SOC fraction (2-0.25 mm size), which is used as an indicator of soil quality rather than total SOC, covered 8-17% of total SOC. These two SOC fractions accumulated with the same tendency as the total SOC changes. Comparatively, micro-aggregate SOC (0.25-0.053 mm size), which has high correlation with physical properties, significantly decreased with time, irrespective of the inorganic fertilizers or compost application, but the mechanism of decrease is not clear. Fertilization had a significantly beneficial impact on soil microbial properties, and, in particular, continuous compost fertilization improved markedly soil microbial properties compared with chemical fertilization only. The ratio of fungi to bacteria was apparently increased by long-term fertilization, but no difference between chemical and organic fertilization. The ratio of gram(+) bacteria to gram(-) was markedly increased by single compost application, but decreased by chemical fertilization. Big difference of microbial community structure was found among Control, NPK, and Compost, but NPK+Compost treatment showed similar microbial community structure with Compost. In conclusion, the combined fertilization of chemical and organic amendments could be more rational strategy to sustain soil productivity as well as improve health statues than the single chemical fertilizer or compost application.

**PS3_8**

## Legumes in crop rotations under zero-tillage and pastures promote soil C build up

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The world-wide expansion of zero-tillage agriculture, which has now reached over 100 Mha, has led many soil scientists to investigate the potential for increasing soil C stocks by the change from plough tillage to this system. A few years ago very optimistic estimates for soil carbon sequestration due to the change to no-till were published, but more recent work suggests that many of these studies produced overestimates owing to insufficient sampling depth. However, recent work from Brazil has shown that where winter or intercropped legumes are introduced into crop rotations under no-till, very considerable rates of soil C accumulation. Parallel studies with a maize/oat sequence accumulated no soil carbon over a 17 year period even when the maize was fertilized with approximately 150 kg N $ha^{-1}$ $yr^{-1}$. Studies on pastures in both north and south America have clearly shown that the introduction of a $N_2$-fixing legume into the sward can increase soil C accumulation, while grass-alone swards may accumulate little soil C even when receiving N fertilizer. In the Brazilian Cerrados, a comparison of soil C stocks under native vegetation and under degraded, fertilized and mixed legume pastures, along with other areas under conventional and no-tillage and ley cropping, revealed soil C build-up close to the level of that under the native Cerrado vegetation only under high fertility conditions and in the presence of a legume. Conventional tillage systems stimulates soil organic matter (SOM) decomposition or to reduce the potential of SOM protection, which implies release and loss of mineral N. On the other hand, the soil under zero tillage systems and pastures is left undisturbed and it seems that the organic N derived from the legume residues stimulates the immobilization of soil carbon more effectively than N derived from mineral fertilizers.

PS3_9

## Modeling carbon and nitrogen dynamics in agricultural systems using DNDC: examples of rice, maize, and sugarcane

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The DNDC (De¬Nitrification DeComposition) model, initially developed in the early 1990's to simulate nitrous oxide and methane emissions from agricultural lands in the USA, continues to be expanded and is now capable of modeling the impacts of a wide range of agricultural practices on crop yields, greenhouse gas emissions, nitrate leaching and long-term transformations of soil organic matter pools. DNDC is a one-dimensional, partitioned-pool (labile and resistant residues, humads, and humus; organic and inorganic N) model that explicitly models soil microbial activity (decomposition) on daily time steps through a sequence of soil layers and utilizing a thermal-hydraulic submodel to shift to a separate short time-step routine to model nitrous oxide, dinitrogen, and methane gas production following rainfall or irrigation events. The agricultural version utilizes daily weather inputs, soil physical properties and initial biochemical conditions, as well as cropping, tillage, amendments, fertilizer application and irrigation schedules.

Modern agriculture demands complex management systems to optimize sustainable yields and soil carbon storage while minimizing fertilizer inputs, greenhouse gas emissions, and nutrient leaching under varied technological, economic and climatic conditions. Agro-ecosystem models, when adequately validated by field trials, permit the extrapolation of site-specific studies to assess the regional impacts of various agricultural practices. For example, the spatial impacts of changing Chinese paddy-rice hydraulic inputs on both crop yields and nitrous oxide and methane release from paddy soils were analyzed with DNDC in a regional GIS mode. A series of soil-specific longitudinal runs helped to develop best management practices to maintain corn yields and enhance carbon sequestration while reducing both nitrate leaching and nitrous oxide volatilization in Iowa.

Sugarcane, a leading crop in terms of both biomass and food production, is particularly valuable as a biofuel crop because of the high biomass yield, high C:N ratios which demand less nitrogen fertilizer input per unit biomass production, and the efficient conversion of cane sugar to ethanol. Numerous sugarcane models such as APSIM-Sugarcane successfully simulate crop growth and particularly stalk and sucrose yield. DNDC-Sugarcane is being developed to add further capabilities to model soil carbon and nitrogen dynamics and to help develop climate- and soil-specific best management practices for soil carbon management and nitrogen application with minimized nitrous oxide and nitrate losses.

**PS3_10**

## Grassland management effects on long-term C and N changes in soil and mixed native grass canopies

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There are 2.9 million conservation reserve program (CRP) acres in South Dakota and Minnesota. This region is also slated to provide cellulosic feedstocks for biofuels. Thus, scientific inquiry on CRP/grass management and its effect on soil condition as well as the transfer of this knowledge to producers in this region are important priorities. This study was conducted to determine whether soil and grass C and N could be manipulated through canopy management and different grass mixtures. Effects of forced management (burning in early spring, mowing and residue removal at grass anthesis, or no management) on grass (native grass plantings of mixtures of cool season species, warm season species, or combined cool and warm season species) growth as well as C and N levels in soil and grass tissues were investigated at Brookings, SD, on a Barnes clay loam (fine-loamy, superactive, frigid Calcic Hapludoll). Soil C (0-15 cm depth) increased linearly over the 8 years of the experiment. Soil C accumulation rate was significantly greater under no management (714 kg C /ha/year) than burn treatment (333 kg C /ha/year) while that under mow was intermediate (504 kg C /ha/year). In years 7 and 8, soil C (burn 22.0 g/kg; no management 23.4; mow 23.2; P=0.009) and soil C/N ratio (burn 11.4; no management 11.9; mow 11.8; P=0.02) were all reduced by burn treatments. The burn treatment significantly reduced grass biomass (burn 2730 kg/ha; no management 4656; mow 3421; P=0.0001). Cool season grasses also produced less biomass than the other grass mixtures (cool season 2814 kg/ha; warm season 3989; and mix 4004; P=0.0001). Significant management by grass mixture (2-way) interactions for biomass (P=0.02) resulted from increases in biomass for the warm and warm/cool grass mixtures under the no management treatment. Grass C/N ratio was less under the mow treatment (burn 48.9; no management 51.4; mow 43.8; P=0.0001). In conclusion, the burn treatment was detrimental to soil C concentration and C/N ratio as well as to the growth of cool season grasses. Mow and remove management, which would be compatible with cellulosic biomass production, showed values of soil C concentration and C/N ratios comparable with those seen under the no management treatments. However, mow and removed also reduced grass biomass as well as grass tissue C/N ratio. Additional time-course data is being collect to determine if mow and remove would be sustainable in terms of long-term soil resource quality.

**PS3_11**

**Understanding long-term organic matter dynamics based on fresh organic matter degradation kinetics and nitrogen mineralization potential of soils**

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Decomposition of crop residue and manure is an integral part of nutrient cycling in agricultural soils. Degradation of newly added organic matter plays an important role in carbon sequestration and nutrient management in agricultural fields. Nitrogen Mineralization Potential (NMP) of a soil is an indicator of soil fertility directly related to potentially mineralizable nitrogen content in a soil. The NMP is usually estimated using the soil organic matter mineralization rate constant without addition of new organic material. In this study, the degradation rate of fresh organic substrate in a sandy soil was estimated and compared with nitrogen mineralization potential of the soil. Half-life, DT50 and DT90 estimates for the fresh organic matter were calculated together with their thermal unit or degree-day equivalents. In addition to the information on half-life for the crop residue or organic manure degradation in soil, this approach could be used to evaluate nitrogen mineralization potential and long-term impact of crop residue incorporation and organic manure application under various cropping systems.

**PS3_12**

## Nitrogen Mineralization in Soils with Different Types of Use and Application of Residues Crop

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The soil organic matter (SOM) has a positive effect on the productive capacity of soil. In order to carry out an efficient management of SOM, it is necessary an understanding of their dynamic, such as the interaction between SOM and soil characteristics. In this study, was evaluated the nitrogen mineralization (Nm) and its variation due to soil management. The nitrogen mineralization was evaluated measuring potentially mineralizable nitrogen (N0). The measures were made in soils of different climatic zone and different tillage management, which were mixed with alfalfa (Medicago sativa L.) or wheat straw (Triticum aestivum L.) at doses of 20 ton dry matter $ha^{-1}$; and incubated for 20 weeks under controlled temperature and humidity. The N mineralized was measured during the incubations and N0 was obtained. The relationship between measured NL and incubation weeks was described by a potential model, and the relationship between NE and time was described by a logistic model. The greatest estimated amounts of NL (93 μg g-1) and NE (128 μg g-1) were detected in an Alfisol planted with red cedar and the minimum values for NL (15 μg g-1) and for NE (34 μg g-1) in an Entisol cropped with corn. The N0 detected in the Alfisol and the Entisol was positively related to the different fractions of NL and NE.

**PS3_13**

## Long-term stabilisation of the N released by fire on soil organic matter in Mediterranean scrublands and grasslands

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The increase of forest areas due to agricultural abandonment has caused an increase in frequency and intensity of fires in the Mediterranean region. Fire increases short-term soil nitrogen availability. Plant uptake, volatilization, leaching and accumulation on soil organic matter are the main processes that determine N allocation after fire. Our aim was to study the stabilisation of the N released by fire in the soil organic matter over a period of 12 years in two Mediterranean grasslands and in a scrubland.

We selected a series of old fields abandoned about 50 years ago. They were colonized by three types of vegetation. Two communities were grasslands with a high capacity of resprouting. One of them was dominated by Brachypodium retusum and the other one by B. retusum and the N fixing scrub Genista scorpius. The third community was dominated by a seeder scrub, Rosmarinus officinalis. Twelve years ago we chose 6 plots (between 16 and 45 $m^2$) of each type of vegetation and we made 18 experimental fires. The day after the fire we labelled the N released by fire (that was mostly in $NH_4^+$ form) in a subplot (2 x 2 $m^2$) inside each burnt area, with $^{15}NH_4^+$-N (99 atom % excess). Soils were sampled three days after the fires (just after labelling), after 1 year, 5 years and 12 years and were analyzed for delta-$^{15}$N, organic C and total N. On the first two sampling dates soils were taken from 0 to 5 cm while on the last two sampling dates soils were taken from 0 to 30 cm depth. We also collected soil samples in unlabelled burnt areas in order to check natural abundances.

Twelve years after the fires the amount of $^{15}$N was much higher on labelled plots than on control plots to a depth of 15 cm. Soil from 15 to 30 cm showed small increases after 12 years. Preliminary results showed that soil $^{15}$N stabilisation varied depending on the vegetation type. During the first year $^{15}$N enrichment decreased drastically in the upper layer (0-2.5 cm) of the labelled plots. After 5 and 12 years plots with N fixing scrubs showed large delta-$^{15}$N decreases as compared to the other vegetation types. This decrease might be due to the input of atmospheric N.

**PS3_14**

## Residue quality controls short- but not long-term C and N dynamics in Integrated Soil Fertility Management Systems

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Soil organic matter and its associated fertility decline is the most important constraint to crop production in Sub-Saharan Africa. The Integrated Soil Fertility Management paradigm recognizes the potential interactive benefits of the combined use of organic residue and mineral fertilizer inputs for crop yield and soil organic matter built up. However, these interactions may be controlled by the relationships between residue quality and soil C and N stabilization mechanisms. We examined the short- to long-term C and N dynamics across a gradient of (1) inputs and (2) residue qualities in three experiments comprising different levels of environmental control and different timescales of measurement. These included a short-term laboratory incubation using inputs enriched in $^{13}C$ and $^{15}N$, a single season field trial monitoring short-term N dynamics under maize cropping, and 3 yr field data to measure longer-term C and N stabilization in a Kenyan red clay Humic Nitisol. The combined results of these studies indicate that N fertilizer additions and increasing residue quality stimulate short-term C and N mineralization. Combining low quality residue and fertilizer inputs stimulated the release of residue-N but immobilized a greater amount of fertilizer-N resulting in a significant negative interactive effect on potentially available N. However, this interactive effect changed from negative to positive with increasing residue quality. Under field conditions, the reduction in available N by combining low quality residue and N fertilizer reduced environmental N losses and created a positive interactive effect on crop N uptake. While input management manipulated short-term C and N dynamics, these practices did not influence the long-term stabilization of input-derived C and N in soil organic matter. After 3 applications of 4 Mg litter-C $ha^{-1}$ $yr^{-1}$ in the field, equivalent amounts of SOM were stabilized in all residue quality treatments. Thus, the input of residue, regardless of quality, contributes to long-term soil fertility improvement. We conclude that capitalizing on short-term interactions between fertilizer and low quality organic residues allows for the development of sustainable nutrient management practices.

**PS3_15**

## Carbon Dynamics in Differentially Zinc Fertilized Maize-Mycorrhizal System

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A field experiment was conducted at the Research Farm, Tamil Nadu Agricultural University, Coimbatore, in order to assess the carbon flow in maize-mycorrhizal system with differential Zn fertilization. The experimental soil had low organic carbon status (0.32%) and deficient level of available Zn (0.8 mg $kg^{-1}$). Treatments consisted of two levels of organics (FYM @ 6.25 and 12.5 tonnes per ha) and three levels of Zn (0, 2.5 and 5.0 kg $ha^{-1}$) replicated three times in a factorial randomized block design. One half of maize (cultivar COMH5) plants were inoculated with Glomus intraradices (M+) and others were kept uninoculated (M-). During the experimentation, biomass carbon, organic carbon and glomalin were estimated besides Zn distribution in soil and plant. Mycorrhizal symbiosis significantly increased the soil organic status by 25% and 20% under low and high organic treatments, respectively, in comparison to M- treatments. Glomalin and biomass C also consistently higher in M+ than M- treatments regardless of differential fertilization of Zn. Mycorrhizal response was more pronounced under low organics than higher organics suggesting that the functionality of mycorrhiza is more effective when the soils were manured low. Consequently, the available Zn status of mycorrhizal soils were 5.26 and 5.34 ppm while M- soils had 3.29 and 4.02 ppm in low and high manured soils, respectively. Addition of organics assists in release of organic acids that facilitate chelation of Zn and make in available to the plants that reflected on the host plant Zn status. Further, glomalin (glycoprotein) serves as adsorptive site of Zn besides enhancing organically bound Zn in soils. As a result of improved organic status and availability of Zn, mycorrhizal treatments produced 6-8% higher grain yield regardless of levels of addition of organics or Zn fertilization. Overall, the data suggest that mycorrhizal symbiosis improves Zn status of host plants regardless of levels of organic manuring. The improved host plant Zn nutritional status is primarily attributed to the favourable biochemical changes that facilitate availability of Zn in soils.

**PS3_16**

## Interactions of micro-flora and soil dynamics in an insect eco-system

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Global warming affects soil organic matter turn-over and mineralization in the insect ecosystem of Western Ghats and Eastern Ghats of India. Termite and its mound contribute significantly to climate change due to their ability to emit the green-house gases viz., methane (1596.32 mmol /g /h) and carbon dioxide (49.0 mmol /g /h). Termites are also valuable because they influence the nitrogen dynamics of forest ecosystems.To understand how soil biota respond to soil nitrogen amendments we measured organic C (0.98%) and N (0.19%), microbial biomass, extra-cellular enzyme activities, soil respiration, and the community composition of active fungi. Nitrogen addition, though suppressed fungal activity, stimulated carbon degrading enzyme activities and soil respiration. Heterotrophic microbes, viz., Actinobacteria (37.5x 104) and Termitomyces (19.3x104) that derive nutrients from below ground decomposed organic matter and, biofilm, extra cellular polysaccharide producing and N-fixing Azotobacter (26.5x 104) and Beijerinckia (49.0x 104) dominate the above ground microbial populations. These type of microbial dynamics regulate sequestered $CO_2$ in the terrestrial ecosystem. Our investigation revealed the effect of climate change on the soil carbon cycle and microbial dynamics.Further understanding of the soil fauna microbe interactions might through light on the current ecological theory which is a major challenge for soil biologists.

# Posters

# Session 4:

# “Soil C Quantification for GHG Accounting”

**PS4_1**

## Understanding Spatial Variability-
## Protocol for Measuring and Monitoring Organic Carbon

Habib Diop, C. W. Rice, E. Lund

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Effective measurement of soil C at the field scale requires an understanding of the spatial variability of soil C on a landscape scale. Recent technological advances in soil C measurement contents offer new opportunities in this area. Our objectives were to (1) evaluate the differences between field and laboratory measurements of different soil characteristics such as total C, total N and bulk density, (2) production of spatially explicit maps of soil C to scale-up site specific measurements. Six fields were studied, each field divided into 5-8 EC zones or using NIR map as having similar soil properties within 3-4 m distance. Fields were mapped on 20 m transects at 8-10km/hour and probed to 60 cm depth using both Veris NIR (500-2200 nm) Spectrophotometer shank and NIR Spectrophotometer Probe. Within each zone, 3 soil profiles were sampled at an equal distance of 3 m for examining total carbon, total nitrogen and bulk density. Samples were analyzed for total Carbon with a Thermo-Finnigan Flash EA 1112 and a Leco CN 2000. Spatial variability of these soil properties was evaluated using both Minitab regression procedures and Proc Mixed from SAS 9.1.

The results indicated that there was significant difference in the soil C at different spatial scales; within soil profile, within 3 m triangle and across fields. The carbon was stratified by depth with the top 5 cm containing significantly higher level of carbon. However, at the individual depths 45-60 and 60-75 cm, there were no significant difference on soil C. Statistical analyses showed that 3 out of the 6 fields had similar carbon content and, soil C predicted by NIRS and measured by dry combustion laboratory measurements was correlated with an R-squared of 0.62. These results support the potential future utilization of NIRS as an alternative to intensive grid soil sampling for accurate soil carbon determination.

