North American Forest Soils Conference - International Symposium on Forest Soils 2018

Soils-Forests Interactions in Changing Environments

June 10-16, 2018
Quebec City, Quebec, Canada

PROGRAM & ABSTRACT BOOKLET

Presenting author is the first author listed except where an * is noted

Program Schedule

All activities are in the Des Plaines room unless otherwise stated.

Theme 1
The role of forests and forest soils in climate change adaptation and mitigation
Theme 2
Technological advances in forest soils research
Theme 3
Management practices, land-use change and soil-forest productivity
Theme 4
Societal change and forest soils: a balancing act
Theme 5
Fire effects on forest soils
Theme 6
Forest soil monitoring networks and environmental change: successes and challenges

Sunday, June 10th, 2018

2:00-6:00pm Registration opens (Espace Foyer des Plaines)
5:00pm Icebreaker (Jardin 4-Saisons)

Monday, June 11th, 2018

7:00am Breakfast (coffee, tea, juices, muffin, pastries, yogurt, cheese) (Espace Foyer des Plaines)

Opening

8:00am
Facilitator: *Caroline Rochon, Canadian Forest Service*

8:15am Keynote Opening
Dan Binkley
Forest soil research: how it got us here, and where it can take us

THEME 1: The role of forests and forest soils in climate change adaptation and mitigation

Monday, June 11th, 2018
8:55-11:55am
Moderators: *Lindsey Rustad, US Forest Service; Lauren Gilespie, Université de Montpellier*

8:55am Keynote Theme 1

Mark Johnston
The role of forests and forest soils in climate change adaptation and mitigation

9:30am O.1.1 *Manuella Strukelj et al.*
Tree species richness and water deficit interact to affect microbial community activity and soil carbon and nitrogen pools in temperate plantations

9:45am O.1.2 *Kenton Stutz et al.*
European beech deadwood and soil functioning: Is decayed lignin the culprit?

10:00am Table Talk

10:15am Break

10:40am O.1.3 *Stephen Hart et al.*
Consequences of warming and altered snowmelt timing on greenhouse gas fluxes and soil N cycling in the Sierra Nevada rain-snow transition zone

10:55am O.1.4 *Sylvie Tremblay et al.*
Transplanting boreal soils to a warmer region increases soil heterotrophic respiration as well as its temperature sensitivity

11:10am O.1.5 *Lars Vesterdal et al.*
Tree species effects on stocks and vertical distribution of soil carbon: links to mycorrhizal association, microbial characteristics and soil fauna communities

11:25am O.1.6 *Joanie Piquette et al. (*Maxime Paré)*
Nine years of in situ soil warming increases the recalcitrance of organic carbon in boreal forest soils

11:40am Table Talk

THEME 1 and THEME 2: Rapid Fire

Monday, June 11th, 2018
11:55am-12:15pm
Moderator: *Brian Strahm, Virginia Tech University*

RF.1.1 *Colin Fuss et al.*
Considering effects of changing C and N dynamics during forest regrowth on the accumulation and stability of soil organic matter

RF.1.2 *Dai Saito et al.*
Tree diversity effects on fine-root production, distribution and trait values modulated by soil nutrients in young tree communities

RF.1.3 *Janna Wambsganss et al.*
Fine-root responses to changing tree species diversity in mature forest stands across Europe

RF.1.4 *Brian Wallace et al.*
Soil water balance of a harvested opening in a dry forest and tree seedling establishment

RF.2.1 *Nicolas Bélanger et al.*
The Deleaves drone – A tool for fast and easy sampling of foliage from large trees

12:15pm Lunch (Abraham-Martin and George V rooms)

THEME 2: Technological advances in forest soils research

Monday, June 11th, 2018
1:30-3:45pm
Moderators: *Michael SanClements,* National Ecological Observatory Network*; Kalra Jarecke, University of Oregon*

1:30pm Keynote Theme 2
Nathan Basiliko
Technological advances and challenges in forest soils research: environmental microbiology perspectives

2:05pm O.2.1 *Tommaso Bardelli et al.*
Slope exposure effects on chemical and microbiological properties of Norway spruce deadwood and the underlying soil

2:20pm O.2.2 *Brian Strahm et al.*
Nitrogen isotopes to predict forest ecosystem responses to fertilization

2:35pm O.2.3 *Roland Riggert et al.*
Soil degradation caused by forestry machinery – an assessment scheme for soil ecology and trafficability of skid trails

2:50pm O.2.4 *Jean-Daniel Sylvain et al.*
Digital mapping of soil properties for the Province of Quebec using legacy soil data

3:05pm Table Talk
3:20pm Break

THEME 1 and THEME 2: Poster Session

Monday, June 11th, 2018
3:45-5:15pm (De la Coline room)
Please install your poster Monday morning and remove at the end of the day

P.1.1 *Mary Beth Adams et al.*
Belowground wood stake decomposition in forested wetlands with varying levels of restoration

P.1.2 *Xue Bai et al.*
Do we know how much carbon is in Maine, USA forest soils?

P.1.3 *Alexandre Collin et al.*
Sugar maple litter decomposition and nutrient release rates in southern Quebec: Influence of forest species composition and other environmental factors at various scales

P.1.4 *Yiyang Ding et al.*
Fine root turnover of a north boreal *Betula pendula* forest

P.1.5 *Annemieke Gärdenäs et al.*
Soil microbial responses to changing climate and nitrogen availability – implications for carbon sequestration

P.1.6 *Lauren Gillespie et al.*
European forest soil microorganisms in the face of drought: the influence of tree diversity

P.1.7 *Steffen Herrmann et al.*
Assessment of dead roots biomass in German forests

P.1.8 *Roxane Jaffray et al.*
Silicon dynamics in hardwood and conifer trees of temperate forests with a focus on interactions with lignin and tannin metabolism

P.1.9 *Karla Jarecke et al.*
Soil-water retention and saturated hydraulic conductivity of near-surface forest soils in topographically complex terrain

P.1.10 *John Kabrick et al.*
Does increasing Pinus echinata in mixed *Quercus* forests increase above- and below-ground carbon stocks?