**PS4_2**

## Assessing NIR & MIR Spectral Analysis as a Method for Soil C Estimation Across a Network of Sampling Sites

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Monitoring soil C stocks is critical to assess the impact of future climate and land use change on carbon sinks and sources in agricultural lands. A benchmark network for soil carbon monitoring of stock changes is being designed for US agricultural lands with 3000-5000 sites anticipated and re-sampling on a 5-to10-year basis. Approximately 1000 sites would be sampled per year producing around 15,000 soil samples to be processed for total, organic, and inorganic carbon, as well as bulk density and nitrogen. Laboratory processing of soil samples is cost and time intensive, therefore we are testing the efficacy of using near-infrared (NIR) and mid-infrared (MIR) spectral methods for estimating soil carbon. As part of an initial implementation of national soil carbon monitoring, we collected over 1800 soil samples from 45 cropland sites in the mid-continental region of the U.S. Samples were processed using standard laboratory methods to determine the variables above. Carbon and nitrogen were determined by dry combustion and inorganic carbon was estimated with an acid-pressure test. 600 samples are being scanned using a bench-top NIR reflectance spectrometer (30 g of 2 mm oven-dried soil and 30 g of 8 mm air-dried soil) and 500 samples using a MIR Fourier-Transform Infrared Spectrometer (FTIR) with a DRIFT reflectance accessory (0.2 g oven-dried ground soil). Lab-measured carbon will be compared to spectrally-estimated carbon contents using Partial Least Squares (PLS) multivariate statistical approach. PLS attempts to develop a soil C predictive model that can then be used to estimate C in soil samples not lab-processed. The spectral analysis of soil samples either whole or partially processed can potentially save both funding resources and time to process samples. This is particularly relevant for the implementation of a national monitoring network for soil carbon. This poster will discuss our methods, initial results and potential for using NIR and MIR spectral approaches to either replace or augment traditional lab-based carbon analyses of soils.

**PS4_3**

## Does tropical reforestation lead to soil carbon sequestration?

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Reforestation of agricultural lands has been proposed by the IPCC as a way for sequestering C in plant biomass and in soils. While reforestation is associated with aboveground C accumulation, the effects on belowground C are varied. Studies report gains, losses, or no net change. We describe results from a long-term chronosequence of forests regenerating on abandoned pastures in Puerto Rico and from a literature review including more than 200 tropical secondary growth sites. We tested for the effect of soil type, previous land use, and climatic life-zone on bulk soil C stocks with forest age. We identify important mechanisms for predicting the fate of soil C during reforestation, and provide recommendations for future studies.

The Puerto Rican reforestation chronosequence soils did not reflect increased C in tree biomass. Pastures, primary forests, and secondary forests aged 10, 20, 30, 60, and 80 years old had similar bulk soil C stocks down to 1 m depth. The gain in new, secondary forest-derived C was compensated for by the loss of residual pasture-derived C, resulting in no net change in bulk soil C stocks. Using physical density fractionation data and stable and radiocarbon isotopes we show that different soil organic matter pools were sensitive to land use and land cover change. The pantropical dataset showed similar results, with no significant differences in average soil C stocks between forests < 20 and > 20 years old. Time since abandonment had a statistically significant ($p< 0.01$) but very weak ($r^2= 0.05$) effect on soil C stocks to 0.25 m depth, though the importance of time varied among climatic zones and former land uses. Dry forests showed the strongest positive relationship between age and soil C, but this life-zone also had the fewest data. Past land-use had a significant effect on soil C, with forests on formerly cleared land showing a stronger increase in soil C over time ($r^2= 0.41$, $p = 0.06$) than those on former cultivated sites. Sites re-growing on former pastures did not show any trend with time, similar to what we observed in Puerto Rico. Our results indicate that factors other than forest age drive the rate and direction of soil C changes with secondary succession in the tropics. Carbon sequestration strategies for abandoned lands must consider the interacting influences of land use history, climate, and the potential for complexity in the response of soil C pools to reforestation.

**PS4_4**

## MiCNiT - modeling of microbial carbon and nitrogen turnover in soil and greenhouse gases emission

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$N_2O$ and NO emissions from soils often show distinct temporal peaks driven by the changes in climatic conditions such as rainfall event following a long lasting drought period. These peaks may contribute significantly (up to several tens of %) to annual N oxides emission. Simple SOM models, however, often failed describing such short-term events. They do not explicitly model microbial biomass dynamics or do regard the microbial biomass as an inert pool. However, for the precise description of $CO_2$ and N trace gas exchange between soils and the atmosphere in process-oriented models it is essential to explicitly describe microbial life in soils. In suggested model we applied the microbial activity concept. In this case microbial biomass is considered as one pool, which can change its activity with time (Blagodatsky, Richter, 1998). Our goal was to model both microbial and physico-chemical processes in soil in sufficient detail in order to follow the extreme emission peaks. We developed new Microbial Carbon and Nitrogen Turnover (MICNIT) model, which operates in the MoBiLE framework. The following soil processes were described:

-- mineralization of plant residues and soil humus (decomposition, ammonification),
-- dynamics of soil microbial biomass (C and N),
-- denitrification, with explicit description of production and consumption of intermediates
-- autotrophic nitrification and nitrifier denitrification, with description of growth of nitrifiers
-- heterotrophic nitrification
-- chemodenitrification
-- dynamical change in proportion between anaerobic and aerobic parts of soil
-- transport of gaseous and soluble substrates through soil profile.

Sequential peaks of NO, $N_2O$ and $N_2$ production were simulated using $O_2$ dependent induction and repression of respective denitrification enzymes in soil microorganisms (Blagodatsky et al., 2006) under conditions of transient soil wetting. Model was parameterized against data set for forest soils. Our study confirms the importance of detailed simulation of both microbiological and physico-chemical soil processes, when good prediction of N-gas emission is needed.

Blagodatsky S et al., 2006. Geomicrobiology J 23:165-176.

Blagodatsky, S.A. and Richter, O. (1998) Microbial growth in soil and nitrogen turnover: a theoretical model considering the activity state of microorganisms. Soil Biol. Biochem. 13, 1743-1755.

**PS4_5**

## The Carbon Benefits Project:
## Modeling, Measurements and Monitoring (CBP:MMM)
## Component A

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Currently, it is estimated that human activities emit greenhouse gases (GHGs) equivalent to over 50 billion tonnes of $CO_2$ $yr^{-1}$. Approximately 30% of these emissions come from land use and land use change. Sustainable land management (SLM) projects have the potential to not only reduce GHG emissions, by reducing emissions from biomass burning, biomass decomposition, and the decomposition of soil organic matter (SOM), but also to sequester carbon (C) through practices that increase biomass production and promote the build up of SOM. The GEF finance a wide range of SLM activities in developing countries from reforestation and agro-forestry projects, to projects that protect wetlands or foster sustainable farming methods. The carbon benefits of these and other non GEF SLM projects are likely to be considerable. However at the moment it is difficult to compare the C benefits of different land management interventions as a wide range of different methods are used to measure them. Equally it is difficult for SLM activities in developing countries to gain the financial rewards they deserve from emerging carbon markets.

The Carbon Benefits Project (CBP) is working to produce a standardized system for GEF and other SLM projects to measure, monitor and project C stock changes and GHG emissions. The project builds on existing C inventory tools developed over the past 15 years at Colorado State University. These include the GEFSOC system which provides a tier 3 approach for developing countries to estimate changes in soil organic carbon at the national scale, the ALU software which puts the IPCC method into an accessible format for national scale GHG inventories and COMET-VR, an online farm scale assessment tool which allows land managers to estimate $CO_2$ and $N_2O$ fluxes for defined land management changes. The CBP will produce a modular web based system which allows the user to collate, store, analyze, project and report C stock changes and GHG emissions for baseline and project scenarios in SLM interventions. Existing SLM projects in Brazil, China, Kenya and the transboundary area between Niger and Nigeria are being used as test cases. The project runs from May 2009 to May 2012.

**PS4_6**

## Measuring Soil Carbon with Field-Deployable Sensors: Is Detailed Mapping Affordable?

Eric Lund, Chase Maxton , Giyoung Kweon

*Veris Technologies, Inc. , USA*

Significantly reducing the confidence intervals of soil carbon estimations typically requires a large number of soil samples. The amount of sampling that can be justified depends on sampling costs and value of sequestered carbon. Using a combination of soil sensors and lab analyses, soil carbon to a depth of 0-60 cm was measured on several Kansas fields. Mapping costs and confidence intervals using sampling alone are compared with those from a sensing and sampling approach.

**PS4_7**

## Hierarchical Controls on the Accrual of Physically Protected Soil Carbon Pools Following Tallgrass Prairie Restoration

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Long-term cultivation has depleted the soil C stocks that developed under native ecosystems. The ability of soils to regain this lost C following reestablishment of perennial ecosystems is constrained by plant inputs, soil properties, and environmental conditions. However, internal soil mechanisms governing the dynamics of accruing soil C stocks are poorly understood. Most temperate soils appear to have a finite capacity to protect soil organic matter (SOM) from mineralization, which may limit their potential C sink strength. We investigated how physical protection by hierarchical soil aggregate structure affects the rate of soil C accumulation in restored tallgrass prairie and determined whether these protection mechanisms become saturated despite continuing C inputs. We used a chronosequence approach and exponential modeling to (1) assess the dynamics of 12 distinct SOM pools distributed within four aggregate protection classes [particulate organic matter (POM), silt, and clay from non-aggregated soil, macroaggregates, microaggregates-within-macroaggregates, and free microaggregates] and (2) quantify the relative contributions of these pools to soil C accrual. Aggregate mass rapidly returned to pre-cultivation levels, but aggregate-protected C took longer to recover. The rates of C accrual varied significantly among the measured fractions, suggesting that some pools reach steady state faster than others or that the protective capacity of some pools saturates while other pools continue to accrue C. Most of the C accrual occurred in the silt-sized fraction from microaggregates-within-macroaggregates, but this fraction reached an apparent steady-state lower than pre-cultivation levels, suggesting that it is a heterogeneous pool. The clay-sized fractions from all aggregate classes contributed the least to soil C accumulation. The POM from non-aggregated soil accrued slowly but continually, suggesting that C builds in relatively unprotected pools even after soil protective mechanisms approach steady state or saturation. Our results improve understanding of internal soil C dynamics and the capacities of SOM protection mechanisms and will contribute to the next generation of SOM and ecosystem C models.

**PS4_8**

## Quantification of net annual C input in terrestrial ecosystems of the Italian peninsula, under different land-uses

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Soil organic matter is a very important compartment of the biosphere: it represents the largest dynamic carbon pool where the C is stored for the longest time period. Root inputs, as exudates and root slush, represent a major, where not the largest, annual contribution to soil C input. Root C input has generally turn-over times of few days; however a fraction of it can be stabilized in the SOM on the long-term. Despite, root growth and exchange may constitute the fate of the largest part of C assimilated by vegetation; the correct measuring method of belowground net annual C input is a still object of discussion. The objective of the present study is to estimate net annual belowground C inputs in a range of ecosystem under different climates, land uses and vegetation types, in the Italian peninsula. This information is very important to constrain ecosystem C balance measured by Eddy covariance, and to accurately quantify the contribution of belowground C input to soil carbon sequestration. Isotope mass balance was used to measure net annual soil C input from roots. In the autumn of 2006, C4 soil ($\delta^{13}C \approx -17$‰) cores were implanted in 10 ecosystems characterized by C3 vegetation ($\delta^{13}C \approx -26$‰) of different types and land-use. Cores were incubated in the field for one year, before being sampled and total C and $^{13}C$ in each core analysed, by depth intervals. Cores were 30 cm high and 4 cm in diameter, and made of a PVC net of 2 mm mesh size to allow the ingrowth of only fine roots, which are the most metabolically active. Net annual C input ranged from 750 to 200 g C/m$^2$ in forest ecosystems, from 590 to 120 g C/m$^2$ in Macchia ecosystems and from 418 to 274 g C/m$^2$ in grassland. Generally below-ground C input is higher in the upper soil layer (0-15 cm) than in the lower one (15-30 cm), according with the relative density of fine roots. The relative contribution of new C was the highest in forest ecosystem, where it accounted for 0.11-0.38 % of total soil C. Our approach does not allow to determine whether this new C correspond to a net sequestration of C to the soil or if it C replacing existing one. Comparison of this data with data on ecosystem C balance measured by Eddy covariance at the sites will allow answering to this question.

**PS4_9**

## Long-term sensitivity of soil organic C and N stocks to the use of manure in the frame of organic and conventional farming practices

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Organic fertilisers have been used throughout the agricultural history but, during the last decades, in many cases, mineral fertilisers have replaced or largely minimised the use of manure. Organic farming practices enhance internal nutrient cycling by increasing or maintaining soil organic matter stocks. The moderate application of stabilised (composted) organic fertilisers is probably the main strategy used by the organic farmers to promote soil organic matter and soil fertility. Conventional farmers also apply organic fertilisers such as manures or slurries. However, they often use fresh (not composted) manures and slurries combined with mineral fertilisers. Our aim was to study the sensitivity of soil organic C and N stocks to the fertilisation practices used by the extensive organic and conventional farmers of central Catalonia. We selected 15 extensive organic farmers growing cereals and grassy crops in central Catalonia. In each farm we selected a cereal field organically managed for at least 10 years. Next or nearby each field we selected another field conventionally managed. In each of the 30 selected fields we collected soil samples in 4 areas. In each area we extracted three soil cores with a volumetric auger form 0-30 cm that were divided into three layers (0-10, 10-20 and 20-30 cm) and bulked to one sample per layer and area. Organic C and total N and potentially mineralisable N (NPM) were analysed in all soils. At the same time, all farmers were interviewed in order to define its fertilisation practices. Based on the interviews we calculated the mean annual organic C and N inputs in the studied fields. Organic farmers applied composted manures ranging from 0 to 1100 kg C $ha^{-1}$ $yr^{-1}$ with C/N ratio ranging from 10 to 20. In contrast, conventional farmers applied fresh manures combined with slurries and/or mineral fertilisers ranging from 200 to 1900 kg C $ha^{-1}$ $yr^{-1}$ with a C/N ratio lower than 10. Despite the application of low amounts of manure organically managed soils showed higher C and N content in terms of soil mass than conventionally managed soils. C content in terms of land surface was also higher in organic soils. Moreover, organic C and N stocks in organically managed soils were sensitive to the inputs of organic C in manures while in conventionally managed they were not. Stabilised N in composted manures enhanced C sequestration while readily available N of synthetic fertilisers or slurries mixed with fresh manures did not. In organically managed soils organic N stocks were more stable than in conventional soils. However, N mineralisation in organic soils was sensitive to the rate of application of the organic fertilisers. The use of manures appeared to be a key factor for C sequestration and for the availability of N in organic crops. This trend was not observed in conventional soils.

**PS4_10**

## A New Database and Graphical User Interface for Ecosystem Model Development

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One of the most difficult tasks modelers face is consolidating data from multiple experiments on multiple sites in a meaningful way, and using those data for developing new models or improving/validating existing models. Individual investigators or research teams rarely standardize data collection or measurement methods in order to meet the needs of modelers who might use their data. For example, in North America there are at least 164 agricultural experiment sites on which soil carbon or organic matter was measured, with more than one thousand experimental treatments measured at those sites. Within those sites soil carbon is measured at 378 distinct soil profile depths, using at least five different measurement methods, and reported using eleven different units. Associated plant production and soil physical property measurements show similar amounts of variation. Yet these data used in combination are invaluable to modelers, and we felt the need to develop a common data structure and graphical user interface that allows users to enter data from a wide variety of experiments and use those data to drive different models using a variety of weather data sources. A graphical user interface refactors the data into common reporting units for comparison against modeled results from those experiments, and data from the experimental measurements are used to drive ecosystem models. The data structure currently allows users to run CENTURY, DAYCENT, CSAT, SATURN and C-STORE models using PRISM, DAYMET, CRU 2.1, GHCN or locally-collected weather data. The interface is written in Microsoft Access with a MySQL database server on the back end.

**PS4_11**

## Using a mechanistic model to identify decomposing carbon and nitrogen litter pools

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Accurate prediction of nitrogen (N) turnover is necessary to improve the economic and environmental performance of farming systems. Agricultural policy in Norway promotes a regional segregation of arable and livestock farms, which especially challenges organic cereal producers who depend on timely N mineralization as fertilization. We parameterized the decomposition submodel of the SPN (Soil-Plant-Nitrogen) agroecosystem model and identified the rapid and slowly decomposing carbon (C) and N pools of 60 plant materials. This was done by Levenberg-Marquardt optimization on C and N mineralization data from a 220-day incubation experiment. First, the initial C partitioning between the two litter pools and the litter pool decay rates were optimized with $CO_2$ evolution as output. Secondly, the N litter pool partitioning, the C/N ratio of the microbial biomass pool, and the microbial growth yield efficiency were optimized. The calibrated model gave acceptable simulations with linear regressed simulated versus measured $CO_2$ and N mineralization of $y = 1.0428x - 13.727$, $R^2 = 0.95$ and $y = 0.9141x + 4.4168$, $R^2 = 0.89$ respectively. Estimating the initial litter pool partitioning is critical; therefore, the optimized parameters were identified from measurable quantities. The data encompassed litters of various qualities in terms of C/N ratio and the C and N distribution in biochemical fractions, which were determined by stepwise chemical digestion. We hypothesized that for certain plant materials using the neutral detergent soluble N is a poor initialization criterion for rapidly decomposing N. However, the biochemical fractions contain information, which interpreted by simple regression models and variance analysis, can estimate the optimized initial litter pools. Additionally, near infrared reflectance spectra of the plant materials were used to predict the estimated initial pools sizes by principal component regression.

**PS4_12**

## COMET-VR: An online decision support tool for mitigation of GHG emissions from agricultural soils

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Mitigating the build-up of greenhouse gases (GHG) in the atmosphere is a major challenge for society and stronger policies for reducing GHG emissions in the US, including cap-and-trade systems, are being considered. Participation by agriculture in GHG offset markets will hinge, in part, on the implementation of accurate yet practical and low-cost methods to quantify carbon sequestration and greenhouse gas emissions at the project scale. Model-based estimation tools facilitate practice-based quantification, monitoring and verification approaches by integrating the effects of varying climate, soil, land use history and management conditions on soil carbon.

The COMET-VR system, developed for the US voluntary GHG reporting registry, integrates a variety of geospatial and more aggregated databases of climate, soil and land use and management practices in the US, together with measurement data from long-term field experiments and the Century ecosystem simulation model, to provide estimates of soil C stock changes and $N_2O$ emissions, including uncertainty, from cropland, grassland, orchards and agroforestry systems in the US. The user interface is designed with simplicity in mind so that agricultural producers can apply the system without prior training, while still providing sufficient information for robust estimates. User inputs are structured as a series of pull-down menus, which compile the appropriate data (e.g. climate, crop sequences and management practices) from a database server in order to run the Century model and a meta-model derived from the DayCent model (for $N_2O$). Illustrations of model applications are given and the model is available for real-time demonstration.

Our ongoing efforts are to develop a full-farm (COMET-Farm) on-line decision support tool for all agricultural related GHG emission/removal categories and to collaborate with USDA in developing a national scale soil monitoring network to provide the basis for a fully-integrated measurement and modeling system to support agricultural GHG reductions.

**PS4_13**

## Nitrogen mineralization potential strongly correlates with percent soil carbon (C) across eight established farming systems

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The specter of imminent climate change and its costly consequences motivate policy makers at all levels to develop and implement ambitious and verifiable carbon sequestration programs. Current methods to quantify soil C changes are laborious, cumbersome, costly, and cannot verify year-to-year changes. Since 1981, the Rodale Institute - Farming Systems Trial (FST) has maintained and compared organic and conventional systems in Kutztown, Pennsylvania. Our organic faming systems have sequestered significant soil C ($p<0.005$), while soil C in the conventional farming system has not changed significantly. In 2008, we investigated the accuracy, speed, and cost effectiveness of nitrogen mineralization (Nmin) potential as an alternative means of assessing C sequestration relative to standard combustion methods of soil C quantification. Within 6 organic and 2 conventional farming systems in FST we determined total soil percent C (% C), total soil percent nitrogen (%N), extractable inorganic N ($NH_4$-N and $NO_3$-N), and Nmin potential at 4 times throughout the 2008 growing season. Preliminary results demonstrate a strong ($R^2$=0.96) significant ($p$=0.003) linear correlation between Nmin potential and total soil % C across all sampling dates and farming systems. These results suggest Nmin potential can serve as an accurate verification of soil carbon sequestration in carbon crediting programs for farmers; however, cost and speed of C change verification remain challenging. Additionally, these data reinforce the verifiable place for organic farmers and their practices in emerging carbon crediting markets and economic incentive programs.

**PS4_14**

## Carbon in soils of Central Asia: *status quo* and potentials for sequestration

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Expectations have been raised repeatedly that soils in Central Asia, with the five countries Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan and Turkmenistan, might have a carbon (C) sequestration potential of global importance. However, data sets on C in soils of Central Asia are scarce, as is knowledge on land use change and accompanying losses of C. So far, C-sequestration estimates were done with only little "ground truthing". Also, no attempts were made to put such carbon sequestration potentials in relation to worldwide C-emissions. To address this issue, the current status of organic carbon in soils (SOC) of Central Asia and their potential to act as C-sinks was assessed based on soil maps, local information on SOC dynamics and a land use cover (change) map recently released by ICARDA.

Past conversion of virgin rangelands in the north of Kazakhstan into rainfed or irrigated agricultural land â€“ given the vast areas affected â€“ is responsible for most of the losses of SOC in response to land use. Hotspots of high SOC depletion are former wetlands with SOC-rich soils, which were drained for cultivation, such as for instance land around the nowadays shrinking Lake Balkhash in eastern Kazakhstan. On the other hand, SOC increased in some areas along the Amu Darya and Sur Darya rivers, where desert areas were converted to intensive irrigated agriculture. For Central Asia as a whole, we estimate that conversion of virgin land into rainfed or irrigated agricultural land in combination with conventional land management (heavy tillage and residue removal) is responsible for a reduction of SOC contents (0-30 cm depth) of roughly 783 Tg of carbon, i.e. 4 % of total SOC stocks. Degradation of rangeland has caused further losses; the magnitude of which is currently assessed.

Assuming that SOC levels in all of Central Asia cropland can be brought back to native levels in the next 50 years, 15.7 Tg C could be sequestered each year. This represents about 15 % of Central Asia annual anthropogenic carbon emissions, but only 0.2 % of current global emissions.

The Central Asia example shows that, unfortunately, the strategy of soil C sequestration as a stand-alone measure is not a viable bridge to a future in which alternative energy source can substitute fossil fuel burning, but can only be part of a set of mitigating measures. In other words, C sequestration in soil is not the solution to unconstrained fossil fuel $CO_2$ emissions.

**PS4_15**

### Soil Carbon Stocks on Long-term Soil Agroecosystem Experiments in Canada

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Canada has several long-term soil agroecological experiments (LTSE) that have been maintained over many decades. Globally LTSEs make up the largest database available for understanding the impacts of ecosystem change on agriculture and the environment. A sampling program was initiated on 25 LTSEs at 14 locations across the country in 2005 with the goal to use a standard soil sampling protocol to assess the response of soil organic carbon (SOC) to changes in area of perennial/annual cropping, changes in tillage practices and changes in area of summerfallow. The sampling also gave us an opportunity to assess the effects of soil depth on measures of SOC differences. When replacing annual crops with perennial species SOC stock increased by an average of 6.6 (±2.0) Mg C $ha^{-1}$ over 16 years and can sequester significant $CO_2$ from the atmosphere. Direct seeding or no-tillage in western Canada increased SOC stocks by 0.14 Mg $ha^{-1}$ $yr^{-1}$ and this compared favourably to estimates used for this region in Canada GHG inventory. In eastern Canada SOC storage when converting to no-tillage is minimal and highly uncertain, as supported by analyses in the scientific literature. Removing fallow from rotation in western Canada increased SOC stock by 5.1 (± 1.1) Mg $ha^{-1}$ over 22 years or about 0.23 Mg $ha^{-1}$ $yr^{-1}$ regardless of frequency. Average CVs for the 0-15, 15-30, 30-45 and 45-60 cm depths increments were 8.7, 16.2, 21.1 and 20.9% respectively. Variability in bulk density typically also increased with depth yielding larger CVs for SOC storage when calculated to lower depths in the profile.

**PS4_16**

## Development of a simple spreadsheet tool to manage carbon emissions from wind farms on peatlands

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The Scottish Government has set ambitious targets for electricity generation by renewables (Scottish Government, 2007). To meet the interim target of 31% electricity generation from renewable sources by 2011 and 50% by 2020, a substantial increase in the number of onshore wind farms is likely to be required. In Scotland a large number of proposed wind farm developments are on peatlands. One concern raised over the development of wind farms on peatlands questions whether the expected saving in carbon emissions due to electricity generation using wind power will be offset by increased carbon losses associated with the development. If carbon payback time exceeds the life time of the wind farm, then the development represents a net carbon cost. Our calculations show that even on peatlands, good management practices can be used to minimise carbon losses and achieve carbon payback times that are significantly less than the lifetime of the windfarm. However, the risks of high carbon emissions due to poor site management are significantly higher on peatlands than on mineral soils. Using floating roads instead of excavated roads can minimise carbon loss. Restoration of the site could halt carbon loss processes, so allowing carbon dioxide emissions to be limited to the time before restoration, and reducing the carbon payback time by as much as 50%. Habitat improvement at disturbed sites can also significantly reduce carbon emissions, preventing further losses and increasing carbon stored in the improved habitat. We present calculations for a range of windfarm across Scotland, differing in soil type, climate, management practices and site design. We assess the impact of management and design on carbon emissions, and demonstrate the importance of good practices in reducing carbon emissions, especially for windfarms sited on peatlands.

Scottish Government (2007). Renewable energy potential, Scottish Government News. http://www.scotland.gov.uk/News/Releases/2007/11/27095600

Nayak, DR, Miller, D, Nolan, A, Smith, P, Smith, JU, 2008. Calculating carbon savings from wind farms on Scottish peatlands. Mires and Peats, submitted.

**PS4_17**

## Organic and inorganic carbon determination for intact, field-moist soil cores using LIBS and VisNIR

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There is growing need for rapid, accurate, and inexpensive methods to measure soil carbon in situ. Laser-induced breakdown spectroscopy (LIBS) and visible-near infrared spectroscopy (VisNIR) are complementary analytical techniques that have the potential to fill that need. The LIBS method provides precise elemental analysis of soils, but cannot directly distinguish between organic C and inorganic C. VisNIR has been established as a viable technique for measuring soil properties including SOC and inorganic carbon (IC). As part of a larger carbon sequestration study, 80 intact soil cores (3.8 x 50 cm) were collected from six agricultural fields in north central Montana and one agricultural field near Pullman, WA, USA. Each core was probed concurrently with LIBS (200-800 nm, 0.1 nm resolution) and VisNIR (350-2500 nm, 2-8 nm resolution) at eight depths from 2.5 to 45 cm without pretreatment. In addition to the 247.8 nm carbon emission line, the LIBS instrument also collected emissions from elements typically found in inorganic carbon (Ca and Mg) and organic carbon (H, O, and N). Subsamples of soil (~ 4 g) were taken from interrogation points for laboratory determination of SOC and IC. Using this analytical data, we constructed several full spectrum multivariate VisNIR and LIBS calibration models for SOC and IC. These models were tested using whole-field independent cross-validation. The LIBS instrument best predicted IC ($R^2$=0.75, RPD=2.0, RMSD=4.1, RPL= 9.4) and total C ($R^2$=0.62, RPD=1.6, RMSD=5.3, RPL= 19.0). Soil organic carbon was not well predicted using LIBS ($R^2$=0.03, RPD=1.0, RMSD=4.4, RPL= 8.0). Preliminary results suggest LIBS measures total and inorganic carbon with mapping accuracy; however LIBS did not accurately measure soil organic carbon. Carbon predictions using VisNIR are pending.

**PS4_18**

## Effectiveness of the Soil Conditioning Index to Predict Soil Organic Carbon Sequestration in the Southeastern USA

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Rapid and reliable assessment of the potential of various agricultural management systems to sequester soil organic C is needed to promote conservation and help mitigate greenhouse gas emissions. A growing database is emerging from detailed field experiments on how conservation agricultural systems can sequester soil organic C. Unfortunately, many results appear to be site-, soil- and cropping system-specific, resulting in uncertainty of how to predict the effect of management in different environments, soil types, and crop management systems. The soil conditioning index is a relatively simple model used by the USDA Natural Resources Conservation Service that can predict relative changes in soil organic C based on three important conditions: (1) organic material grown or added to the soil, (2) field operations that alter organic material placement in the soil profile and that stimulate organic matter breakdown, and (3) erosion that removes and sorts surface soil organic matter. Our objective was to develop a quantitative relationship between (1) published soil organic C data derived from field experiments under various management systems throughout the southeastern USA and (2) index values predicted from those management systems using the soil conditioning index. Data will be analyzed for the strength of overall relationship, as well as for identifying unique relationships for certain management conditions. This information will be essential to validate the use of the modeling approach across the diverse set of conditions prevalent in the southeastern USA.

**PS4_19**

## Dryland Agriculture Impact on Soil Carbon Sequestration in the Pacific Northwest

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Growing interest in marketing soil C sequestration for agricultural systems of the Pacific Northwest (PNW) requires a synthesis of current and historic soil organic C (SOC) research to quantify the impact of management on the regions SOC stocks. Our objectives are to: (1) identify SOC studies under diverse agricultural management and agro-ecological zones relevant to the dryland PNW; (2) summarize research results with respect to agricultural management impacts on rates of soil carbon change over time; and (3) identify future efforts required to provide realistic, science-based estimates of agricultural management effects on soil C stocks. A subset of the 131 SOC datasets identified within five agroclimatic zones of the PNW were analyzed to assess the change (Mg C/ha*yr) in SOC with depth and on a total soil profile basis under different management scenarios. These data were expressed as mean and standard deviations of SOC changes as well as cumulative probability functions of soil profile changes due to management. Conversion of native to agricultural systems (17 studies) averaged SOC decreases in a 125-cm depth profile of 0.87 (± 0.19), 0.62 (±0.23), and 0.69 (Â±0.52) Mg C/ha*yr, in agroclimatic zones 2, 3, and 5, respectively. The cumulative probability functions showed that 75% of the converted native ecosystems would be expected to have lost at least 0.70, 0.38, and 0.14 Mg C ha-1 $yr^{-1}$ (74, 55, and 7 years) in agroclimatic zone 2, 3 and 5, respectively. In agroclimatic zones 2 and 3, conversion of conventional tillage (CT) to no-tillage (NT) increased mean soil profile SOC stocks by 0.84 (± 0.63) (14 years) and 0.24 (± 0.10) (10 years) Mg C/ha*yr, respectively. In 75% of the situations where CT was converted to NT, the cumulative probability functions predict that SOC change would be at least 0.34 Mg C/ha*yr for zone 2 and 0.14 Mg C ha-1 yr-1 for zone 3. Compared to annual cropping systems, mixed perennial-annual systems increased mean profile SOC stocks by 1.50 (± 0.86) Mg C/ha*yr with an increase of at least 0.79 Mg C/ha*yr expected for 75% of agroclimatic zone 2 sites. There is sufficient SOC data for conversion to cropland, adoption of NT, and use of a mixed perennial-annual rotation for agroclimatic zone 2 and to some extent agroclimatic zone 3. However, changes in SOC stocks for agricultural management practices lacks for agroclimatic zones 1, 4, and 5 of the dryland Pacific Northwest.

**PS4_20**

## Erosion and deposition effects on soil-atmosphere exchanges of carbon: why do we disagree?

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Agricultural activities have substantially increased rates of soil erosion and deposition, and these processes have a significant impact on soil carbon cycling. Here, we present a synthesis of erosion effects on carbon dynamics using data from literature and coupled geomorphic/carbon dynamics models. Based on this synthesis, we discuss the implications of soil erosion for carbon dynamics and identify knowledge gaps. We demonstrate that for a range of data-based parameters from the literature, soil erosion results in increased C storage under high-input agriculture. However, this effect is spatially heterogeneous and is variable on various timescales. This spatial and temporal variability largely complicates the direct measurement of erosion induced fluxes as well as the use of proxies. We argue that this variability and transient behavior explains to a large extent the controversial debate regarding the erosion-induced sink or source. We show that the magnitude of the erosion term and soil carbon residence time, both strongly influenced by soil management, largely control the strength of the erosion-induced sink. A full carbon account must be made that considers the impact of erosion on carbon inputs and decomposition, including effects on net primary productivity and decomposition rates at relevant spatial and temporal scales.

**PS4_21**

**Integrating orchard systems into the COMET-VR system: reporting management effects on carbon changes**

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The Carbon Management and Evaluation Tool for Voluntary Reporting (COMET-VR) was developed for the estimation of soil carbon stock changes and greenhouse gas emissions for agricultural production systems in the US. The first version of COMET-VR was only designed for annual cropland, Conservation Reserve Program and grazing land management systems. However, orchard systems can be also an important sink for atmospheric C. Fruit trees grow over several decades fixing a significant amount of atmospheric $CO_2$, incorporating it as biomass. Also, management practices of the orchard floor can help to increase soil organic carbon levels. In this study, we integrated orchard systems into COMET-VR to account for carbon changes and also we analyzed the effects of management on carbon dynamics in these orchard systems.

**PS4_22**

### Modelling Coarse Root Growth in Reforested Sites of Forest Ecosystems of Northern Mexico

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Below-ground biomass is an important carbon pool for many vegetation types and land-use systems and accounts for about 20% to 26% of the total biomass. Therefore, modeling root biomass stock and productivity of forests is critical for the understanding of ecosystem function and the biogeochemical cycles of several elements. In this study, I report measurements and empirical modeling of coarse roots (basal diameter > 1.0 cm) on 133 forested sites with several pine species in northern Mexican forest ecosystems. Measured mean (confidence interval) values of reforestations were for; a) age 16 years (2), b) final stand density 3500 trees ha$^{-1}$ (680), c) basal diameter 10.9 cm (1.7), d) top height 4.3 m (0.6), e) basal area 15.6 m2 ha$^{-1}$ (3.2), f) timber volume 34.2 m3 ha-1 (8.9), total aboveground biomass 24 Mg ha$^{-1}$ (5). Root biomass, RB, was estimated by applying the root volume, RV, equation, which is a function of basal diameter, BD, multiplied by the root basic density, p; RB = ((1103*BD0.98)/1000000)*0.89. Mean (confidence intervals) root biomass is 10 Mg ha$^{-1}$ (2.7 Mg ha$^{-1}$). Root biomass was empirically modeled by basal area and site index. Basal area explained most coarse root biomass variation and this parameter was statistically a function of final stand density, age, and SI. The model projects for reforestations of 20 years of age and mean site index of 8 m at 15 years of base age, coarse root biomass stocks and productivity values of 26 Mg ha$^{-1}$ and 0.7 Mg ha$^{-1}$ y$^{-1}$. The coarse root growth model has some physical meaning consistent with findings in the scientific literature that most reductions on root biomass productivity are noted in reforestations with large site index values.Key words: Root biomass productivity, stand scale, radial growth.

# Posters

# Session 5:

# “SOM: Global and Regional Perspectives”

**PS5_1**

## The effects of ecological succession on the characteristic of soil humic substances in a Japanese volcanic ash soil: Chemical properties and stabilities of different size fractions of Humic acids

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In our previous study, we investigated the distribution and chemical properties of humic substances in a series of Japanese volcanic ash soils under the grassland and two forest sites; site 1 with maintenance of grassland, site 2 with abandonment of grassland for 30 years, and site 3 with abandonment for more than 100 years. The results demonstrated that the long-term ecological succession caused stable C losses with decrease the HA aromaticity and the greatest changes occurred during the first 30 years. Furthermore, these results suggested that this site situation caused not only stable C losses but also the changes of essential chemical properties and stabilities of HA. This study employs preparative high performance size exclusion chromatography (HPSEC) techniques to separate humic acids (HA) in 10 different size fractions to compare circumstantially their chemical properties and stabilities. In each fraction the $^{13}$C NMR spectroscopy, the degradation experiment (decolorization rate) with hydrogen peroxide, $\delta^{13}$C and $\delta^{15}$N values were determined. The $^{13}$C NMR spectra showed that the size fractions of site 1 was more aromatic in nature except in highest size fraction, whereas O-alkyl and alkyl C moieties in the HA of site 2 increased especially in low and middle size fractions. The $^{13}$C NMR spectra of size fractions of two forest sites (site 2 and 3) showed very similar trend in all size fractions. Percent decolorization of size fractions of site 1 was lower than that of the fractions of site 2 and 3 except highest size fraction, whereas it became gradually high in lower size fractions of site 2 and 3 with succession. The $\delta^{13}$C and $\delta^{15}$N values of ten size fractions of site 2 only slightly changed, however, $\delta^{13}$C values of site 3 totally decreased and $\delta$15N value increased. The $\delta^{13}$C - $\delta^{15}$N diagrams showed that the groups of varying pattern of $\delta^{13}$C: $\delta^{15}$N =1:3 (probably more unstable fractions) increased with succession relative to the 1:1 (probably more stable fractions) groups. The results of this study demonstrated that the long-term ecological succession on grassland caused not only stable C losses but also the changing the essential chemical properties and stabilities. Furthermore, the results suggested that the ecological succession accelerated the turnover time of the materials which was more stable C forms in this site.