P.1.11 *Klaus Katzensteiner et al.*
Thin skin – forest soil dynamics in Karst environments

P.1.12 *Gilles Kayser et al.*
Impact of tree species on C stocks and C sequestration in German forest soils

P.1.13 *Kim Seongjun et al.*
A multi-site approach to assessing the effect of thinning on soil carbon contents in pine, oak, and larch forests in South Korea

P.1.14 *Randy Kolka et al.*
Cutting edge northern peatland research at the SPRUCE experiment: early results

P.1.15 *Marty Kranabetter*
Increasing soil carbon content with diminishing exchangeable manganese in temperate coastal forests of Vancouver Island, British Columbia

P.1.16 *Jaane Krüger et al.*
Is the turnover of soil organic matter in European beech forests P limited?

P.1.17 *Jingle J. Cui & *Derrick Y.F. Lai*
Effects of litter manipulation on soil-atmosphere greenhouse gas exchange in a subtropical secondary forest

P.1.18 *Aleksi Lehtonen et al.*
Novel peatland management practices - key for sustainable bioeconomy and climate change mitigation

P.1.19 *Tengjiao Liu et al.*
Effects of environmental change on long term tree growth and water use efficiency in Tiantong National Forest Park, Ningbo, China

P.1.20 *Theodore Danso Marfo et al.*
Variation of soils properties across forest - agricultural field ecotones of SLP Masaryk Forest Kritiny in the Czech Republic

P.1.21 *Isabelle Ménard et al.*
Evaluation of the mitigation potential of climate change following afforestation of open woodlands

P.1.22 *Rita Razauskaite et al.*
Soil carbon sequestration in long term managed grassland and broadleaf forest

P.1.23 *Rita Razauskaite et al.*
Modelled soil carbon losses after harvesting oak forest on a seasonally waterlogged clay

P.1.24 *Cindy Shaw et al.*
The Canadian Peatland Carbon Modelling Project

P.1.25 *Bastos Rodrigo Pinheiro et al. (*Inge Stupak)*
Long-term changes in soil carbon stocks after afforestation of cropland in Denmark

P.1.26 *Florence Tauc et al.*
Microtopography and rainfall exclusion effects on sugar maple and bitternut hickory fine roots vertical distribution

P.1.27 *Elena Vanguelova*
Afforestation aid forest soil carbon sequestration

P.1.28 *Joanna Walitalo et al. (*Martin Jurgensen)*
Wood decomposition in forest soils: the role of subterranean termites

P.1.29 *Hui Wang et al.*
Three years of experimental warming increased heterotrophic respiration and decreased root-dependent respiration in a subtropical plantation

P.1.30 *Hannes Warlo et al.*
Greenhouse gas exchange affected by *Alnus glutinosa* when used to recover compacted anaerobic forest soils

P.1.31 *Tyler Weiglein et al.*
A continental - scale investigation of factors affecting soil organic matter vulnerability to decomposition

P.1.32 RF.1.1 *Colin Fuss et al.*
Considering effects of changing C and N dynamics during forest regrowth on the accumulation and stability of soil organic matter

P.1.33 RF.1.2 *Dai Saito et al.*
Tree diversity effects on fine-root production, distribution and trait values modulated by soil nutrients in young tree communities

P.1.34 RF.1.3 *Janna Wambsganss et al.*
Fine-root responses to changing tree species diversity in mature forest stands across Europe

P.1.35 RF.1.3 *Brian Wallace et al.*
Soil water balance of a harvested opening in a dry forest and tree seedling establishment

P.2.1 *Steeve Deschenes et al. (*Brian Wallace)*
Determining a wildfire-induced forest soil erosion index using remotely sensed images and the Terrestrial Ecosystem Information data

P.2.2 *Julien Beguin et al.*
Predicting soil properties in the Canadian boreal forest with limited data: comparison of spatial and non-spatial statistical approaches

P.2.3 *Robert A. Colter et al.*
Ecological classification on the White Mountain National Forest using the Soil Inference Engine

P.2.4 *Jason James et al.*
Forest management and land-use change alter the radiocarbon age, fluorescence characteristics, and lability of dissolved organic matter

P.2.5 *Patrick Levasseur*
Estimating mineral surface area and acid sensitivity of forest soils

P.2.6 *Nicolas Mansuy et al. (*Osvaldo Valeria)*
Predictive mapping of paludification in black spruce forests of eastern Canada using remote sensing and a Random Forest approach

P.2.7 *Christine Martineau et al.*
Effects of forest harvesting and Hemlock Looper infestations on boreal forest soils: a microbiome perspective

P.2.8 *Marine Pacé et al.*
Lichens contribute to open woodland stability in the boreal forest through detrimental effects on pine growth and root ectomycorrhizal development

P.2.9 *Michael SanClements*
Evaluating a solid phase fluorescence approach to the study of soil organic matter

P.2.10 *Boris Ťupek et al. (*Alexsi Lehtonen)*
Evaluating CENTURY, Yasso07, and Yasso15 soil carbon models against boreal forest soil CO2 emissions and soil organic carbon stocks

P.2.11 RF.2.1 *Nicolas Bélanger et al.*
The Deleaves drone – A tool for fast and easy sampling of foliage from large trees

Monday, June 11th, 2018
Dinner on your own

Tuesday, June 12th, 2018

6:30am Breakfast (coffee, tea, juices, muffin, pastries, yogurt, cheese) (Espace Foyer des Plaines)
7:30am/8:30am Depart for field tour
Check your nametag for departure time (7:30 or 8:30) and please be on time. Bring warm clothes, rain gear, good shoes/boots, sunscreen and insect repellent.