**PS5_2**

**Soil Organic Matter Dynamic and Aggregate-size stability Distribution Under Fruit-Tree Orchards**

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Land use change takes place in the recent years in China under the new policy for planting structure changes of farm crops. With the changes some agricultural land is no longer used for grain production, instead, being replanted with perennial vegetation, soil organic carbon can accumulate. In recent years, the apple production in the North China Plain region rapidly increased, but the knowledge about the potential of C sequestration and aggregate stability in this special vegetation is highly scarce. The objective of this study was to estimate the fruit-tree establishment effects on the distribution of SOM fractions and soil aggregate stability. Bulk soil samples were collected from incremental soil depths (0-10, 10-20, 20-40, 40-70, and 70-100 cm) from three land-use types: fruit-tree orchards established in 2003, 1995, 1987, and 1980; Cropland and Forage field planted to alfalfa. Soil samples collected from these plots were analyzed for aggregate stability after wet sieving into four aggregate size classes (>2000 µm; 250-2000 µm; 53-250 µm and <53 µm). The concentration of total organic carbon (TOC) and total nitrogen (TN) were determined in each size fraction. Density fraction separation methods were used to isolate free light fraction organic matter (LFOM), from heavy fraction organic matter (HFOM). We also determined the microbial biomass carbon (MBC), using the fumigation extraction method. The total weight of aggregates varied in the order Grassland>cropland>fruit-tree land. Large amounts of aggregates were accumulated in the 250-2000 µm size class and the smallest amount was found in large macro-aggregate size (>2000 µm). TOC, TN, LFOM and MBC were higher under Fruit-Tree orchards than under Forage field and cropland, and were mainly concentrated in the top soil layer (0-20cm). For this research, the aggregates with diameter <53 µm had a higher SOC concentration than aggregate of other classes, regardless of the depth or land uses and they may therefore contribute to soil C sequestration.
Keywords: fruit-tree orchards; soil aggregate stability; soil organic matter; land-use changes; carbon sequestration; China

**PS5_3**

## Comparing Modeled versus Measured Agricultural Soil C stocks in the Mid-Continental Region

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Improved land use and management on agricultural lands in the United States represent a significant opportunity for the sequestration of atmospheric carbon in agricultural soils. Increased incorporation of soil organic matter and decreased decomposition of organic carbon in soil due to the improved land management can benefit soil quality as well as help mitigate carbon dioxide emissions. Yet, current estimates of soil carbon stocks are based primarily on simulation modeling and have large uncertainty. A national soil monitoring network is being developed to quantify and track long-term changes in soil carbon at regional and national levels. Carbon data from soil samples collected in this network can be used to improve uncertainty associated with modeled estimates. Initial sampling of soil carbon from 45 row-crop sites in the mid-continental region between 2006 and 2007 will be compared to estimates of soil carbon made by an improve version of the CENTURY ecosystem simulation model. MODIS EVI data are used in a modified version of CENTURY to improve site-specific biomass estimates and produce enhanced estimates of soil carbon at locations where soil samples have been taken. Initial results will be presented from running this improved model at the 45 sites. The improved model will be compared with model results from the nominal CENTURY runs, without the use of MODIS EVI data. A planned statistical approach will be presented that will estimate uncertainty from the comparison of measured versus modeled soil carbon at these 45 sites that can be used for adjusting model bias. Using benchmark soil monitoring data along with statistical models of uncertainty are expected to greatly improve estimates of regional and national soil carbon, which can inform policy on land use and management of agricultural lands.

**PS5_4**

## Using Soil Survey Data to Educate the Public About the Role of Soils in Carbon Storage

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Soils have been identified by many researchers as having the largest terrestrial stock of organic carbon; estimates indicate that soils store about twice the amount of organic carbon as above-ground vegetation. The USDA - Natural Resources Conservation Service (NRCS) in mapping the soils of the United States retains soil organic matter values for map unit soil components by horizon in the National Soils Information System (NASIS). Using an interpretation generator within the NASIS platform it is possible to export classes of soil organic carbon (SOC kg/m$^2$ to either 1 meter or 2 meters) to create maps and tables that clearly illustrate the distribution and relative amounts of organic carbon stored in soils. The National Park Service is using this data to educate the public about the important role soils play in storing carbon and to help park staff better manage their lands in terms of a park's carbon footprint. Carbon maps can help prioritize restoration areas and can also be used to help select areas for detailed soil carbon research. Comparative levels of SOC from different park units will be displayed and discussed in relation to their soil climate regimes.

**PS5_5**

## Soil Organic Matter and Mercury at Variable Spatial Scales

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Mercury, which forms complexes with soil organic matter (SOM) and is methylated by some microorganism in the presence of dissolved organic carbon (DOC), is an element of concern from human and ecosystem health perspectives. The interaction of SOM and Hg can be recognized at scales from continental to microscopic. Scale-dependent factors controlling these interactions include climate (continental), bedrock type (regional), hydrology (watershed), and microbial transformations in soil micropores. Continental scale variations in Hg and SOM were examined using mineral soils collected along N-S (Manitoba to Texas) and E-W transects (along the 38th parallel) during the U.S. Geological Survey and Geological Survey of Canada pilot study for a continental soil geochemistry program. Phospholipid fatty acids indicative of microbial processes (PLFA; n=182) evaluated in conjunction with organic carbon (n=251) show distinct patterns that are related to rainfall and temperature. Organic carbon and PLFA concentrations were low in regions with low annual precipitation, including the Great Basin, Colorado Plateau and southwestern Great Plains, with greater concentrations in the Appalachian Mountains, northern grasslands and in the mountains and Central Valley of California. At this scale Hg concentrations were not significantly correlative with organic carbon parameters due to anthropogenic and geologic Hg sources that vary by region. Geologic sources impacted by mining occur in California and Nevada, and atmospheric Hg deposition from coal-fired power plants is extensive the eastern United States. At the regional scale, a study conducted in Northern California showed a strong relationship between organic carbon, N and bedrock type, with greater nutrient concentrations associated with metamorphosed basalts and ultramafic rocks relative to sedimentary rocks. Regional Hg concentrations were a function of land use, primarily historic Hg mining, and geomorphic setting for alluvial soils. It was not until the soils were examined on a small catchment scale that a direct statistical relationship between organic C and Hg could be observed. A recently study found that soil moisture had a strong influence on concentrations of PLFAs, pore water DOC and methylmercury in soils from a small (~1km$^2$) watershed impacted by historic mercury mining in northern California. Similarly a data set from an alpine watershed in northern Colorado showed a strong relationship between soil moisture and PLFA biomass, organic C and bulk Hg concentrations in granitic soils impacted by atmospheric deposition. These data sets collected at continental, regional, and watershed scale reveal a complex relationship between soil organic matter and Hg.

**PS5_6**

## The effects of ecological succession on the characteristic of soil humic substances in a Japanese volcanic ash soil. Concentration and chemical properties of humic substances

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In the grassland/forest ecotone of volcanic ash soil in Japan, we examined how such different land cover can impact the distribution and chemical properties of humic substances. The study sites were managed as grasslands for several hundred years. The regular maintenance of the grassland at site 1 was still being practiced, while the maintenance on site 2 and 3 was discontinued approximately 30 and more than 100 years ago, respectively. The two latter sites were left to return to forest. The dominant vegetative cover was Miscanthus sinensis at the site 1, Pinus densiflore at the site 2 and Quercus crispula at the site 3. The soil is derived from volcanic ash, classified as Typic Melanudand (USDA Soil Taxonomy). The concentration of humic acids (HA) and fulvic acids (FA), extracted from each mineral soil horizon were investigated. Furthermore, molecular size and liquid-state $^{13}$C NMR spectroscopy of HA and FA from each A horizon were determined to clarify the effects of long-term ecological succession on the quality of humic substances. The concentration of HA (C gram per kilo gram dry soil bases) in A horizon significantly decreased with succession until 30 years and then remained constant or slightly decreased at site 3. The concentration of HA in the B horizon is unchanged. These trends paralleled those of the total C content. The concentration of FA however, was not so drastically changed in both A and B horizon. The FA/HA values of two forest sites were larger than those of the grassland site. The molecular size of HA clearly became high with succession while that of the FA remained constant. The chemical properties of HA and FA appeared to be affected by the longevity of succession especially for HA. The amounts of alkyl C moieties in the HA of site 2 and 3, as shown by the $^{13}$C NMR spectra, increased with succession and the greatest changes occurred during the first 30 years. On the other hand, the $^{13}$C NMR spectra of FA showed only slightly changed with succession. The results of this study demonstrated that long-term ecological succession caused the stable C losses with decrease the HA aromaticity and the greatest changes occurred during the first 30 years in a Japanese volcanic ash soil.

**PS5_7**

## Global assessment of the spatial and temporal variability of soil organic carbon transport and burial under accelerated erosion

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Soil organic carbon (SOC) is recognized to be an important parameter of soil fertility and a major compartment of the global carbon cycle. Current estimates of continental or global carbon fluxes largely depend on unverified assumptions and model applications that ignore lateral fluxes. In recent studies, geomorphologic processes (soil erosion and sedimentation) and site attributes (slope steepness and land use) have been postulated to be the driving factors in human-impacted landscapes for decomposition and stabilization of SOC. We assume topography and land use as the factors controlling soil carbon relocation for modeling from global to regional scale. Furthermore, depositional environments are assumed to be strong sinks for terrestrial carbon due to burial of former topsoil horizon SOC in deeper soil layers, leading to reduced decomposition rates. There is need to investigate these processes in connection with accelerated carbon decomposition during transportation and higher levels of sequestration of atmospheric carbon on eroded sites to improve existing carbon models. In order to accurately quantify the human-induced influence on SOC stocks it is crucial to increase our understanding of carbon cycling processes in complex terrains under the impact of soil redistribution. Although recent work has substantially improved our process of understanding, existing estimates of the amount of sediment and associated carbon being laterally transferred and buried in terrestrial environments diverge largely. With our work, we aim to reduce this uncertainty by presenting a spatial and temporal explicit model of global carbon fluxes (1000 AD to 2000 AD) within terrestrial environments, induced by agriculture. We use existing worldwide datasets of recent and historical land use, climate, topography and soil attributes in combination with global erosion rates under cropland. Based on this information we estimate the amount of eroded and deposited soil organic carbon as well as the temporal evolution of soil profile properties. We confronted our estimates with sediment and carbon transport measurements of major river systems from terrestrial to oceanic regimes. We compare our results with existing estimates using different methods and discuss the implications of our findings in relation to the global significance of erosion-induced carbon uptake/release.

**PS5_8**

## Effects of Clay Organic Carbon on the hill region

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An attempt had been made to estimate the comparison between the soil organic carbon and soil proportion under two typical land-use types including Pinaster and Maize field which located at the boundary between the yellow sea and Bohai in south of Lvshun. The results showed that the difference in the soil organic carbon contents at two typical land-use types was highly significant ($P<0.01$) and the soil organic carbon contents order was: Pinaster (3.57%) > Maize field (2.41%). But the soil proportion order was: Maize field (2.67g $cm^{-3}$) > Pinaster (2.55g $cm^{-3}$). The enrichment modulus of different levels soil organic carbon showed that the soil organic carbon mainly enriched in the surface soil (0~20cm). Soil organic carbon contents decreased with soil depth increasing while the soil proportion reversed. Also, the soil proportion was high while the soil organic carbon content was low. There was a significant positive relationship between soil organic carbon and soil proportion ($R^2$ Pinaster =0.9297, $R^2$ Maize field =0.9214). It showed that soil proportion could be a sensitive index as soil organic carbon, while the soil organic carbon could be the important index of the soil fertility and the diversification of soil. It is suggested that woodland has a great potential in making a significant contribution to C storage and environmental quality.

**PS5_9**

## Long-term litter decomposition/stabilization and soil organic matter dynamics

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Assumptions about long-term litter dynamics are inherent in most models of terrestrial carbon cycling. Well characterized is the initial phase of rapid litter decay during two months to two years immediately following litter deposition. Relatively scant information is available on the extent to which litter continues to decompose or is stabilized during two years to two decades after deposition. Most available information on long-term decomposition is from the persistence of $^{14}C$-labelled plant residues studied during 1960-80. We recently (fall 2007) implemented a long-term, trans-Canada decomposition study to investigate the persistence of $^{13}C$-enriched barley residues in a diversity of annually cropped soils spanning the agricultural region of Canada. In this presentation we will describe the rationale for the study, how it was implemented, and some initial results.

**PS5_10**

## Effect of Soil Properties and Management on the Activity of Soil Organic Matter Transforming Enzymes and the Quantification of Soil-Bound and Free Activity

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Soil organic matter transformation is accomplished by extracellular enzymes of soil microorganisms, mainly soil fungi. The SOM transformation processes are thus dependent on the factors affecting both the microbial enzyme producers and the activity and mobility of enzymes in soils. The aim of this work was to the soils with of Central Europe for the activity of extracellular enzymes involved in SOM transformation (laccase, Mn-peroxidase, endocellulase, cellobiohydrolase, beta-glucosidase, endoxylanase, beta-xylosidase, alpha-glucosidase, chitinase, arylsulfatase, phosphatase, phosphodiesterase, alanine aminopeptidase and leucine aminopeptidase). The soil were selected to cover a wide of physico-chemical properties (pH(KCl) 2.1-7.8, Cox 1.5-21.9%, Ntot 0.05-1.35%, P 5-250 ppm, Ca 50-12400 ppm) and management type (forest, grassland, arable field). 10 cm of topsoil below the litter horizon were sampled. Closely located sites under permanent grassland versus tilled arable field (cereals) were compared. Principal component analysis revealed that soil pH and organic matter (C, N) content are the most important factors defining enzyme activities. Enzyme activity most closely reflected the content of C and N in the soil. The activity significantly increased with organic matter content for all enzymes except arylsulfatase, endocellulase and endoxylanase. Activities of beta-xylosidase, phosphatase, laccase and endoxylanase decreased with increasing pH. Chitinase activity decreased with P content in soils most probably due to dominance of bacteria in these soils. Beta-Glucosidase, cellobiohydrolase and alanine aminopeptidase significantly increased with soil Ca content. The extractable fraction of activity varied among soils and enzymes but typically accounted for just a few per cent of the total activity. It typically decreased with increasing pH and also with increasing total enzyme activity in the sample. The comparison of tilled arable soils versus grasslands showed significantly higher content of Cox and Ntot by a factor of 1.7-1.8. Significantly higher activity was found in grassland sites for alpha-glucosidase (2.4x), beta-xylosidase (2.2x), arylsulfatase (2.8x), phosphatase (1.9x), phosphodiesterase (1.8x), alanine aminopeptidase (2.3x), laccase (1.8x) and especially Mn-peroxidase (11.0x). The results show that environmental factors and management type affect the rates of SOM transformation and that only a minor and variable fraction of the total enzyme activity is freely mobile in the soil.

**PS5_11**

## Differences in soil properties in Norway spruce, Scots pine and Silver birch stands in south Sweden

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A changing climate will likely influence the selection of tree species in the future, and this management decision may in turn affect the size of the pools and turnover of carbon in different ways. Tree species differ in growth rate, fine-root turnover and quality of litter and tend to produce different types of understory vegetation. In Sweden three tree species (Norway spruce [Picea abies] 43%, Scots pine [Pinus sylvestris] 39% and birch [Betula spp.] 11%) dominate. In the present study we use field experiments in south Sweden to see how these tree species differ in root distribution and turnover, ground vegetation cover and soil carbon stocks. All plots have a similar history, established on old heather moorland, with one succession of spruce before the present plantation. Depth of the humus layer differed between species. Spruce had a thick mor layer whereas birch, with higher pH and earthworms mixing the soil, had a thin organic layer mixed with mineral soil. At 20-30 cm depth in the mineral soil, differences in pH between species were small. Soil carbon content was highest for spruce and lowest for birch, with pine in between. Nitrogen content followed the same pattern. For all three species, both carbon and nitrogen decreased with depth. There were no clear changes in C/N ratio with depth for any of the species, but C/N ratio tended to be lower for birch than for pine whereas spruce had the highest C/N ratio. All base cations (Ca, K, Mg, Na) had the highest levels in the humus layer but small differences between mineral soil layers for all three species. Birch had the highest Ca and K levels, whereas spruce had the highest levels of Mg and Na in the humus layer. The clear differences in soil carbon content between stands of different species can be explained both by differences in production and in decomposition rates. Spruce has a higher production than birch in this part of Sweden. Birch may have a faster turnover, since the presence of earth worms and other soil fauna accelerate decomposition.

**PS5_12**

## Carbon sequestration of winter cover crops in mono rice cropping system

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In mono rice cultivation system in Korea, winter cover crop cultivation is strongly recommended for improving soil quality and carbon sequestration. Selection of appropriate cover crops requires an adequate knowledge of the quality and quantity of each plant biomass produced and its carbon sequestration potential. This study investigated the effect of four winter cover crops (barley, Chinese milk vetch, hairy vetch, rye) having different C/N ratio on pant above-ground and root biomass productivity and carbon sequestration in paddy soil before rice transplanting. Cover crops were seeded in the late October after rice harvesting on the dried soil condition and harvested the mid May before flooding for rice transplanting. In comparison, the control treatment without cover crops was naturally covered by short awn [Alopecurus aequalis var. amurensis]. Above ground dry matter of planted cover crops increased by ca. 430 to 1500% compared to that of the control (0.98 Mg $ha^{-1}$), ranging between 2.9 Mg $ha^{-1}$ for Chinese milk vetch and 15.3 Mg $ha^{-1}$ for rye. Root biomass was markedly increase by cover crop plantation with the same tendency with the above ground plant productivity. Total carbon sequestration of short awn in the control was ca. 570 kg C $ha^{-1}$, and increased from 254% by Chinese milk vetch to maximum 1560% by rye. Since short awn is not harvested for animal feeding but the selected cover crops are mostly removed in our rural side, barley and rye could increase carbon sequestration to 151 and 301% by single root biomass production, respectively. In contrast, Chinese milk vetch and hairy vetch, which have lower root biomass productivity than total biomass of short awn, could not increase carbon sequestration by root biomass supply. As a result, high biomass cover crops such as barley and rye might be reasonable as a winter crop to increase soil carbon sequestration and to improve soil organic carbon related properties.

**PS5_13**

**Do tree species affect the C distribution in soil physical fractions in the Canadian boreal forest?**

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Understanding the role of the boreal forest in the global C cycle is essential to increasing our ability to predict and mitigate the consequences of climate change. We hypothesized that different stand types (black spruce, trembling aspen and mixedwood) differentially affect soil organic C (SOC) distribution among size-density fractions. The surface mineral soil (0-15 cm) of 24 plots differing in forest composition was sampled in forested Luvisols (Alfisols) of the Abitibi region, Canada. The soil was first separated into three water-stable aggregate size fractions (>1000 μm, 1000-250 μm and <250 μm) by wet sieving, followed by a density flotation (NaI: 1.7 g cm-3) and a dispersion (with glass beads) to isolate the free light fraction (LF), the intra-aggregate particulate organic matter (iPOM) and the silt plus clay fraction (SC). The C content of the nine size-density fractions was determined. According to a mixed linear model, the proportion of whole soil C within size-density fractions was responsive to stand type. More SOC was found in the iPOM (all three size fractions) and in the LF (>1000 μm m fraction) under black spruce compared with the mixedwood and trembling aspen, while less SOC was found in the SC fraction (>1000 μm m and 1000-250 μm m fractions combined). These results suggest that black spruce increases the amount of C in the less physically-protected SOC fractions compared with trembling aspen, with the mixedwood being intermediate in between. Considering that the wet and cold conditions usually found in black spruce soils limit decomposition, the potential improvement of soil conditions with climate change might cause losses of these less protected SOC fractions in black spruce stands.

# Posters

# Session 6:

# "SOM and Soil Depth: Controls on C and N Dynamics"

**PS6_1**

## Soil Organic Matter Transformation by Saprotrophic Microfungi from the Upper Layers of Forest Soil

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The upper layers of forest soils are characterised by a high content of organic matter mainly present as biopolymers: cellulose, hemicelluloses and lignin contained within wood and plant litter and chitin, a structural component of fungal hyphae and invertebrate exoskeletons. Saprotrophic basidiomycetes are often regarded as the main degraders of lignin and cellulose in forest soils. The aim of this work was to investigate the isolates of nonbasidiomycetous microfungi from the forest floor of the Quercus petraea forest for their ability to degrade cellulose and to utilize the cellulose-derived components. The isolates were obtained by dilution plating and the isolation resulted in a majority of opportunistic microfungi, r-strategists utilizing preferentially simple carbon sompounds present in SOM or provided by the action of soil enzymes. Most isolates belonged to the Ascomycota or to the related anamorphic genera. Based on ITS and β-tubulin gene sequencing, the genus Penicillium represented more than 66% of all isolates, followed by Geomyces (10%), Hyalodendriella (5%), Acremonium, Alternaria, Cladosporium, Hypocrea, Myrothecium, Umbelopsis and unidentified members of the Zygomycota. Highest rate of cellulose hydrolysis was found in Hypocrea, Alternaria and Cladosporium genera, while 52% of the Penicillium strains were unable to depolymerise it. Alternaria showed the highest activity of α-glucosidase, while Umbelopsis was the only genus unable to produce this enzyme. All tested strains were able to grow on cellobiose; three strains of Penicillium grew even faster on this disaccharide than on glucose. The utilization of hemicelluloses, xylan and galactomannan, was also recorded for most isolates. N-acetylglucosamine, the structural component of chitin was a good substrate for the majority of isolates and more than 60% of strains were able to degrade polymeric chitin. None of the strains tested was, however, able to oxidise phenols and transform soil humic acids. The results showed that more than a half of the tested opportunistic microfungal species are able to degrade cellulose, although the rate of degradation is lower than in the saprotrophic basidiomycetes. Other substrates, namely hemicelluloses and chitin, represent in general a more preferred substrate for the members of this ecological group of fungi. In soils, the activity of microfungi is limited to the forest floor with accessible plant and microbe-derived polysaccharides while the deeper soil layers do not represent a suitable environment for opportunistic saprotrophs.

**PS6_2**

**Estimation of DOC and DON Fluxes Under Miscanthus and Lolium Cover; Effects of Land Use Change**

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Soils play an important role in carbon (C) cycling as they contain more than twice the amount of C than the atmospheric or vegetation pools. Management practices could slow atmospheric CO2 rise and associated warming by promoting soil C storage or they could exacerbate warming by causing soil C to decline. Conversion of agricultural land to energy crops has been identified as the land use change with the greatest potential for C mitigation across Europe. However, it is difficult to evaluate such a land use changes due to lack of data on soil C dynamics beneath energy crops. Soil C and nitrogen (N) pools are ultimately determined by the equilbrium between soil C and N input by plants, and C and N losses through leaching and decomposition. Although losses through leaching of dissolved organic carbon (DOC) are much smaller than the release of $CO_2$ from soils, DOC may play an important role in the many biochemical soil processes and sequestration of organic carbon. Several studies measured DOC and fewer DON fluxes following land use changes. However the effect of land conversion to bioenergy crops such as Miscanthus needs investigation in order to meet the chalenge of managing soil C and N pools.The effects of conversion from agricultural land to Miscanthus on DOM will be investigated at Teagasc, Crop Research Centre, Carlow, Ireland. Dissolved organic matter concentrations under a newly established Miscanthus stand (March 2008) and a well established Miscanthus stand (14 years old) are being assessed by collecting leachate using tension lysimeters placed within the A horizon (~25cm) and mineral B horizon (~45cm). An adjacent Lolium perenne plot is representative of the pre-establishment soil scenario (i.e. a ‘time zero’ reference).When the dominant vegetation type is converted from plants using C3 pathway to C4 pathway there is a shift in the isotopic signature of C sequestered to the soil which can be used to determine the proportion of OM derived from the new vegetation. DOC will be tracked through the soil profile using Miscanthus’ natural $\delta^{13}C$ tracer. Reference $^{13}C$ values for C3-derived DOC will be derived from the leachate in the L. perenne site. This data will enable us to identify the amount of ‘new C’ in the soil under the bioenergy crop i.e. what proportion of DOC is Miscanthus derived and also give an indication of the depth distribution of C4 Miscanthus derived C.

**PS6_3**

## Distribution of soil carbon and microbial biomass under different tillage regimes

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We have measured total soil organic carbon (SOC), dissolved organic carbon (DOC), microbial lipid contents (as an index of microbial community structure and proxy for microbial biomass) and microbial respiration and their distributions with depth in soils from replicated medium-term (2003-2009) experimental arable plots subject to different tillage regimes at SCRI (Scotland). The samples have been collected on a depth and volume specific basis from 0-55 cm depth. The treatments of the experiment were deep ploughing to 40 cm, conventional ploughing to 20 cm, reduced tillage to 7 cm depth and zero tillage with direct drilling. Sampling depths corresponded with major changes in soil horizons, so that the plough pan and cultivated surface soil could be isolated in each tillage treatment. Many studies on tillage effects only measure surface soils, whereas this study integrated the measured properties over the entire depth to 55 cm and accounted for density effects. SOC contents declined with depth and SOC contents were significantly greater in the surface 30 cm of the zero and reduced tillage treatments, but beneath this depth, the SOC contents were similar in all treatments. DOC contents were also greater in the near the surface of the zero and reduced tillage plots compared to the other treatments, although the difference was confined to the surface 0-5. There was no change in DOC content with depth in the conventional and deep ploughing plots and in the below 5 cm there was no difference in DOC content with depth beneath 5 cm. The total microbial biomass, and both the bacterial and fungal biomass all decrease with the increasing of soil depth. Total microbial biomass contents were greater in the minimum tillage treatment, except in the surface few centimetres of the zero tillage plots. The bacteria and fungal biomass contents of soil surface under reduced tillage are greater than under the conventional and deep ploughing treatments

**PS6_4**

## Field-Scale Spatial Heterogeneity and Relationships Among Soil Organic Carbon, Terrain Attributes, and Crop Performance

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Understanding field-scale variability and relationships among soil organic carbon (SOC), terrain attributes and crop performance will benefit field sampling strategies, predictive capacities and precision agricultural applications. Our objectives were to: (1) characterize SOC (0 to 1.5-m depth) within a 37 ha field with soil and terrain attributes typical of the Palouse region in Eastern Washington and Northern Idaho; and (2) assess relationships among SOC, soil properties, terrain attributes and crop performance (biomass production, harvested yield). A systematic, non-aligned grid of 369 geo-referenced sample locations was established at the Washington State University Cook Agronomy Farm (CAF) near Pullman, WA, USA. Soil samples (0-10 cm) were collected at all 369 locations and intact soil cores (0-1.5 m) at alternating points (182 locations). Soil horizonation and morphology were described, the soils classified and then divided by horizon for analyses of SOC, total N and pH. Soil bulk density was determined by horizon for each soil classification. A digital elevation model (DEM) was developed using a survey-grade Global Positioning System and terrain attributes (slope, aspect, curvature, global solar insolation, flow accumulation, flow direction, specific catchment area, and wetness index) were derived (10-m grid) from the DEM. Crop yield and aboveground biomass were sampled at the geo-referenced points for the next five years and relative yields determined. Apparent electrical conductivity (ECa) was determined using a kinematic survey during the spring and fall of 2000. SOC in the surface 10-cm ranged from 7.2 to 25.1 g C/kg and was linearly related to crop yield. SOC declined exponentially with depth, but considerable variability in subsoil SOC occurred with values ranging from 0.2 to 18.6 g C/kg . Further analyses and results will be presented.

**PS6_5**

## Different response of soil microbial respiration rate and community composition to high $CO_2$ concentration in topsoil compared to subsoil.

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Although the concentration of $CO_2$ in subsoils can be 100-fold higher than at the soil surface, the effects of such a high $CO_2$ concentration on microbial community structure and function are largely unknown. In food processing, the use of $CO_2$ to suppress microbial activity is well known, but the effects of high $CO_2$ concentrations (i.e. more than 1% $CO_2$) on soil microbial activity have hardly been investigated. Still, this seems important in view of the recent debate on subsoil SOM dynamics related to climate change. Therefore, we designed a laboratory set-up that allows measuring soil respiration at varying $CO_2$ concentrations, and combined this with measurements of phospholipid fatty acid (PLFA) biomarkers to assess the effect of $CO_2$ concentration on microbial community structure. Homogenised topsoil and subsoil (1 m deep) samples from a Fluvisol were pre-incubated at 20°C for two weeks under ambient atmospheric conditions, after which they were exposed to a constant airflow containing either 500 ppm $CO_2$ (Low $CO_2$) or 3% $CO_2$ (High $CO_2$) for 5 days. Every day, respiration rates were measured by closing the incubation jars for several hours and measuring the $CO_2$ concentration increase. Care was taken to avoid an excessive increase in $CO_2$ concentration. At the end of the incubation, PLFA content was determined. Under Low $CO_2$ conditions, soil respiration rate in the topsoil was 60 times higher than in the subsoil, but for High $CO_2$, this difference was reduced to a factor of 6. This was mainly caused by a sharp drop in topsoil respiration rate, while subsoil respiration rate did not decrease significantly with increasing $CO_2$ concentration. Total PLFA content in the topsoil decreased from 2.9 mg PLFA-C kg-1 soil for Low $CO_2$ to 0.5 PLFA-C $kg^{-1}$ soil for High $CO_2$, while subsoil PLFA content remained constant with increasing $CO_2$ (0.4 mg PLFA-C $kg^{-1}$ soil). Analysis of the distribution of biomarkers representative for Actinomycetes, Fungi, Gram-positive and Gram-negative bacteria revealed that microbial community structure changed with increasing $CO_2$ only in the topsoil. Furthermore, topsoil microbial biomarker distribution and total PLFA content seemed to change towards the pattern observed in the subsoil. Our results suggest that subsoil microbial community structure and function are better adapted to high levels of $CO_2$, and that microbial community structure can be altered by changing $CO_2$ concentrations.

# Posters

## Session 7:

## "SOM Dynamics in Flooded, Organic, Alpine and High Latitude Soils"

**PS7_1**

## Will Secondary Vegetative Succession Reduce Carbon Dioxide Efflux from a Carolina Bay Histosol?

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North Carolina has over 600,000 ha of Histosols located in poorly drained areas along the lower Coastal Plain, in Carolina bays, and in pocosins. Restoration of hydrology and native plant communities in agricultural fields occupying Histosols may result in net soil C sequestration and provide an economic incentive via C credit sales. Understanding of soil C dynamics as secondary succession proceeds is currently lacking for organic soils. We hypothesized that average daily soil temperature will decrease with vegetative succession as canopy density and surface shading increase, leading to a net reduction in microbial respiration and $CO_2$ efflux, especially when hydrology is restored and soils become reduced. A greenhouse experiment was designed to test the combined effects of soil moisture and surface shading on C loss from a Carolina bay organic soil material. Intact cores (20-cm height— 20-cm diameter) were subjected to a water table (-15 cm) under three conditions of sunlight reduction: 0 (unshaded), 70, and 90% for 60 d. Thereafter, shading treatments were maintained for an additional 30 d with the water table removed. The soil $CO_2$ efflux was measured periodically with a portable photosynthesis analyzer. Soil redox potential was measured concurrent with $CO_2$ efflux and temperature was recorded hourly for the duration of the experiment. Preliminary results indicate that there was no interaction ($p = 0.58$) between the two factors. The $CO_2$ efflux differed ($p < 0.0001$) among shading treatments (unshaded > 75% > 90%) and increased ($p = 0.004$) after the water table was removed. Results suggest that soil C loss will decrease as secondary succession proceeds and hydrology is restored. A field study is underway to observe CO2 efflux from in-situ soil material under similar shade treatments.

**PS7_2**

## Denitrification And Carbon Gas Production Of Gulf Coast Wetland Soils

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The wetlands at the Gulf Coast are subjected to both influences of river diversion and seawater intrusion. These influences could affect biogeochemistry of these wetlands. In this study, denitrification and relationship between carbon gas production and selected electron acceptors for Gulf Coast wetland soils were characterized. Composite soil samples were collected from three different wetlands of increasing salinity gradient, namely, bottomland forest swamp (FS), freshwater marsh (FM), saline marsh (SM) located in the Barataria Basin estuary, Louisiana, U.S.A. Potential denitrification rate (PDR) along with various soil chemical properties was characterized. In addition, a laboratory microcosm study was carried out to evaluate effects of different levels of $NO_3^-$ and $SO_4^{2-}$ on carbon (C) gas emissions. Of the three wetlands, the FM soil profile exhibited the highest PDR on both unit weight and unit volume basis as compared to FS and SM. The FM also tended to yield higher amount of N2O as compared to the FS and SM especially at earlier stages of denitrification, suggesting incomplete denitrification and potential for greenhouse gas emission. Saline marsh soil profile had the lowest PDR on the unit volume basis. Regression analysis showed that organic C was the dominating factor in regulating PDR. Of the compositional C functionalities, polysaccharides positively influenced denitrification rate whereas phenolics (likely phenolic aldhydes and ketonics) negatively affected denitrification rate in these wetland soils. Comparing C gas production under anaerobic conditions for the FM soil showed that the presence of elevated $NO_3^-$ concentration (3.2 mM) significantly decreased $CO_2$ productions from the freshwater marsh soil whereas the presence of equivalent $SO_4^{2-}$ concentration did not. On the other hand, both $NO_3^-$ and $SO_4^{2-}$ treatments decreased $CH_4$ production but the $NO_3^-$ almost completely inhibited $CH_4$ production. The study also revealed that a large proportion of anaerobic carbon mineralization for the untreated sample (without presence of added $NO_3^-$ and $SO_4^{2-}$) was unexplained by any of the measured major electron acceptors in the wetland soils.

**PS7_3**

## Assessing the Stability and Interactions of Iron and Aluminum Hydroxide with Dissolved Organic Matter

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The stability of floc formed from the addition of different metal based coagulants to water collected from Twitchell Island, in the San Joaquin Delta in California, were determined through incubation studies simulating anaerobic conditions experienced in wetland environments and with thermogravimetric analyses. Preliminary six-week incubation studies conducted under anaerobic and aerobic conditions showed the floc to be stable; minimal release of DOC and metal into the top water were detected. However, in a preliminary incubation study where sulfide was added to ensure iron reduction, a significant amount of iron was taken out of the top water and some DOC was released. This may be due to interaction with the sulfide and the formation of pyrite, although there is need for further investigation. Variation in dosage of metals in the precipitate were conducted to determine potential effects of metal-DOC ratio in precipitate stability.

Preliminary thermogravimetric results using differential thermogravimetric analysis show both the precipitate of iron sulfate and iron chloride with DOC had two exothermal peaks. On the other hand, the curve for DOC precipitated with the polyaluminum chloride coagulant had only one broad exothermal peak. Significant differences between the aluminum and iron coagulants give insight into potential interactions of these different metals with DOC, which may provide information regarding carbon stabilization mechanisms. Further studies will be conducted using differential scanning calorimetry, which will provide more thermal resolution and insight into the thermal characteristics of the sample such as enthalpy.

This study will provide information regarding the long-term stability of metal-DOC precipitate under anaerobic conditions, similar to what is experienced in a wetland environment. Models created from this study may then be used to shed light on organic matter stabilization processes found in both wetland and soil environments.

**PS7_4**

# Peat composition in cool temperate bogs of different drainage history

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Oxygen supply in the Catotelm (i.e., anoxic subsoil) of bogs is typically strongly limited. These reducing conditions cause O/C and H/C ratios in the peat to decline with depth whereas the relative C concentration increases. Upon drainage and subsequent oxidation, the decomposition rate is accelerated; a fraction of organic carbon is lost as $CO_2$ and inorganic compounds accumulate. We examined how different drainage histories affected the chemical composition and the ash content of four cool temperate bogs in Switzerland and evaluated whether a relative change in ash concentration is a useful proxy for historical drainage-induced C losses. In all profiles, O/C ratios declined to reach a constant value of around 0.45 in 2 m depth. Ash contents did not follow exactly the same pattern indicating that either i) these two parameters are influenced by different processes or that ii) organic matter remaining after oxidative peat consumption is chemically more reduced. Calculated C losses based on the relative increase in ash were highly variable, indicating a limited power of this indicator for estimating drainage-induced C losses. Further studies using $^{13}C$ NMR and XPS spectroscopy showed pronounced changes in the functionality of carbon that is related to the conditions for decomposition. The suitability of these chemical peat parameters for estimating C loss is discussed.

**PS7_5**

## Modelling the effect of land use and climate change on upland soil carbon stock of Wales using ECOSSE

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Within Wales soils hold between 400-500 MtC, over half of this carbon is stored in organic and organo-mineral soil which cover less than 20% of the land area of Wales. It has been predicted that climate change will increasingly have an impact on the C stock of soils in Wales. Higher temperatures will increase the rate of decomposition of organic matter, leading to increased C losses. However increased net primary production (NPP), leading to increased inputs of organic matter, may offset this. Land use plays a major role in determining the level of soil C and the direction of change in status (soil as a source or sink). We present here an assessment of the effect of land use change and climate change on the upland soil carbon stock of Wales in 3 different catchments i.e. Migneint, Plynlimon and Pontbren using a process-based model of soil carbon and nitrogen dynamics, ECOSSE. The uncertainties introduced in the simulations by using only the data available at national scale are determined. The ECOSSE model1,2 has been developed to simulate greenhouse gas emissions from both organic and mineral soils. ECOSSE was derived from RothC3 and SUNDIAL4,5 and predicts the impacts of changes in land use and climate on emissions and soil carbon stock. Simulated changes in soil C are dependent on the type of land use change, the soil type where the land use change is occurring, and the C content of soil under the initial and final land uses. At Migneint and Plynlimon, the major part of the losses occurs due to the conversion of semi-natural land to grassland. Reducing the land use change from semi-natural to grassland is the main measure needed to mitigate losses of soil C. At Pontbren, the model predicts a net gain in soil C with the predicted land use change, so there is no need to mitigate. Simulations of future changes in soil C to 2050 showed very small changes in soil C due to climate compared to changes due to land use change. At the selected catchments, changes in soil C due to the impacts of land use change were predicted to be up to 1000 times greater than the changes predicted due to climate change. This is encouraging, as it illustrates the great potential for C losses due to climate change to be mitigated by changing land use.