Dinner on your own

Wednesday, June 13th, 2018

7:00am Breakfast (coffee, tea, juices, muffin, pastries, yogurt, cheese) (Espace Foyer des Plaines)

Opening

8:00am
Facilitator: *Evelyne Thiffault, Laval University*

THEME 3: Management practices, land-use change and soil-forest productivity

Wednesday, June 13th, 2018
8:00-11:30am
Moderators: *Liisa Ukonmaanaho, Natural Resources Institute Finland; Linnea Hansson, Swedish University of Agricultural Sciences*

8:15am Keynote Theme 3
Cindy Prescott
Decomposition, transformation, humification, and soil organic matter formation: how can we reverse land degradation?

8:50am **O.3.1** *Peter Beets et al.*
Soil productivity drivers in New Zealand planted forests

9:05am **O.3.2** *Alan Gordon et al. (*Andrew Gordon)*
50 plus years of base cation depletions in forest soils, following stand conversion of old growth tolerant hardwoods to managed conifer plantations in southcentral Ontario, Canada

9:20am **O.3.3** *Timothy Philpott et al.*
Retention trees slow post-harvest fine-root decomposition in coastal temperate rainforests

9:35am **O.3.4** *Martin Jurgensen et al.*
Wood stakes: an index of soil properties and conditions affecting organic matter decomposition

9:50am Table Talk

10:05am Break

10:30am **O.3.5** *Marty Kranabetter et al.*
Recent key findings in crop tree and site biota response to soil compaction and site organic matter removal (Long-term Soil Productivity study) in central British Columbia

10:45am **O.3.6** *Dave Morris et al.*
Loss and recovery patterns in soil carbon and nutrient reserves following different levels of biomass removal in boreal, conifer-dominated site types in northern Ontario, Canada

11:00am **O.3.7** *Loretta Garrett et al.*
End of rotation impact of harvest removals and fertiliser addition on soil nutrients and productivity in Pinus radiata forest, New Zealand

~~1~~1:15am Table Talk

THEME 3: Rapid Fire

Wednesday, June 13th, 2018
11:30am-12:00pm
Moderator: *Brian Strahm, Virginia Tech University*

RF.3.1 *Simon Bilodeau Gauthier et al.*
A second fertilization with biosolids and wood ash near canopy closure shows significant benefits in hybrid poplar plantations

RF.3.2 *Richard Bowden et al.*
Long-term nitrogen addition decreases organic matter decomposition and increases soil carbon in a temperate deciduous forest

RF.3.3 *Seth Myrick et al.*
The effects of management and disturbance on forest soil properties in Sierra Nevada forest ecosystems – a synthesis

RF.3.4 *Christine Martineau et al. (*David Paré)*
Can salvage harvesting speed up the recovery of nutrient cycling in insect killed stands?

RF.3.5 *Simeon Smaill et al.*
Building more productive, higher quality forests for the future

12:00pm Lunch (Abraham-Martin and George V rooms)

THEME 4: Societal change and forest soil: a balancing act

Wednesday, June 13th, 2018
1:30-3:15pm
Moderators: *Ken Van Rees, University of Saskatchewan, Tiina Törmänen, University of Helsinki*

1:30pm Keynote Theme 4

Ellen Bergfeld
Societal change: a balancing act

2:05pm **O.4.1** *Barbara Kishchuk et al.*
State of policy for forest soil conservation in Canada

2:20pm **O.4.2** *Ronald Taskey*
Silviculture, soils, syphilis, and social events

2:35pm Table Talk
2:50pm Break

THEME 3 and THEME 4: Poster Session

Wednesday, June 13th, 2018
3:15-4:45pm (De la Coline room)
Please install your poster Wednesday morning and remove at the end of the day

P.3.1 *Bethany Avera et al.*
Soil organic matter stocks and formation pathways in bark-beetle infested lodgepole pine: implications for salvage logging and residue management

P.3.2 *Sanatan Das Gupta et al.*
Nutrient bioavailability is related to microbial functions in reclamation soils: an incubation experiment

P.3.3 *Cara Farr*
Using soils information and mapping to inform land management planning in the Pacific Northwest

P.3.4 *Cara Farr et al.*
USDA national forest soil interpretations from the National Cooperative Soil Survey for the USA – updates, revisions and new interpretations

P.3.5 *Adrian Gallo et al.*
Root carbon contributions are uniform across intensive biomass removal treatments in a western Oregon Douglas-fir forest

P.3.6 *Armando Gomez-Guerrero et al.*
Soil and plant nutrient reservoirs in a *Pinus montezumae* Lamb. in Tlaxcala, Mexico

P.3.7 *Andy Gordon et al.*
Changing the dynamics of agricultural soils by introducing trees into agricultural landscapes

P.3.8 *Sue Grayston et al.*
Digging deeper: How do introduced deer affect soils and carbon storage on Haida Gwaii?

P.3.9 *Linnea J. Hansson et al.*
Root zone hydrology in and around wheel tracks on boreal forest clear-cuts: 2D modelling and vegetation inventory

P.3.10 *Linnea Hansson et al.*
Impacts of off-road traffic on soil physical properties of forest clear-cuts: X-ray and laboratory analysis

P.3.11 *Amir Hass et al.*
Soil water quality at a reclaimed mine site 12 years after reclamation

P.3.12 *Scott Holub et al.*
Modern timber harvesting practices have little short-term effect on soil carbon stores in industrial forests of western Oregon and Washington, U.S.A.

P.3.13 *Florentin Jaeger et al.*
Effects of mixing *Fagus sylvatica* and *Abies alba* on below-ground complementarity at a submontanous site of the Buntsandstein region of Baden-Württemberg, Germany

P.3.14 *Lilli Kaarakka*
Forest soil and vegetation dynamics following a disturbance - recovery from stump harvesting

P.3.15 *Lilli Kaarakka et al.*
Artificial groundwater recharge and forest soil - sprinkling infiltration impacts on boreal forest soil, tree growth and understory vegetation

P.3.16 *Mohit Kaura et al.*
The role of forests in soil amelioration and securing hydropower needs of Cambodia

P.3.17 *Kevin Keys et al.*
Use of alkaline-treated biosolids (ATB) as a possible liming amendment on spruce plantations in Nova Scotia, Canada

P.3.18 *Hal Liechty et al.*
Changes in soil carbon abundance and characteristics after converting agricultural fields to bioenergy crops in the lower Mississippi alluvial valley

P.3.19 *Eva Masson et al.*
Nitrogen deposition, edge effect, sugar maple, soil composition, foliar nutrition

P.3.20 *Amanda Matson et al.*
Nitrogen movement after urea application to a young Pinus radiata forest on pumice soil

P.3.21 *George McCaskill*
The effects of low-dose chemical control on soil biogeochemistry and tree establishment in a wet longleaf pine savanna of the southern US

P.3.22 *Jean-David Moore et al.*
Exotic Asian pheretimoid earthworms (*Amynthas* spp., *Metaphire* spp.): Potential for colonisation of south-eastern Canada and effects on forest ecosystems

P.3.23 *Lawrence Morris et al.*
Soil mediated interactions between southern pine trees and forest insects

P.3.24 *Samantha Mosier et al.*
Soil organic matter from southern pine biofuel feedstocks under different soil types and management systems

P.3.25 *Rock Ouimet et al.*
Characterization of soil fertility in lichen woodlands and adjacent black spruce-feathermoss stands in the continuous boreal forest

P.3.26 *Deborah Page-Dumroese et al.*
Long-term impacts of slash pile burning on wood decomposition and fungal communities

P.3.27 *Christopher Preece et al.*
Long-term effects of harvest residues on spruce-fir site productivity following whole-tree and stem-only harvesting

P.3.28 *Jay Raymond et al. (*Brian Strahm)*
Long-term bioavailability and plant uptake of fertilizer nitrogen in managed coniferous ecosystems of the southeastern United States

P.3.29 *Adriana Rezai-Stevens et al.*
Long-term effects of whole-tree harvesting and residue management on spruce-fir soil quality in central Maine

P.3.30 *Jessica Sarauer et al.*
Microbial community diversity in biochar amended forest soils in the Pacific Northwest, USA

P.3.31 *Cindy Shaw et al.*
The Forest Floor Recovery Index: a tool to assess ecosystem recovery using forest floor criteria

P.3.32 *Zuomin Shi*
Responses of soil microbial community composition and enzyme activities to land-use change in the Eastern Tibetan Plateau, China

P.3.33 *Simeon Smaill et al.*
Working with soil microbes to build better forests

P.3.34 *Larissa Sage et al. (*Charles Smith)*
Empirical and predicted estimates of balsam fir boreal forest carbon pools following stem-only harvesting in Forêt Montmorency, Quebec, Canada

P.3.35 *Kenton Stutz et al.*
Storage and recycling of residue nutrients on skid trails

P.3.36 *Brian Titus et al.*
What do guidelines for forest harvesting residue removals tell us about “sensitive soils”? A review of international guidelines

P.3.37 *Tiina Törmänen et al.*
The effects of logging residue piles of different tree species on soil nitrogen losses

P.3.38 *Liisa Ukonmaanaho et al.*
Impacts of logging practice on base cation budgets of boreal coniferous stands – a sustainability study

P.3.39 *Landon Sealey & *Ken Van Rees*
Quantifying cumulative effects of harvesting traffic and residual slash on aspen regeneration at a harvest block scale

P.3.40 RF.3.1 *Simon Bilodeau Gauthier et al.*
A second fertilization with biosolids and wood ash near canopy closure shows significant benefits in hybrid poplar plantations

P.3.41 RF.3.2 *Richard Bowden et al.*
Long-term nitrogen addition decreases organic matter decomposition and increases soil carbon in a temperate deciduous forest

P.3.42 RF.3.3 *Seth Myrick et al.*
The effects of management and disturbance on forest soil properties in Sierra Nevada forest ecosystems – a synthesis

P.3.43 RF.3.4 *Christine Martineau et al. (*David Paré)*
Can salvage harvesting speed up the recovery of nutrient cycling in insect killed stands?

P.3.44 RF.3.5 *Simeon Smaill et al.*
Building more productive, higher quality forests for the future

6:00pm Banquet at the Séminaire de Québec.
Walking routes to the Séminaire on page 17.