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**PS7_6**

## Seasonal dynamics of soil organic matter in a sporadic permafrost-affected soil covered by a dwarf forest (Creux du Van, CH)

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The presence of sporadic permafrost below the timberline may strongly affect plant growth, leading, in some cases, to the formation of peculiar dwarf forests. In those environments soil-forming processes appear to be closely connected with organic matter (OM) accumulation, due to the prevailing cold and wet conditions that constrain or slow down the OM decomposition and to the quality of the organic substrate, which is, in turn, function of plant species and growth forms. Seasonal changes also may strongly affect the decomposition rate of OM and then the production of nutrient forms promptly available for the plants and microorganisms living in those hostile environments. An example of a cold site below the limit of discontinuous alpine permafrost is Creux du Van, located in the Jura Range, in North-western Switzerland. This site is characterised by the presence of patches of peculiarly dwarfed Norway spruce trees. The limited plant growth has been associated for many years with the presence of permafrost and, more recently, to plant physiological stresses and to a limited OM decomposition. In order to better understand the dynamics which govern the availability of nutrients to plants in this environment we have monitored soil temperature and OM changes in the Oa horizon during winter and spring (November 2004 to May 2005). The different carbon and nitrogen forms have been quantified; water extractable organic matter fraction, fulvic and humic acids, and the non- extractable fraction were then characterised by elemental analysis, FT-IR, and $^{13}C$ NMR. The organic material accumulated in the Oa horizon of the soil under study was characterized by the presence of plant remains at a low degree of decomposition, with a large percentage of alkyl moieties and N-containing compounds. From November to February all organic fractions showed significant modifications in the C and N content and in the saccharidic and aromatic component. This may be the result of different phenomena produced by the critical pedo-climatic conditions, such as cryoturbations due to the presence of permafrost, and by a shift in the microbial community associated to the low soil temperatures. In the early spring, when the soil temperature was still below zero (with an air temperature of +15ºC) and the soil frozen, a higher production of soluble C and N forms was observed. These findings suggest an asynchrony between the availability of critical resources and their utilization by plants, with potential losses of nutrients before the roots start their uptake.

# Posters

# Session 8:

# “SOM, Soil Disturbance and Tillage”

**PS8_1**

## The Effect of Organic Annual Forages Grown in Rotation with Winter Vegetables on Soil Quality

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Crop rotation and the addition of manure and/or compost in organic cropping systems are two of the fundamental practices used to maintain and improve soil quality. However, evaluation of different forage species within the context of organic soil fertility management is not well understood in the intermountain west, and merits study. In order to evaluate the usefulness of annual forage crops in an organic vegetable production rotation, Teff (Eragrostis tef) and German millet (Setaria italic) were seeded in the summer of 2008. The grasses were either seeded alone or in combination with either forage soybean (Glycine max) or Sesbania (Sesbania macrocarpa). The viability of these forage crops was evaluated in terms of their yield, crude protein content, and digestibility. In the spring after the harvest of the forage crops (Spring 2009), a crop of lettuce (Lactuca sativa) was planted, and yield and chlorophyll content will be measured. Additionally, soil fertility inputs included either manure or composted manure. The effect of both the forage and fertility treatments on soil quality will be evaluated through measurements of available micro and macro nutrients, distribution of soil aggregate size (>2000 μm, 2000-250 μm, and 250-53 μm), and amount of particulate organic matter (POM). Initial results will be available later in April.

PS8_2

## Long-term dryland cropping systems studies to determine soil carbon sequestration rates in the semiarid northern Great Plains

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Until recently, the potential of agricultural soils to sequester carbon following adoption of best management practices has not received much attention in Montana because of the absence of long-term cropping system research. The objective of this study is to determine the impact of no-till and increased cropping intensities on soil organic carbon levels in semiarid climates via long-term (10+ year) experiments. In 2002, replicated plots (0.016 ha) were initiated at the Montana State University-Post Farm near Bozeman and field-scale trials (8 - 12 ha) were begun at six farm locations in northern Montana. Cropping systems for the replicated plot trial include till fallow-wheat, no-till fallow-wheat, no-till wheat-wheat, and no till legume-wheat, plus a perennial alfalfa-grass system. Soil organic C levels (0-30 cm) after four years were equivalent to 34.9, 35.7, 36.5, 36.1, and 38.0 MT/ha for these respective treatments. Soil organic C (0-30 cm) is being sequestered at a rate of approximately 0. 25 MT/ha/yr in the annual cropped no-till systems compared to fallow-wheat systems (P=0.02). The perennial alfalfa-grass system is sequestering SOC (0-30 cm) at a rate of 0.67 MT/ha/yr compared to fallow-wheat systems. No significant effects have been observed to date from tillage reduction on soil organic carbon in wheat-fallow systems at Bozeman. Field-scale trials in northern Montana include comparison of tilled wheat-fallow, no-till wheat-fallow, tilled wheat-legume, and no-till wheat-legume. Results from the field-scale trials at six farm locations were inconclusive after four years. Previous studies have shown that significant changes in soil organic carbon are often not detected until after six year following adoption of best management practices. We are currently analyzing soil from the 6th year of the study (2008) at both the field-scale and replicated plot trials. Results promise to increase our understanding of soil organic carbon sequestration rates for semiarid dryland cropping systems in Montana. This project has been, or is currently, being supported by CASMGS, NRCS-Conservation Innovation Grants program, DOE Big Sky Regional Carbon Sequestration Partnership, and Montana Wheat and Barley Committee.

**PS8_3**

## Soil organic carbon changes with depth: Effects of tillage and crop rotation

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*USDA-ARS, USA*

Decades of wheat-fallow rotation with intensive tillage have resulted in reduced soil organic carbon (SOC) content in the Pacific Northwest dryland region. Adoption of alternative cropping systems such as intensive cropping, direct seeding or sweep tillage (ST) has been slow because of limited available long-term data on the viability of alternative cropping systems in this semiarid region. The objective of this study was to determine effects of tillage and cropping systems on SOC stocks of a Typic Haploxeroll. A randomized complete block design alternative tillage and crop intensity study commenced at Pendleton in 1998 with the following treatments: 1) continuous winter wheat (Triticum aestivum L.) under direct seeding (no-tillage), CW/DS; 2) winter wheat–winter wheat–sudangrass (Sorghum sudanese L.) rotation under direct seeding, W–W–S/DS; and 3) winter wheat–fallow under sweep tillage, W–F/ST. Using a grid scheme, six geo-referenced soil cores per plot were collected in 2004 and 2008. Cores were sectioned at 0-5, 5-10, 10-20, 20-30, 30-60, 60-100, 100-120, and 120-150 cm. Organic and inorganic C were determined at each soil depth. Wheat yield, and residue yield for wheat and sudangrass were measured. Results from the alternative tillage and crop intensity study were compared with an adjacent long-term conventional (inversion moldboard plow, MP) wheat-fallow rotation and control (permanent chemical fallow, CF) treatment. After 10 years of direct seeding and increased crop intensity, very significant ($P < 0.0001$, $n = 42$) amounts of C were found down to the 150-cm depths. Compared to W–F/MP, SOC increased at the 0-5, 5-10, 10-20, 20-30, 30-60, 60-100, 100-120, and 120-150 cm depths by 16, 5, 1, 6, 25, 33, and 44% under CW/DS, respectively. The SOC in the top 5 cm increased by 14, 16, 32 and 43% for W–F/ST, CW/DS, CF, and W–W–S/DS, respectively, compared to W–F/MP. Increased SOC is expected to reduce losses of soil, water, plant nutrients and agrichemicals.

**PS8_4**

## Tillage, Crop Rotation, and Cultural Practice Effects on Dryland Residue and Soil Organic Matter

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Novel management practices are needed to increase dryland soil organic matter and sustain crop yields in the northern Great Plains, USA. The effects of tillage, crop rotation, and cultural practice were evaluated on crop biomass (stems + leaves), surface residue, and soil bulk density and organic C and total N contents at the 0-20 cm depth in the dryland agroecosystem from 2004 to 2007 in eastern Montana, USA. Treatments were two tillage (no-tillage and conventional tillage), four crop rotations [continuous spring wheat (CW), spring wheat-pea (W-P), spring wheat-barley-pea (W-B-P), and spring wheat-barley-corn-pea (W-B-C-P)], and two cultural practices [regular (R) (conventional seed rates and plant spacing, conventional planting date, broadcast fertilization, and reduced stubble height) and ecological (E) (variable seed rates and plant spacing, delayed planting, banded fertilization, and increased stubble height). Crop biomass was greater in W-B-C-P than in CW in 2004 and 2005 and greater in E than in R in 2004. Biomass N content was greater in W-B-C-P than in CW in 2005 and greater in E than in R in CT. Residue amount and C content were greater in NT than in CT, greater in CW, W-P, and W-B-C-P than in W-B-P, and greater in 2006 and 2007 than in 2004 and 2005. Similarly, residue N content was greater in NT than in CT, greater in CW and W-P than in W-B-P in 2006, and greater in E than in R. Soil bulk density at 0-10 cm was greater in CT with W-B-P and E than in other treatments. Soil organic C and total N at 10-20 cm were greater in CT with W-P than in CT with CW and in NT with W-P. Both soil organic C and total N at 0-20 cm were greater in 2007 than in 2004 and 2005. Increased crop rotation and delayed planting with higher seed rates and banded fertilization increased the amount of crop residue returned to the soil and surface residue C and N. Although no-tillage increased surface residue C and N, conventional tillage increased dryland soil organic C and total N at the subsurface layer in the W-P system in the northern Great Plains. Continued addition of crop biomass residue from 2004 to 2007 increased soil organic C and total N.

**PS8_5**

## Tall Fescue Management Impacts on Soil Carbon Pools and Aggregation

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Maintenance of soil organic matter in pasture ecosystems has long been recognized as a strategy for soil conservation and carbon sequestration. Tall fescue management that can improve soil organic carbon will consequently build stronger soil aggregates. The objectives of this study were to investigate the impacts of endophyte-infected and endophyte-free tall fescue on the distribution of soil carbon pools: total organic carbon, microbial biomass carbon, particulate organic carbon, and carbon storage in aggregates and to compare the ratio of macroaggregates to microaggregates. The experiment was conducted in Maury silt loam Kentucky at depths of 0-7.5 cm, 7.5-15 cm and 15-30 cm. In general, endophyte infection of tall fescue provided more soil organic matter, less labile carbon, a greater proportion of macroaggregates, and increased carbon sequestration. However, the effects were predominantly occurred in the surface layer.

**PS8_6**

### Assessment of Crop Residue Cover using Remote Sensing in the Tiffin Watershed, Michigan

Nancy H.F. French, Richard B. Powell, Benjamin W. Koziol, Traci Dajos, Brian Thelen

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Soil loss by erosion has a negative impact on agricultural soils and the water quality of rivers and lakes. Conservation tillage is promoted as a best management practice for improving soil quality, retaining soil carbon, and reducing erosion. The U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) administers programs to implement conservation practices and monitor compliance. However, the NRCS lacks the resources to provide field-level assessment. Remote sensing techniques provide the ability to monitor conservation tillage practices. The objective of this study was to explore the potential of using remote sensing and advanced remote sensing data analysis methods for crop residue cover estimation in southern Lower Michigan. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) , a NASA satellite sensor systems, provides data with a 15 meter spatial resolution in the visible and near-infrared wavelengths and 30 meter spatial resolution in the shortwave infrared wavelengths which are suitable for field-level residue cover estimation. Field spectroradiometer measurements, point-line transects, and ASTER imagery collected in early April 2008 were used to calculate and compare several crop residue indices such as the Lignin-Cellulose Absorption Index, the Modified Soil Adjusted Crop Residue Index, and the Normalized Difference Tillage Index. In addition, we demonstrate an analysis based on adapting the latest concepts/techniques from the statistical machine learning community to an image classification/estimation problem. The results indicate that, using established remote sensing methods, ASTER imagery is suitable to identify residue within corn grain fields and less suitable for soybean and corn silage residue estimation in the study area. Shortwave infrared bands have the most promise in estimating crop residue when compared to the visible and near-infrared bands. The preliminary results of the machine learning analysis show promise for improving crop residue classifications from remote sensing data sets beyond the initial analyses presented. The new remote sensing data exploitation methods demonstrated have the potential for making remote sensing-based crop residue feasible and applicable as a rapid decision making tool for NRCS programs.

**PS8_7**

## Soil organic matter dynamics in paddy fields: influence of different agronomic practices

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Redox processes in wetland ecosystems play an important role in soil nutrient availability, biogeochemical cycling of elements, and ecological functions of rice ecosystems [1]. The adoption of large-scale intensive cropping and the need to offset the consequential decrease in soil organic matter (SOM) have promoted cropping systems and management practices that ensure greater amounts of crop residues returned to the soil [2]. However, the supply and decomposition of organic materials in rice fields, and the consequent nutrient bioavailability are markedly versatile and closely related to field management [3]. To enable an in-depth understanding of how different agronomic practices influence soil processes in paddy fields, soil samples were collected in October 2008 at two soil depths (0-25 and 25-50 cm) from six hydrologically isolated plots within a research platform in Vercelli (N Italy) under continuous rice cultivation since 2001. The major differences between each plot were related to organic matter input, fertilisation and flood-water management. The reference plot was based on a single annual crop of irrigated rice planted in spring under flooded conditions, with tillage and crop residue incorporation after harvest in autumn. This was compared to another 5 treatments: (i) tillage in spring instead of autumn; (ii) burning of straw and stubbles after harvest and tillage in spring; (iii) application of livestock-derived organic wastes; (iv) planting in dry soil conditions and delayed flooding (about 1 month); and (v) a three-year rice-rice-maize crop rotation. Crop yield data collected over a 4 yr period showed higher mean annual yields for the three-year rotation plots with respect to the other treatments. Moreover, soils under this agronomic practice also showed significantly higher organic C and N contents with respect to the reference plot, although this enhancement was restricted to the plow layer. In such systems, SOM distribution between different pools may be a crucial issue for better understanding the effect of soil management practices on SOM dynamics. For this reason, the distribution of organic matter between stable and more labile pools was evaluated by the chemical and physical (densimetric) fractionation of SOM.

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**PS8_8**

## Soil Carbon Sequestration and Soil Quality Improvement Potential of Created Prairie Landscapes in the Ohio Valley

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Created tallgrass prairie landscapes have a great potential for rebuilding degraded agricultural soils and sequestering C in soil organic matter (SOM) in North America. Thus a field study was conducted in a created tallgrass prairie landscape with the primary objectives of: 1) assessing the soil organic C (SOC) pool in created prairie landscapes and to compare it with the SOC pools in conventional agricultural systems on the same soil, and 2) quantifying the impact of the SOC pool on soil quality parameters under created tallgrass prairie and compare with soils under conventional agricultural land uses. The primary study site being analyzed is the Prairie Nature Center (PNC) at the Marion Campus of the Ohio State University. The PNC is an 11 acre site that began the creation/restoration of tallgrass prairie plantings in 1977. Soil samples were taken from created prairies of 31, 13, and 8 years age, as well as from lawn and an annually cultivated corn (Zea mays) – soybean (Glycine max) field on similar soils. Soil samples were taken from 0-10, 10-20, 20-30, and 30-40cm depths, from 4 sites in each treatment during the summer of 2008. Total C, total N, and C:N ratio of soils were analyzed by combustion on all samples. Assessment of the soils physical quality was done through analysis of water stable aggregates (WSA), mean weight diameter (MWD) of aggregates, total porosity, available water capacity (AWC) and moisture characteristics, soil pH, and a sized based fractionation of coarse particulate organic matter (C-POM) in the 2mm-53micron size class. Results demonstrate the impacts of this land use change on SOC and soil quality.

**PS8_9**

## Soil Organic Carbon Dynamics in the Conversion from Tallgrass Prairie to Agriculture in north central Kansas

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Land use change and soil management directly affect the level and dynamics of soil organic carbon (SOC). This study is designed to understand and quantify the effects of soil and vegetation management on SOC pools, in sites converted from tallgrass prairie to annual agriculture. The long term and short term effects of the conversion of prairie to agriculture are being investigated in the two components of this research. The long term effects of land use change on SOC pools are being analyzed by sampling five farms that contain both virgin annually harvested tallgrass prairie remnants and conventional agricultural fields on the same soil types. This study also assessed the initial effects of soil and vegetation management on SOC pools on an experimental site converted directly, through herbicide application, from annually harvested tallgrass prairie meadow to no-till (NT) annual agriculture. All treatments were laid out in a replicated complete block design (n = 3), established in 2004. Management effects on SOC pools were assessed by determining changes in total SOC, particulate organic matter (POM) and microbial biomass C (MBC) to a depth of 1m. The POM and MBC were used as indices of change in labile pools of SOC. The POM is strongly influenced by land use and soil management, and the POM fraction is a good indicator of subtle changes in SOM over relatively short periods of time. POM was sampled using a sized base fractionation of SOM in the particle sizes 250-53 micrometers. Additionally, SOC associated with the coarse sand, silt and clay size fractions were separated and analyzed. The MBC was sampled using a chloroform fumigation extraction technique. The C:N ratio of the POM, by combustion analysis, was used to establish a relationship between this SOM fraction and N concentration. Total SOC concentration to 1m was assessed by the dry combustion analysis. Samples were taken as cores to 0-10, 10-20, 20-40, 40-60, 60-80 and 80-100cm depths in May and June of 2008. Results will be presented at the SOM meeting in July 2009.

**PS8_10**

## Modelling agricultural practices with the land surface model, JULES

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The agriculture sector emits a significant amount of greenhouse gases (10-12% of all anthropogenic emissions in 2005 (IPCC fourth assessment report)), primarily methane ($CH_4$) and nitrous oxide ($N_2O$). However, it also offers significant potential to mitigate climate change; the IPCC states that by 2030 it should be economically feasible to mitigate of the order of 1.5 - 4.3 $GtCO_2$-eq (compare with total annual emissions of 7.2 $GtCO_2$-eq/yr from 2000 to 2005). This can be achieved by reducing GHG emissions directly, offsetting emissions from fossil fuel burning by using alternative fuel sources, and by enhancing drawdown of $CO_2$ from the atmosphere into agricultural soils. Agricultural practices can be adapted to achieve the latter, such as zero- or reduced-tillage, increased productivity through the use of high-yield cultivars or irrigation, restoration of degraded land, and nutrient management, amongst others. The Met Office Hadley Centre has a long tradition of modelling natural ecosystems, but intends to include some of these land management processes in future models for two reasons:

- to improve the way that managed lands, which make up 40% of the land surface, are modelled in its climate change simulations

- to investigate the potential for these processes to help to mitigate climate change

As a first step towards achieving these goals, we have incorporated some of the above processes into a version of the land surface simulator, JULES (Joint UK Land Environment Simulator), through collaboration with scientists at the School of Biological Sciences at the University of Aberdeen. We will present preliminary results from simulations of C3 and C4-based crops at Bondville, Illinois, USA. We compare methods for modelling tillage, their long term effects on soil carbon, how this compares with no-till, and other such questions.

**PS8_11**

## Tillage effects on soil organic matter fractions after conversion of long-term pasture to annual cropping

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Soil organic matter (SOM) can decline rapidly when pasture soils are cultivated to grow crops. Management practices that conserve SOM may be crucial to sustaining long-term arable cropping. The aim of this study was to identify tillage and winter cover crop management practices that maintain SOM and crop productivity following soil improvement under pasture. The Millennium Tillage Trial was initiated in 2000 on a Wakanui silt loam (Udic Dystocrept) in Canterbury, New Zealand. The site had been under ryegrass/clover pasture for >10 years and had a relatively high SOM content. The trial is split plot design with tillage (Intensive tillage [IT], minimum tillage [MT] and no-tillage [NT]) as main-plot treatments and cover crop (+/- winter forage crops) as sub-plot treatments (n=3). Spring-sown crops (barley, wheat, or pea) were followed by winter grazed (sheep) cover crops (forage brassica). Continuous grazed pasture and chemical fallow (not cultivated, plant free) sub-plots were maintained as controls. Soil samples were collected annually (0-7.5, 7.5-15, 15-25, and 25-30 cm) and total C and N stocks were estimated using the equivalent mass method. Measured SOM fractions included microbial biomass C (chloroform fumigation-extraction, MBC) and particulate organic matter C (>50 µm fraction, POM-C).The total mass of C (top 3500 Mg/ha soil) under pasture was 84 Mg/ha and changed very little during the trial. Soil C initially declined more rapidly under IT than under MT or NT, but after 7 years of continuous cropping, C loss was similar for all tillage treatments (~13 t C/ha). Interestingly, the loss of C from the uncultivated chemical fallow was larger (~17 Mg/ha) than the loss under cultivated cropping, confirming that inputs of plant matter are essential to maintain SOM. There was no detectable effect of the cover crops on soil C, presumably because yields were relatively low. POM-C losses accounted for a large part (~40%) of the total C loss under continuous cropping. MBC remained a constant percentage of total soil C (~1.7%) in the cropping treatments but was much higher under pasture (~2.4%) and lower under chemical fallow (~1.3%).

**PS8_12**

## Soil Carbon Sequestration in Labile Organic and Stable Mineral Fractions of Natural Forests and Cultivated Lands in Sri Lanka

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Soil C sequestration is an important process for mitigating global warming depends on the complex interactions among climate, soil, tree species and management. In agro ecosystems, C sequestration potential may be enhanced by the adoption of reduced tillage, type of residue management and altering the cropping sequences. This study was conducted in natural forests and adjacent cultivated lands in Sri Lanka to study the effect of land use changes and agricultural management practices on the soil C sequestration under tropical conditions. The natural forests included tropical wet evergreen (2 forests), semi evergreen, moist monsoon, dry monsoon, montane and dry mixed evergreen forests. Cultivated lands included plantations of tea, rubber, coconut and export agricultural crops (i.e. pepper, cardamom and cacao), potato, home garden and a chena cultivation. Organic C content in clay and soil litter fractions of 0-20 cm soil depth were determined. The result showed that forests of different vegetation structures did not show much variation in C content in soil litter, as there were no soil disturbances involved to result differences in decomposition rates. However, the soil management practices among the cultivated lands are highly variable and have induced significant variations in C content in soil litter fraction possibly by changing the litter decomposition processes. The highest C content in soil litter fraction was observed in export agricultural crops plantation and the lowest was observed in chena cultivation. The highest C contents in clay fraction were observed in Semi evergreen forest and tea plantation. Increase in C input to the soils through manuring and use of fertilizers could be beneficial in enhancing soil C sequestration in tea soils. As the soil depth is very low in tea soil, (Ap1 0- 5 cm, Ap2 5-20 cm, B1 20- 50 cm) there was a high clay content (23.57 g 100 $g^{-1}$) in 0-20 cm depth. This could have helped binding of humus to clay particles, which protects them from further decomposition (McCauley et al. 2003). This could be another reason for the observed high C content in the clay fraction of the tea soil. The minimum soil tillage in tree crop plantations reduces the rate of decomposition and thereby increases the C sequestration as shown by the perennial tree plantation planted with the export agricultural crops.The significant differences in the soil C content of the two fractions between the forests and the adjacent cultivated lands in the same location showed that Crop species play important role in soil C sequestration because their residues vary in litter quantity and quality affecting their turnover rates in the soil. It is interesting to note that Sri Lanka represents almost all main tropical forest types and croplands suggesting that it is a suitable place for studying C sequestration in tropical climatic conditions.

**PS8_13**

## Humic substances in soils from different geomorphologic features in the Edge of Rio Grande do Sul Plateu.

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Agricultural land use in scarped areas of Rio Grande do Sul State (RS) is dominated by family farms based on low-input of technology and non-conservative soil management practices. Such areas are very susceptible to land degradation due to steep slopes and shallow soils combined to improper land use system. In these environments, the understanding of soil organic matter (SOM) dynamics assumes a very important role in order to restore and improve soil quality. Nevertheless, few are the studies focusing on SOM, especially about the relations between humic fractions and local relief, what possibly would render remarkable information about SOM reactivity. The aim of this study was to evaluate the influence of land use on the distribution of humic fractions of SOM and soil chemical attributes as a function of soil depth and landscape positions, in three transects of the Edge of Rio Grande do Sul Plateu region. Soil samples were collected from three layers (0 to 10 cm, 10 to 20 cm and 20 to 30 cm) in Entisols and Inceptisols in three environments: native forest, grass-bushy vegetation and cropped area in three different landscape position (summit, backslope and footslope). Humic substances (humic acids, HA, fulvic acids, FA, and humin, HU) were fractionated and their proportions were estimated from the carbon content in the acid extract (CHCl), in the alkaline extract (CHSs) and in the FA extract (CFA). The HA (CHA) and HU (CHU) proportions were estimated by difference. To assess the significance of the depth effects, land use and relief on the humic fractions contents, analysis of variance and multivariate analysis (PCA) were performed. The distribution of the humic fractions differed among the studied land uses, and the cultivated area showed the lowest values for all fractions in comparison to the native forest. The CHSs corresponded to the largest proportion of the humified SOM for the studied soils. The proportion of HA surpassed that of FA in almost all depths and positions in the landscape considered.

**PS8_14**

### The effect of long-term Mediterranean conventional and no-tillage corn-based cropping system

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Soil organic matter (SOM) plays a key role in sustaining crop production and prevents land degradation. SOM mineralization has contributed to $CO_2$ emissions from soils to the atmosphere and to the global climate change. A reduction in the intensity of tillage has been widely recognized as a successful strategy to reduce SOM losses. Enhancing SOM through soil management can be achieved by reducing SOM decomposition and/or increasing residue inputs. We hypothesize that in Mediterranean region a shift from the conventional tillage (CT) to notillage (NT) could maintain SOM and reduce mineralization. Our aim was to- (i) evaluate the effect of tillage on soil $CO_2$ emissions, (ii) assess the influence of rainfall, soil temperature and soil moisture on soil $CO_2$ efflux, and (iii) measure soil organic carbon (SOC) under CT and NT. The study was carried out at the "Enrico Avanzi" Interdepartmental Centre for Agro-Environmental Research of the University of Pisa, located in Central Italy between June and October 2002 in a long-term rainfed corn-based (Zea mays L.) system established in 1993 in a poorly drained siltloam soil (Typic Xerofluvents). An automated closed dynamic multiple-chamber system was used for measuring continuously hourly soil $CO_2$ efflux rates (_6 μmol $CO_2$ $m^{-2}$ $s^{-1}$) in the field. Considering the summer of 2002, NT emitted a 32% higher soil CO2 than CT. The lower $CO_2$ flux monitored under CT than NT could be due to the lower soil microbial activity observed under CT. In October CT emitted a 39% higher than NT, probably due to the higher temperature recorded in the first 10 cm under CT respect to NT. In terms of carbon stock, CT led to a negative soil C balance, indicating a loss of soil C. At soil surface (0-10 cm), the highest total SOC concentration was found under NT than CT (2.08% vs. 1.65%). However, below 10 cm soil depth the lowest total SOC content was found under NT. Looking at the entire soil tillage layer (0-30 cm), greater total SOM stock content was found under NT (75.24 Mg C per hectare) than CT (72.37 Mg C per hectare). We conclude that in rainfed corn-based cropping systems, alternative agricultural management practices (NT) increases soil organic carbon pool and contributes to mitigate greenhouse gases emissions.

**PS8_15**

## Water stable aggregates under different tillage practices and their relationship with SOM

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Tillage practices disrupt the soil surface, breaking down the macroaggregates and increasing the soil organic matter (SOM) mineralization. Thus, macroaggregate stability may be improved under conservative practices because soil is left undisturbed and the crop straw is left on the surface, leading to a higher SOM content. A positive correlation between SOM and the aggregate stability was found by several authors. The objective of this study was to determine the macroaggregate stability under different tillage practices and to relate them to SOM content. The experimental design was a split-plot where the main treatment was tillage: conventional (CT), minimum (MT) and no tillage (NT), and the subplot were the crop rotation: wheat-wheat (W-W) and fallow-wheat (F-W). Soil was classified as a Calciortidic Haplorexalf. Soil samples were collected in November 2006 and October 2007, from the surface: 0-7.5 and 7.5-15 cm depth. Soil was collected undisturbed, gently broke down and left to air dry. First soil was pre-sieved to 8 mm and then the macroaggregates between 2 to 1 mm were collected. The water stable aggregates (WSA) were determined and the soil organic carbon (SOC) from the samples was analyzed. Statistical analyses were performed using the PROC MIXED from the SAS software where Tillage and Rotation were fixed effects; Block was considered as random effect and Date as a repeated measurement. Results showed that date of sampling and the soil water content had a great influence on the aggregate stability. In November 2006 lower WSA was obtained compared to October 2007 probably due to the higher water content during the soil sampling. WSA was higher for the surface 0-7.5 cm compared to the 7.5-15 cm. Regarding to tillage practices, under NT a higher WSA was obtained compared to MT and to CT. For the surface (0-7.5 cm) no tillage had a medium value of 28.9% and 62.6%; for MT, 23.9 % and 51.3%; and for CT, 23.2% and 38.4% in November 2006 and October 2007 respectively. From this data can be noticed that the differences were more pronounced in October 2007 than in November 2006. No differences were obtained between W-W and F-W. The correlation between WSA and SOM was weaker than expected. Only for the surface (0-7.5 cm) a slight correlation between both parameters WSA and SOM was found.

**PS8_16**

### Soil Organic Matter in Different Land Use Systems inFamily Farms of Southern Brazil

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Land use systems play an important role on soil organic matter (SOM) quality and dynamics, with a direct impact in the global carbon cycle and thus influencing climate change. Family farms of central region of Rio Grande do Sul State, Brazil, are based on intense agricultural practices, such as burning and tilling. The aim of this study was to investigate the SOM in differing land use systems in family farms located in complex topography areas of Southern Brazil and to identify the relation between land use and soil organic C and N stocks. Two areas located in central region of Rio Grande do Sul State, showing an rolling to mountainous relief were selected for this study. In Area 1 (Silveira Martins) four land use systems (native forest, > 5-yr Eucalyptus sp., 4-yr no-tilling and > 20-yr tilling) were evaluated, while in Area 2 (São João do Polêsine) five land use systems were studied (native forest, 20-yr secondary forest, > 5-yr abandoned field, 1-yr sugar-cane and > 5-yr sugar-cane). Disturbed and undisturbed soil samples were taken from 0-10 cm in each land use system. Laboratory analysis included bulk density, organic C and N content, and infrared spectroscopy (FTIR) and 13C NMR spectroscopy of soil and HF treated SOM. Soil organic C and N stocks were also estimated. Soil bulk density showed a clear tendency to rise as intensity of land use increased. In accordance with the behavior shown for bulk density, soils under cultivation and forest, in both study sites, showed a divergent behavior of soil C and N content. The stocks of C and N where higher in forest environments (31.0 and 3.31 Mg $ha^{-1}$, respectively), excluding Eucalyptus, than in cultivated soils (18.8 and 1.40 Mg $ha^{-1}$, respectively). Spectroscopic analysis were essential to establish qualitative differences between land use systems, regarding the proportions of easy degradable compounds and more recaclcitrant structures.

**PS8_17**

## Soil Use Effect on Organic and Inorganic Carbon Sequestration in the Argentine Pampas

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The evaluation of the carbon content of the soils and the changes produced by different land uses is important because of the possibility for sequestering carbon in soils and mitigate climate change. Our objective was to establish the impact of soil use on organic and inorganic carbon stocks in soils of the Argentinean Pampas. At eighty-two locations widespread along the Pampas, presenting a very wide range of soil and climatic conditions, five soil type uses were selected in each location: planted forest, undisturbed or very low disturbed grassland sites never cultivated on well drained soil, cropped field, seeded pasture on sites subjected to rotation with agriculture, and flooding site under natural grassland. Soils were sample to 1 m depth in layers of 25 cm with a special device that allowed sample extraction and soil bulk density determination. Soil samples were air-dried, ground through a 2 mm mesh and total carbon concentration determined by wet digestion. Carbonate was determined by acid hydrolysis and organic carbon estimated by difference. Soil carbon content data were analyzed by ANVA and LSD. An average content of 97 t $ha^{-1}$ for organic carbon and 48 t $ha^{-1}$ for inorganic carbon were estimated. Significant differences were detected between different soil uses only in organic carbon (Table 1).

Table 1. Carbon contents of pampean soils to 1 m depth as means of 82 locations in relation to soil use. Different letters in a column represent significant differences between soil uses.

| Soil use | Organic C (t $ha^{-1}$) | Inorganic C |
|---|---|---|
| Planted forest | 134 a | 42 a |
| Undisturbed | 104 b | 47 a |
| Seeded pasture | 90 c | 48 a |
| Cropped field | 87 c | 52 a |
| Flooding site | 70 d | 50 a |

Organic carbon in soils under planted forest was ca. 30 % greater than under undisturbed control sites indicating intense carbon sequestration in soils under forest. Soils subjected to agriculture lost ca. 15 % of their organic carbon content comparing with control sites, which may be attributed to erosion and negative carbon balances. Flooding sites had lower organic carbon content than controls possible due to lower net primary productivity under flooding conditions. The ratio cultivated surface/planted forest surface is ca. 100 for the whole region. Consequently, a net flux of 400 Mt carbon from soils to the atmosphere was estimated due to agriculture. This preliminary estimation doubles previous figures based on surface soil samplings.

**PS8_18**

## Managing Forest Slash to Increase Soil Carbon and Nutrient Stocks in a Loblolly Pine Stand in South Carolina

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Soil organic matter is linked to site productivity and increasing soil carbon is important for sustainable forest resource management. Post-harvest logging debris and previous stand forest floor represent large pools of carbon and nutrients. Incorporating logging residues into the underlying mineral soil could potentially increase soil carbon and nutrient cycling and availability. The degree organic residues influence microbial activity, soil carbon and nutrient mineralization is still largely unknown, but is likely to depend on inherent soil productivity, the amount and composition of incorporated organic matter and nutrient demand of the regenerating stand. In addition, nutrient and carbon dynamics are altered with nitrogen fertilization, a common silviculture treatment in intensive pine management. A study was initiated in 2005 on the upper coastal plain of South Carolina to examine the potential to increase above- and below-ground carbon and nutrient stocks of loblolly pine ecosystems through the incorporation of forest slash into the soil during stand establishment. This site was selected because the soil type supports large areas of intensively managed pine, the soils typically show nutrient limitations during early stand development presumably from nitrogen immobilization, and there is a high and fluctuating water table that allows for examining how water table influences carbon and nitrogen loss or retention. The treatments included differing amounts (none, 25 Mg $ha^{-1}$ and 50 Mg $ha^{-1}$) and qualities (C/N = 112 and 857) of material incorporated into the soil. By sequentially separating soil organic matter into fractions of increasing density, a profile of stabilized carbon and nitrogen emerges. Soil organic matter fractions with lower densities are more labile and transient than higher density fractions. Plots with incorporated forest slash are compared to plots with no slash incorporation to detect any shifts in the total carbon and nitrogen in the different density fractions. Shifts in carbon and nitrogen to higher density soil organic matter fractions indicate a relative stabilization effect whereas; shifts to lower density fractions indicate a destabilization effect.

**PS8_19**

## Management of soil organic C with land application of biosolids

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Management of soil organic C (SOC) is of paramount importance for maintaining soil productivity and mitigating global $CO_2$ elevation. We monitored SOC dynamics from 1972 to 2006 in watersheds of Fulton County (western Illinois), which received various rates of biosolids. The fields in the monitored watersheds included typical midwest corn belt Mollisols and Alfisols, and Entisols derived from strip-mining overburden. The initial surface SOC ranged from 0.2% to 2.3%. Over the three decades, the surface SOC in unmined soil under typical agricultural practices remained unchanged at a level of about 2%. The surface SOC in strip-mined land increased along with cropping, but leveled off at 1.5 - 2% under pasture and 1 – 1.5% under grain crops for the past two decades. This data implies that SOC in midwest corn belt soils might have been stagnant at a level between 1 and 2% under cultivation with the common management. However, with biosolids application, the surface SOC increased to 5 to 6% in one decade. Carbon-$^{13}$ analysis indicated that such increase was not only due to the residual biosolids C, but also to the increased transfer of crop residue-C to soil organic matter (SOM). We found that in unmined soil the humification coefficient of C added from crop residues was tripled by liquid biosolids and doubled by air-dried biosolids that were applied at a level equivalent to the recommended rate in many states (22.4 Mg $ha^{-1}$ $yr^{-1}$). The transfer of crop residue-C to SOM was 2.74 Mg $ha^{-1}$ $yr^{-1}$ in liquid biosolids fields, 1.52 Mg $ha^{-1}$ $yr^{-1}$ in air-dried biosolids fields, and 0.70 Mg $ha^{-1}$ $yr^{-1}$ in unamended fields. The fraction of Fe in SOM was higher in biosolids-amended soil than in the control. It appears that the amorphous Fe in biosolids acts as an additional SOM stabilization agent, thus soil C saturation transcends the limit that may have prevented the further rise of SOC in unamended soil. Such a process brings the SOC equilibrium to a higher level.

**PS8_20**

## Initial Differentiation of Vertical Soil Organic Matter Distribution and Composition After Soil Homogenisation

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An outdoor lysimeter experiment with juvenile beech trees (Fagus sylvatica L.) was used to study the development of depth gradients of soil organic matter (SOM) composition and distribution after soil homogenisation (simulated tillage). The sampling scheme applied to the given soil layers (0-2 cm, 2-5 cm, 5-10 cm and 10-20 cm) was crucial to study the subtle reformation of SOM properties with depth in the artificially filled lysimeters (1 $m^2$, 2 m depth). Due to the combination of physical SOM fractionation with the application of $^{15}N$-labelled beech litter and $^{13}C$-CPMAS NMR spectroscopy we were able to obtain a detailed view on vertical differentiation of SOM properties. Four years after soil disturbance a significant decrease of the mass of light particulate OM (POM) with depth could be found. A clear depth distribution was also shown for carbon (C) and nitrogen (N) within the SOM fractions related to bulk soil. A drastic increase in aliphatic C structures concomitant to decreasing O/N-alkyl C was detected with depth, increasing from free POM to occluded POM. Only a slight depth gradient was observed for $^{13}C$ but a clear vertical incorporation of $^{15}N$ from the applied labelled beech litter was demonstrated probably resulting from faunal and fungal incorporation. We clearly demonstrated a significant reformation of a SOM depth profile within a very short time of soil evolution. One important finding of this study is that especially in soils with reforming SOM depth gradients after land-use changes selective sampling of whole soil horizons can bias predictions of C and N dynamics as it overlooks a potential development of gradients of SOM properties on smaller scales.