Thursday, June 14th, 2018

7:00am Breakfast (coffee, tea, juices, muffin, pastries, yogurt, cheese) (Espace Foyer des Plaines)

Opening

8:00am

Facilitator: *Charles Smith, University of Toronto*

THEME 5: Fire effects on forest soils

Thursday, June 14th, 2018

8:00-10:30am

Moderators: *Daniel Neary, US Forest Service; Jingjing Chen, Virginia Tech University*

8:15am Keynote Theme 5

Thomas DeLuca

Fire as a dynamic driver of nitrogen cycling in forest soils

8:50am **O.5.1** *Melissa R.A. Pingree et al.*
Questioning the concept of soil sterilization: A review of soil heating and biotic thresholds

9:05am **O.5.2** *Benjamin Andrieux et al.*
Causal relationships among abiotic and biotic drivers explain soil carbon stocks change with time since fire in boreal forest ecosystems

9:20am **O.5.3** *Thea Whitman et al.*
Fire effects on soil microbes: burn severity in the boreal forest

9:35am **O.5.4** *Nicholas Dove et al.*
Ecologically novel wildfires impact carbon and nitrogen cycling processes over a decade after disturbance: a tale of two ecosystems

9:50am Table Talk

10:05am Break

THEME 5 and THEME 6: Rapid Fire

Thursday, June 14th, 2018

10:30-10:50am

Moderator: *Brian Strahm, Virginia Tech University*

RF.5.1 *Jingjing Chen*
Effects of recent wildfires in the southern Appalachian mountains on soil hydrophobicity and infiltration processes

RF.5.2 *Elena Ponomarenko et al.*
A recommendation for a new descriptor for pyrogenic soil horizons in the Canadian Soil Classification System

RF.6.1 *Elena Vanguelova et al.*
Base cations budgets of forest ecosystems in the UK

RF.6.2 *Megan Mobley et al. (*Ruth Yanai)*
Detecting change over time with depth in forest soils: an example from the Calhoun Critical Zone Observatory, USA

THEME 5 and THEME 6: Poster Session

Thursday, June 14th, 2018

10:50am-12:10pm (De la Coline room)

Please install your poster Thursday morning and remove at the end of the day

P.5.1 *Sol Cooperdock et al.*
In a hot and dry climate, wildfires slow soil respiration through indirect impacts to the surrounding environment

P.5.2 *Kirsten Hannam et al. (*Paul Hazlett)*
Ashes to ashes: comparing the effects of wildfires and applications of bioenergy ash on soil properties

P.5.3 *Jeff Hatten et al. (*Adrian Gallo)*
The effects of 17 years of repeated prescribed fires on soils in a ponderosa pine forest: do season and interval of burn matter?

P.5.4 *Randy Kolka et al.*
The effect of fire on the cycling of mercury

P.5.5 *Christina Kranz et al.*
Prescribed burning effects on jack pine seeds from high and low serotiny regions: microbial interactions and soil properties

P.5.6 *Chris Miller et al. (*Martin Jurgensen)*
Wood decomposition after wildfires across the western United States

P.5.7 *Daniel Neary*
Forest soil disturbance by wildland fire: Impacts and implications of the severity, scale, fuel loading, slope, infiltration, and rainfall nexus

P.5.8 *Suzanne Owen et al.*
Long-term effect of fire severity on soil properties and fungal communities

P.5.9 *Elena Ponomarenko et al.*
Evidence of coupled wind-fire natural disturbance in Atlantic Maritime forest soils

P.5.10 *Lu Shenggao*
Magnetic record of forest fire: effect of forest soil type on magnetic enhancement in subtropical region of China

P.5.11 *Kyle Steele et al.*
Exploring confusing soil and ecological relationships of the Des Moines Lobe in Minnesota and Iowa, USA

P.5.12 *Pille Tomson et al.*
Wildfires and slash and burn cultivation as sources of forest soil charcoal

P.5.13 RF.5.1 *Jingjing Chen*
Effects of recent wildfires in the southern Appalachian mountains on soil hydrophobicity and infiltration processes

P.5.14 RF.5.2 *Elena Ponomarenko et al.*
A recommendation for a new descriptor for pyrogenic soil horizons in the Canadian Soil Classification System

P.6.1 *Olivia Bartlett et al.*
Disentangling soil heterogeneity at multiple spatial scales for long-term monitoring designs

P.6.2 *Rob Fleming et al.*
Quantifying ecosystem classification soil nutrient regimes

P.6.3 *Dorit Julich et al. (*Stefan Julich)*
Phosphorus fractions along preferential flow pathways in contrasting beech (*Fagus sylvatica* L.) forest soils

P.6.4 *Augusto Zanella et al. (*Klaus Katzensteiner)*
Humusica, humus system, humus forms, topsoil classification, humipedon, diagnostic horizon

P.6.5 *Sibi Kizhakkepurakkal et al.*
Ectomycorrhizal response to long-term nitrogen fertilization in a temperate forest: a pilot study in Maine

P.6.6 *Lukas Kohl et al.*
The origin of soil organic matter controls its composition and bioreactivity across a mesic boreal forest latitudinal gradient

P.6.7 *Jérôme Laganière et al.*
Long term monitoring of soil organic matter dynamics to address bioenergy sustainability questions

P.6.8 *Michael McHale et al.*
Monitoring chemical changes in sandy soils, is it worth the effort?

P.6.9 *Kaizad Patel et al.*
Multi-decadal evolution of nitrogen dynamics at the Bear Brook Watershed in Maine

P.6.10 *Cynthia West et al. (*Jennifer Knoepp)*
A continental scale assessment of soil moisture monitoring of forest and grassland ecosystems in the United States

P.6.11 *Donald Ross et al.*
Sixteen years into a 150-year soil monitoring study

P.6.12 *Lindsey Rustad et al.*
Smart Forests: Insights and lessons learned from a new digital platform for monitoring soil microclimate at USDA experimental forests across the Northeastern US

P.6.13 *Carl Trettin et al.*
Wood decomposition: understanding processes regulating carbon transfer to soil carbon pools using FACE wood at multiple scales

P.6.14 *Elena Vanguelova*
Long term trends and effects of nitrogen inputs on forests and soils in the UK

P.6.15 *Shaun Watmough et al.*
An assessment of traditional chemical indicators of atmospheric pollution in Saskatchewan forest soils

P.6.16 *John Yarie et al.*
Changing soil characteristics during succession in the Alaskan boreal forest

P.6.17 RF.6.1 *Elena Vanguelova et al.*
Base cations budgets of forest ecosystems in the UK

P.6.18 RF.6.2 *Megan Mobley et al. (*Ruth Yanai)*
Detecting change over time with depth in forest soils: an example from the Calhoun Critical Zone Observatory, USA

12:10pm Lunch (Abraham-Martin and George V rooms)

THEME 6: Forest soil monitoring networks and environmental changes: successes and challenges

Thursday, June 14th, 2018
1:20-3:35pm
Moderators: *Ruth Yanai, State University of New York-Environmental Science and Forestry; Olivia Bartlett, University of New Hampshire*

1:20pm Keynote Theme 6
Bruno De Vos et al.
European forest soil monitoring networks and environmental change: successes and challenges

1:55pm O.6.1 *Daniel Richter et al.*
Decadal restructuring of soil carbon and nitrogen in a regenerating forest on long cultivated land in the southern piedmont of the USA

2:10pm O.6.2 *Jennifer Knoepp et al.*
Soil and vegetation recovery from acidic deposition to high elevation spruce fir sites in the southern Appalachian Mountains

2:25pm O.6.3 *Yu Zaipeng et al. (*Zhiqun Huang)*
Global change accelerate soil acidification and base cation release over the past 60 years across subtropical China

2:40pm O.6.4 *Gregory Lawrence et al.*
Soil monitoring provides insights into why decreased nitrogen deposition is having little effect on stream acidification in the Adirondacks of New York, USA

2:55pm Table Talk

3:10pm Break

Closing

Thursday, June 14th, 2018
3:35-4:15pm

3:35pm Keynote Closing

Peter Clinton
What will environmental change mean for forest soils: will they keep pace with change?

Thursday, June 14th, 2018
Dinner on your own

Friday, June 15th, 2018

8:00am Depart for post-conference tour

Saturday, June 16th, 2018

5:00pm Return from post-conference tour

Opening

Keynote Opening - Forest soil research: how it got us here, and where it can take us

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Forest soil science in the 20th Century gave us remarkable insights into the structure, function, and dynamics of forest soils. We learned about long-term soil development, nutrient removals in forest harvest, watershed-scale biogeochemistry, nutrient limitations on tree growth, influences of tree species on soils, possible impacts of acid rain, and much more. A few case studies will be presented to give an idea of the status of knowledge at the time, and how advances came to influence our understanding. History always leaves great opportunities for current and future generations. A variety of great opportunities await our focused attention. We have strong representations of soil characteristics across landscapes, but we need to develop a great deal of insight on spatially explicit changes in forest soils over time. We need to know much more about soil organic matter, including the mechanisms that allow it to accumulate, and how recently added carbon might become stabilized in soils. Almost all forest soils have O horizons as well as mineral soils, and distinctions and similarities in organic matter dynamics (and responses to management) will warrant major research efforts. Perhaps the greatest strides will come from focusing on soils as living systems, with in situ examinations that go beyond lab-bench analysis. Most of the vital dynamics of forest soils depends on huge diversity of extremely small organisms in fantastically varying micro-locations. The next generation of forest soil research is bound to reveal fundamental insights that are on our horizon, and far over our horizon.

THEME 1: The role of forests and forest soils in climate change adaptation and mitigation

Keynote 1 - The role of forests and forest soils in climate change adaptation and mitigation

Mark Johnston
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Forests and forest soils play a critical role in the global carbon cycle, and are therefore important in influencing climate change. Forest ecosystems collectively represent the world's largest C reservoir, although C stocks change over time due to both natural and anthropogenic disturbance. Forest fires emit large amounts of C, but C stocks eventually recover as the forest regrows. Permanent loss of forest cover (deforestation) due to land clearing represents a major loss of C to the atmosphere. Additional losses of C from forests include other natural disturbances (e.g., insect outbreaks, windthrow) and impacts of forest management activities (e.g. timber harvest, road construction etc.). Forests can be managed to maintain or increase C sequestration, and afforestation (tree planting on non-forest land) can add additional C sequestration. Forestry practices can reduce soil C losses through e.g., harvesting on frozen ground and use of low-flotation technology in harvesting equipment. Harvesting practices that maintain biomass on-site will reduce C export. Climate change adaptation should include practices that tend to maintain C in forest ecosystems in order to maintain long-term productivity. These include prompt reforestation of both anthropogenic and natural disturbances, limiting disturbance where possible, matching populations and species to future conditions through assisted migration, and developing better adapted planting stock, e.g. for drought tolerance. Sustainable Forest Management will become increasingly important in the future as a means for increasing C sequestration and reducing C emissions.