**PS8_21**

**Effects of oil and gas infrastructure on carbon dynamics in La Manga Canyon, NM**

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The construction and development of energy infrastructure has caused major disturbances in rangelands of the Inter-Mountain West. Exploration for and extraction of oil and gas has led to an increase in the area of roads, well-pads, and pipelines, causing a reduction in the extent of grasslands, shrublands, and woodlands, as well as changes in ecosystem function. This infrastructure development greatly affects the local and landscape scale structure and function of arid rangelands through changes in hydrology, vegetation dynamics, and soils. We designed a study to quantify soil carbon dynamics in a landscape affected by development of oil and gas infrastructure. To determine energy infrastructure impacts, we measured the changes in extent of roads, well-pads, and pipelines in LaManga Canyon, a small watershed (~20km$^2$) in the San Juan Basin, New Mexico representative of the Colorado Desert Plateau. Soil samples were collected to estimate the soil organic carbon of roads, well-pads, compared to surrounding intact soil/vegetation communities (Ecological Sites). Plots were established in representative ecological sites for baseline and contrast. Remote sensing of historic aerial photography (1935, 1955, 1981, and 2006) was utilized to show the historic extent of energy development. Results of the soil organic carbon values and remote sensing will be presented.

**PS8_22**

## Effects of disturbance on the soil $CO_2$ efflux in boreal forests

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Most of the forests in Europe are intensively managed aiming at providing raw material to the forest industry. The aim of the management is mostly to produce good material for the saw mill and pulp industry meaning that the focus is on the stem-wood of the trees. Other possible ecosystem services such as carbon sequestration are often considered secondary and not a topic for the management. In Sweden, the most common forest harvest method is clear-cutting followed by different types of soil treatment like harrowing in order to secure a good re-growth of the forest. During the rotation period thinning is mostly performed two to three times. These are the most typical soil disturbance factors caused by management in Swedish forestry. Another important natural disturbance is wind-throw which happens with irregular intervals. The expected effect of such disturbances is an increased decomposition of the organic material in the soil. Here we demonstrate the effect on the efflux of $CO_2$ from soils exposed to clear-cutting, wind-throw and thinning, respectively using soil chamber and eddy covariance flux measurements in Sweden. The clear-cut areas are loosing large amounts of carbon during the first year after harvest and it takes c. 15% of the rotation time before the systems are in balance again and then start to gain carbon again. The wind-thrown areas are loosing even more carbon than the clear-cuts, in the order of a factor 2 or 3. Data from the thinning experiment is not available yet since the thinning was performed in January 2009. These data will be analysed and presented at the workshop as well.

**PS8_23**

## Carbon Fractions and its Accumulation in Mexican Cultivated Tepetates

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Tepetates (hardened volcanic tuffs) occupy large extensions in the Central Mexican Highlands and Central America, and some of them have been modified for agriculture. In their native condition tepetates contain traces of C, N, and available P. The objective of this work was to study how different agricultural practices affect the labile organic C availability in cultivated Mexican tepetates. Experimental plots, cultivated since 1986, were subjected to three agronomic managements during 2002-2005: Traditional (Tt), Improved Traditional (Ti), and Organic (To). In 2002 two new plots were subjected to the Traditional (Rt) and Organic (Ro) systems. Two non-cultivated tepetates were chosen as reference (Tv and Td). In 2005 soil samples were collected at 0-10-cm depth and soil organic C (SOC), total N (Nt), microbial biomass C (MBC), mineralized C (Cm), and potentially mineralizable C (C0) were determined. The non-cultivated tepetates, with scarce SOC and Nt contents, had very low microbial activity. In 4 years the values of these soil parameters increased significantly in the recently cultivated tepetates (Rt and Ro) in relation to the non-cultivated tepetates (Tv and Td), indicating that tepetates incorporated to the agriculture improve quickly their biochemical properties. Values of MBC, Cm, and C0 increased with the years of cultivation and they were significantly higher in Ti and To managements, suggesting a higher SOC availability for microbiology with these managements, due to the higher supply of organic substrates added as crop residues (Ti) and organic manures (To). Besides this increase of the labile SOC with the years of cultivation, a significant increment of the recalcitrant fractions of SOC also took place in the three treatments (between 72-84 %) after 19 years. Therefore, results demonstrated that an appropriate cultivation of tepetates produces significant increases of SOC and Nt contents, leading to an improvement of their biochemical properties. Then, cultivated tepetates becomes an important sink of atmospheric carbon.

**PS8_24**

## Different limiting factors for carbon mineral complexation in soils across a land use gradient: forest vs. tilled agricultural sites

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The interaction of organic substances with mineral surfaces is recognized as one of the mechanisms which protect organic matter in soil against decomposition. It therefore follows that vigor of mixing between C-free minerals with fresh organic carbon and their abundances in soils might have effects on carbon stabilization integrated over an entire profile or landscape. Agricultural conversion of forests is often accompanied by reduction in SOC content. Additionally, agricultural plowing dramatically change vertical soil mixing which is largely driven by bioturbation (e.g.animal burrowing, plant rooting, and tree-throw process) and free-thaw cycles in untilled forests. We hypothesized that carbon mineral complexation, while limited by mixing-driven mineral supply in forest soils, is constrained by limited availability of organic carbon in tilled agricultural soils. To test this hypothesis, we targeted a mixed-land use watershed in the Piedmont region of southeast Pennsylvania where agricultural soils, compared to the neighboring forest soils, had low SOC contents and experienced plowing and accelerated soil erosion. It has been recently suggested that the fluvial deposits within the watershed is the legacy from accelerated erosion and mill dams during the colonization. Soil samples were collected in a second-growth forest (~100 years old) and an adjacent agricultural field at upland landscape, and a floodplain within the watershed. We quantified and compared vertical mixing rates using short-lived radioisotopes ($^{210}$Pb & $^{137}$Cs) and quantitatively coupled soil mixing process with OC-mineral complexation. The results showed: plowing induced soil mixing in agricultural soil is much stronger than bioturbation generated by trees and earthworms. Although OC concentration is lowest compared to those other two soils, the vertical carbon flux created by mixing is greatest in the agricultural soil. OC can turnover by mixing in 1-2 years in the agricultural soil but requires several years to decades in the floodplain and forest systems. In natural forest and floodplain system, OC-mineral complexation is limited by available reactive mineral surface supply, while association between OC and minerals is limited by OC supply in agricultural soil.

**PS8_25**

## Soil Carbon and Nitrogen Changes on Semiarid Conservation Reserve Program Lands

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Cropping practices in the Great Plains have led to large losses in soil organic carbon (C). Land taken out of crop production and seeded with perennial grasses through the Conservation Reserve Program (CRP) has the potential to recover these losses and remove $CO_2$ from the atmosphere. We studied twenty years of soil organic C (SOC) and nitrogen (N) recovery in CRP fields in the shortgrass steppe, which is the driest portion of the Great Plains. To address current CRP seeding practices, we examined fields seeded with both native and introduced perennial grasses. Belowground net primary production (BNPP) inputs, respiration outputs, and soil physical characteristics determined SOC storage and were influenced by time since CRP enrollment and seed mix. No soil C storage occurred early in the CRP chronosequence (< 7 years), when BNPP was low and potential respiration losses were high. Perennial grasses in CRP fields had higher BNPP, which reached 70-85% under native and 50% under introduced perennial grasses within 18 years relative to undisturbed shortgrass steppe. SOC under native perennial grasses increased by as much as 22 g C $m^{-2}$ $y^{-1}$ after 18 years, and may have included the formation of recalcitrant SOC. However, low plant basal cover in CRP fields relative to undisturbed shortgrass steppe limited SOC recovery at the field scale to 2 g C $m^{-2}$ $y^{-1}$ across the chronosequence. After 18 years of recovery, CRP fields seeded with native perennial grasses had 60% of the total SOC in undisturbed shortgrass steppe, and CRP fields seeded with introduced perennial grasses recovered less. There was less BNPP and SOC plant scale heterogeneity in fields seeded with introduced compared to native perennial grasses. N was closely linked to C in BNPP and SOC and its availability increased along the chronosequence. When we fertilized CRP fields with inorganic N, there were large effects on C fluxes, especially in early CRP fields.

**PS8_26**

# Fractions of organic matter in long-term experiments and its relationship with agronomic management

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Humic substances (HS) play an important role in soils and plant nutrition. Carbon (C) content is a good indicator of the potential humic-chemistry of a soil, but the way C is distributed in the soil physical and chemical fractions is important. The effect of agronomic managements (tillage system, residues retention and crop type) on humic fractions distribution was studied in this paper. Soil samples (Cumulic Phaeozem, pHw 6) were collected from a long-term experiment (14 years after being established), conducted at a CIMMYT site in the semi-arid subtropical highlands of Central Mexico. Humic acid (HA), fulvic acid (FA) and humins (HN) fractions in the soil (0-5cm) were determined. Samples were taken from eight treatments, a combination of: zero (ZT) and conventional (CT) tillage; maize and wheat monoculture; and with (+) and without (-) residues retention. Soil humic fractions were extracted by conventional procedures (0.1N NaOH + $Na_4P_2O_7$.10 $H_2O$ pH 10, acidification, pH< 2 ). Carbon content was determined with a TOC analyzer. In general, the largest amount of soil C was found in the HN fraction. In the wheat monoculture soil, C in HN found in the ZT+r and ZT-r treatments nearly doubled (60 %) the C in HA (31 %). The C distribution in HN and HA (51 and 40 % of C) was similar in CT+r and CT-r treatments, though slightly lower in ZT. The removal of residues in both types of tillage (ZT-r and CT-r) for this crop caused no difference in the distribution of C in AH and HN. The maize-cultivated soil showed a different performance. In the treatments using residues (ZT+r and CT+r), regardless of the type of tillage, the HN fraction stored more C (68 and 54 %) than HA (24 and 37 % ). But when the residues were removed from ZT-r the HA fraction accumulated more C (6% more C than in HN) and in CT-r the accumulation was similar (43 and 46 % in HA and HN). The amount of C present in the FA fraction was very low in all treatments (1 to 2 % of soil C). The reported mean residence-times for HN and HA are 1140 and 1235 yr, respectively, therefore these treatments are effective for C sequestration, regardless of the tillage system. However, the low contents of carbon in the HN fraction were associated with low yields and physical and chemical characteristics that hardly favor the soil.

**PS8_27**

## Effect of Silicate Fertilization having Electron Acceptors in Tillage and No-Tillage Systems on Mitigating Methane Emission during Rice Cultivation

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Slag type silicate fertilizer (hereafter, silicate fertilizer), being potential source of active and free iron oxides as electron acceptors (Ali et al., 2008a, b), was applied with 4 Mg $ha^{-1}$ in conventional tillage and no tillage rice fields to investigate their effects on suppressing methane emission as well as sustaining rice productivity for two years (2007-2008). The soil Eh decreased rapidly after flooding, while methane emissions significantly increased with the development of rice growth stages. However, silicate amendment significantly decreased $CH_4$ emissions from the tillage and no tillage paddy soils, which could be due to the increased concentrations of active iron and free iron oxides in silicate fertilizer amended soil, being acted as electron acceptors. Total seasonal $CH_4$ emission was decreased by 20 % and 36% in tillage and no tillage rice field, respectively, with 4 Mg $ha^{-1}$ silicate amendment. In addition, the interaction of silicate fertilization (4 Mg $ha^{-1}$) and no tillage system significantly decreased total methane flux by 53.8 % lower compared to that of control tillage plot and 36 % lower compared to control no tillage plot. Total iron, active iron, free iron and ferrous iron concentrations in soil significantly increased with silicate fertilization, which acted as electron acceptors, thereby, reduced methane emission. Soil physical properties such as bulk density and porosity were markedly improved in no tillage system, compared with that in tillage, which significantly contributed to reduce $CH_4$ emission. Silicate fertilizer application markedly stimulated leaf photosynthetic rates and then increased grain yield by 18 % and 13% in tillage and no tillage, respectively. In particular, apparent root development such as root biomass, volume and porosity was observed in the silicate fertilization plots, which might contribute to promote $CH_4$ oxidation in rhizosphere. Conclusively, silicate fertilizer could be a good soil amendment for reducing $CH_4$ emission as well as increasing rice productivity both in tillage and no tillage paddy soil.

**PS8_28**

## Watershed Land Use Impacts on Total and Particulate Organic Carbon in Riparian Soils of Kentucky Lake, USA

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The total organic carbon (TOC) in riparian soils is considered a key component to the ecosystem, because it significantly influences water chemistry and nutrient availability in the ecosystem. Particulate organic carbon (POC) is a positive indicator of soil quality since it is the active portion of carbon that can be used by soil organisms. Particulate organic C can also act as a carrier to transport contaminants along the water systems which will influence water quality. The objective of the study was to determine if TOC and POC trends are present in riparian soils collected from contrasting watershed land-use in the Kentucky Lake area. Sites for this study were selected due to their similar soils present, weather conditions, and their close proximity to one another. Ledbetter Creek is predominantly in an agriculture ecosystem and Panther Creek has 96% forested ecosystem. Samples were collected during August (high water period) and November (low water period) 2008, from the riparian areas at the depth interval of 0 to 10, 10 to 20 and 20 to 30 cm. From each land-use, six sites were selected for soil samples. Soil organic carbon in riparian soils under forest varied greatly from August to November sampling time. At all sampling times, the riparian soils under forested land-use had higher TOC than agricultural land-use. In August, the forested riparian area soil contained 70 g/kg of TOC while November`s soil samples had 41 g/kg TOC. Riparian area under agricultural land-use has similar amounts of TOC in August and November, but has high amounts of POC of 35 g/kg and 26 g/kg, respectively. The result shows that riparian soils have the capability to store and slowly release carbon within one year.

**PS8_29**

## Long-term tillage and nitrogen fertilization impacts on soil organic matter on a silt-loam soil in Central Italy

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Soil organic matter (SOM) is a must for soil processes which have an impact on environment and crop production. In arable lands, SOM pool is a potential sink absorbing $CO_2$ from atmosphere. Soils of the Mediterranean regions are characterized by low SOM content due to environmental conditions (e.g. high evapotranspiration rates, low/erratic rainfall, etc.) and intensive agricultural management practices that alter crop residue production and distribution. These have profound influence on changes in storage and turnover of SOM, both in the short and long-term. Consequently, a reduction in tillage intensity may lead to the decrease of SOM decomposition, while an increase in the N fertilization rates may enhance the amount of crop residues production returned to the soil, influencing their transformation in humus.

The aim of this study was to assess the long-term effects of tillage and N fertilization on vertical distribution of SOM concentrations and stocks in a rainfed soybean [*Glycine max* (L.) Merr.] - durum wheat (*Triticum durum* Desf.) rotation on a poorly drained silt-loam soil (*Typic Xerofluvents*).

The study was conducted in Pisa, Italy, where since 1981 five tillage systems [deep plowing (DP, 50 cm deep), two layer plowing (SPC, 25 cm plowing plus 25 cm chiseling), shallow plowing (SP, 25 cm deep), chiseling (CP, 50 cm), and minimum tillage (MT, 15 cm deep with disk harrowing)] were evaluated and since 1994 three N fertilization rates (0, 100 and 200 kg N $ha^{-1}$) were also applied (to durum wheat only). After 12 years of different tillage and N fertilization management, soil was taken randomly in each plot and divided in three sampling depths (0-15, 15-30, and 30-45 cm).

In the upper layer (0-15 cm), considering the mean effect of tillage systems, the highest SOM concentration was observed under MT (2.44%) while the lowest was under DP (2.07%). The mean effect of N has shown a significant effect of fertilization on SOM concentration while no difference was seen between 100 and 200 N $ha^{-1}$ rates. The tillage x N interaction was high at N 100 and 200 kg N $ha^{-1}$ rates.
For the entire soil tillage layer (0-45 cm), greater total SOM stock content was found under MT (87.42 Mg C $ha^{-1}$) and SP (86.29 Mg C $ha^{-1}$) respect to other treatments.

We conclude that, in silt-loam soil both a reduction in tillage intensity and an increase in the N fertilization would preserve SOM.

**PS8_30**

**Tillage and land-use impacts on soil carbon and nitrogen storage and belowground processes**

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Understanding soil carbon (C) and nitrogen (N) storage and cycling in different ecosystems is essential to accurately forecast land-use changes to facilitate GHG abatement. The current study was undertaken in 2004 in a C3 wheat (Triticum aestivum) tillage agriculture system. Three management systems were initiated to assess tillage and land-use effects: 1) RP - Prairie restoration vegetated in warm season grasses; 2) NT - No-tillage grain sorghum (Sorghum bicolor); and 3) CT - Conventional tillage grain sorghum. These plant species exhibit a C4 respiration pathway, and all systems were managed for maximum yield through N addition, pest management, and annual burning. Additionally, in a subset of plots arbuscular mycorrhizal fungi (AMF) colonization was suppressed (by phosphorus (P) or fungicide) to alter the flow of C and N into the soil. Mycorrhizal control plots received equivalent quantities of water. Soil C and N, AMF root colonization, biologic properties, and the addition of new C4-C were assessed yearly. After 5 y, the soil C levels were similar in each system at 0-5 cm, except for a decrease in NT with P addition, and at the 5-15 cm level, with average values of 20.3 and 20.4 Mg ha-1, respectively. Soil N followed similar trends. Percentage AMF colonization was suppressed in RP receiving fungicide, as compared to the control, with levels of 12 and 23, respectively. Soil microbial biomass C was not different after 2 y of treatment, with a mean value of 282 mg C $kg^{-1}$ soil. Finer resolution measurements provide insight into belowground mechanics. After 3 y, the initial delta $^{13}C$(VPDB) value, -19 ‰ , was higher under CT (-16 ‰ ), as compared to RP (-17 ‰ ), indicating greater SOM turnover with disturbance. The soil microbial community structure was affected by management, with increases in fungal phospholipid fatty acids (PLFA) 18:2w6,9c and 18:1w9c and reductions in branched and methylated gram positive PLFA for RP and NT, signaling a change to a fungal-dominated community in plots not annually disturbed. An opposite trend was observed in CT plots, indicating disturbance may increase bacterial abundance in these microbial communities. Nematode abundances in the RP and NT plots exhibited increases in herbivorous species. In this study, management effects on belowground processes were evident after a short time span (2-3 y) but longer time spans are needed to observe management effects on broader soil nutrient dynamics.

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