O.1.1 - Tree species richness and water deficit interact to affect microbial community activity and soil carbon and nitrogen pools in temperate plantations

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In a context of global change and decline in biodiversity, understanding how microbial communities interact with vegetation communities to influence nutrient cycling processes is an essential issue to adequately manage forests. The objective of this study was to characterize how tree species richness and manipulated water availability affect the functional diversity of microbial communities and soil carbon and nitrogen pools. Two experiments that were established within the TreeDivNet platform allowed us to study the interaction between tree species richness and water deficit (either irrigation during drought or rainfall exclusion), namely the ORPHEE experiment in Bordeaux, and the IDENT experiment in Sault Sainte Marie. Plantations of single species monocultures and species mixtures were realized in 2008 and 2013, respectively, and were subject to treatments of irrigation and rainfall exclusion. At Bordeaux we investigated a gradient of 1 to 3 species (Betula pendula, Pinus pinaster, and Quercus robur) and in Sault Ste Marie, a gradient of 1 to 4 species (Betula papyrifera, Pinus strobus, Picea glauca, Quercus rubra). Mineral soil (0-10 cm) was sampled and analyzed to assess C and N concentrations, and by the Microresp method to assess functional diversity of the microbial community. Contrary to expectations, soil carbon and nitrogen concentrations and microorganism activity did not increase in all plots with species richness, nor with irrigation. Consistently, the interactions species richness x water irrigation were significant, indicating that the effects of diversity depend on soil water availability. The regions of Aquitaine and Ontario are particularly concerned by changes in seasonal precipitation and occurrence of drought, and tree diversity in plantations may have important impacts on carbon and nitrogen budgets.

O.1.2 - European beech deadwood and soil functioning: Is decayed lignin the culprit?

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Deadwood can improve soil functioning including storage and stability of soil organic matter (SOM), a key component in terrestrial carbon cycles. Yet a unifying explanation for such effects is missing due to variations in tree species, decomposers, and forest ecological conditions. We hypothesize that soil functioning improves with progressing oxidation of lignin from deadwood. We tested this hypothesis through 42 paired points adjacent to *Fagus sylvatica* deadwood and 2-3 m away in ten stands in Southwest Germany with various forest floor and bedrock types. Cupric oxide- oxidation products were used for lignin concentration, composition, and degree of oxidation. For all pairs, lignin concentrations increased significantly in the mineral soil near deadwood, but not in the organic layer. Syringyl lignin from deadwood was found in mineral soil at mull sites and in the organic layers at moder sites; for heavily decayed deadwood, syringyl lignin was in both layers. Lignin oxidation changed minimally near deadwood, but was significantly higher in mineral soil compared to the organic layer. This suggests lignin from both litter and deadwood entered the mineral soil already oxidized. Soil particulate organic carbon (OC) increased as well at mull-silicate sites, while water-extractable OC increased at moder sites; mineral-bound OC concentrations did not change in any site or decay class. Exchangeable base cations increased too in mineral soil and the organic layer parallel to shifts in deadwood lignin and labile carbon. In summary, decayed lignin and nutrients from deadwood can move into soil and alter soil functioning as regulated by site conditions.

O.1.3 - Consequences of warming and altered snowmelt timing on greenhouse gas fluxes and soil N cycling in the Sierra Nevada rain-snow transition zone

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The legacy of winter warming on summer soil greenhouse gas emissions and soil nitrogen cycling remains unclear. Effects of winter warming on summer hydrology and biogeochemistry may be most obvious in rain-snow transition zones and in a Mediterranean-type climate with almost no summer precipitation. We simulated climatic warming in the rain-snow transition zone of the Sierra Nevada in California over a two-year period by: (1) moving a mixed conifer forest soil down in elevation from predominantly snow precipitation to equal amounts of precipitation as rain and snow; and (2) manipulating the date of spring snowmelt at the snow-dominated site, both earlier using black sand and later using white Tyvek cloth. Increasing non-growing season mean soil temperature by 1.4 °C by moving soil cores down in elevation, with little change in summer temperature or total precipitation amount, increased soil CO2 emission by ~30% during snow-free periods over two years. Warming also increased CH4 uptake by ~50%, but had no effect on N2O fluxes. Earlier snowmelt tended to decrease soil CO2 emission (5% after wet winter and 9% after dry winter), decrease soil CH4 uptake (15% and 23%), and increase soil N2O emission (12% and 75%). During the wet year, soil transfer to the warmer, lower elevation site and earlier snowmelt had no significant effect on rates of soil net N transformations. However, during the dry year, soil transfer to the lower elevation site decreased soil net N transformations, while an earlier snowmelt increased them. Taken together, our results suggest that warming in these Mediterranean ecosystems impacts soil processes both directly by increasing microbial activity, and indirectly by altering the growing season length and the amount of water stored in the soil during this period. Furthermore, the amount of winter precipitation strongly interacts with warming-induced impacts on these key soil processes.

O.1.4 -Transplanting boreal soils to a warmer region increases soil heterotrophic respiration as well as its temperature sensitivity

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Under a warming climate, the boreal forest could become one of the largest terrestrial net CO2 sources, as increasing disturbances and soil organic matter decomposition rates (heterotrophic respiration, Rh) could offset net primary production. Since soil represents the boreal forest's largest C pool, it is critical of correctly predicting future changes in Rh, as well as its sensitivity to temperature (Q10 of Rh). We simulated a soil warming by transplanting soil cores from boreal balsam fir (*Abies balsamea*, BF) and black spruce (*Picea mariana*, BS) stands to a more southern Eastern hemlock stand (*Tsuga canadensis*, EH). We measured Rh and soil properties over 3 years, from June to October. Over three snow-free seasons, soil temperature (first 10 cm, including the FH organic layers) and Rh increased for BF (+3.2 °C, +60% of Rh) and BS cores (+2.3 °C, +27% of Rh). Microbial C concentration decreased by 54–73% in the FH layers of warmed and control cores relative to initial values, despite unchanged chemically labile C, probably due to excised roots and mycorrhizal hyphae. This suggests a possible underestimation of Rh during the experiment. In BF soils only, the increase in Rh was accompanied by an increase in its sensitivity to temperature. Under a +5 °C soil warming, mean predicted Rh of BF soils would increase by 83% rather than by 56%. Relative to BS soils, such increase in sensitivity could be partly due to a higher

fraction of chemically labile C (+52%) in the FH layers and a higher mean warming effect. It suggests that for BF forest soils, predicting decomposition rates for a warmer climate based on current temperature sensitivities could be inadequate. However, longer-term studies are needed to see if this increase in Q10 of Rh for BF soils would be maintained for longer periods.

O.1.5 - Tree species effects on stocks and vertical distribution of soil carbon: links to mycorrhizal association, microbial characteristics and soil fauna communities

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Tree species selection is one of the relevant forest management options in the context of mitigating increasing atmospheric CO2 by soil organic carbon (SOC) sequestration. Information on tree species effects is also needed to assess the influence of tree species change with predicted climate warming. Tree species with leaf litter traits driving slow rates of leaf litter decomposition have traditionally been associated with accumulation of higher SOC stocks than tree species with fast litter decomposition rates. This hypothesis has mainly been based on observations of thick C-rich forest floors under tree species associated with ectomycorrhizae (ECM). However, a recent hypothesis has suggested that tree species with foliar litter traits conducive to fast decomposition will lead to more pronounced microbial transformation and stabilization of litter C. The latter tree species are often associated with arbuscular mycorrhizae (AM) and may enhance deeper incorporation of C by more active soil fauna communities and by higher belowground rates of litter input. The Danish common garden tree species experiments include both ECM and AM tree species that differ widely in traits such as foliar litter chemistry. Six common European tree species formed distinct groups that largely reflected their mycorrhizal association. Forest floor C stocks were consistent with the traditional perception of slowly decomposing ECM species being conducive to high SOC stocks, but an intriguing pattern of more C in the mineral soil in AM tree species supported the recent microbial stabilization hypothesis and suggested deeper incorporation of C in more stable forms. Based on new results on microbial, macro- and mesofauna communities, fine root dynamics and repeated soil sampling, this talk will revisit Danish common garden tree species experiments for a synthesis of processes and patterns in organic matter formation that may explain observed patterns in SOC stocks and vertical SOC distribution.

O.1.6 - Nine years of in situ soil warming increases the recalcitrance of organic carbon in boreal forest soils

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Global warming and atmospheric nitrogen (N) deposition resulting from anthropogenic activities may affect the biogeochemical cycling of carbon (C) in boreal forest soils. This study was carried out at Lake Simoncouche, Québec, Canada in a mature black spruce stand (*Picea mariana* [Mill.] BSP) located within the balsam fir–white birch bioclimatic domain. We used a 9-years field experiment (2008-2016) to assess the effect of soil warming and N deposition on soil C quality. Soil warming (W) was applied from April to July using heating cables placed into the F horizon to simulate an in situ 4 °C increase in soil temperature. Meanwhile, artificial rain was applied from June to September to simulate a 50% increase in canopy nitrogen additions (CNA). The two experimental factors and their respective controls were crossed in a factorial design, where each of the four treatment plots (+W+CNA; +W-CNA; -W+CNA; -W-CNA) were replicated three times. Soil samples (F horizon) were collected from each plot in October 2016 and soil respiration rates (RR, µg C-CO_2 g^{-1} C-soil hr^{-1}) were measured using laboratory incubations at each of four temperatures (T) (16–40 °C, 8 °C increments). The van 't Hoff functions describe the dependence of C mineralization on soil T ($RR=Be^{kT}$, and $Q_{10}=e^{10k}$), where C quality-temperature theory predicts that recalcitrant C-soil is more sensitive to changes in T (lower B and higher Q_{10} values) than labile C-soil. Soil warming (+W treatments) significantly increased the recalcitrance of C-soil by reducing B (P=0.017) and increasing Q_{10} (P=0.002) values of the functions, whereas CNA had no significant impact on C-soil quality. Treatments had no significant impact on C-soil content nor the soil C:N ratio. Our results demonstrate that in situ soil warming changes soil C quality in boreal soils, with attendant consequences on soil fertility, nutrient cycling, and C sequestration.

THEME 1 and THEME 2: Rapid Fire

RF.1.1 P.1.32 - Considering effects of changing C and N dynamics during forest regrowth on the accumulation and stability of soil organic matter

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Organic matter in soils underlying northern hardwood forests accounts for the largest stores carbon (C) and nitrogen (N) in the ecosystem. The stabilization of soil organic matter (SOM) is important to mitigating climate change through sequestration of C from the atmosphere and regulating water quality through the control of N concentrations in runoff. These ecosystem functions will become increasingly important management priorities for forests broadly. However, relatively little is known about how stabilized soil C and N respond to the disturbance pressures of forest harvest and regrowth. We were specifically interested in how changing N demand during regrowth influences SOM formation and stability. We studied SOM dynamics across a chronosequence of sites in the White Mountains of New Hampshire, USA. These sites ranged from young, actively growing forests where SOM is an important nutrient pool to support growth, to old growth stands where we expected SOM to be in steady state and closer to effective C and N saturation. Here we will present results from several novel studies considering soils and forest age, including subsoil C and N accumulation as indicated by isotopic tracers, nanoscale characterization of newly-formed SOM, and biogeochemical modeling. SOM characteristics varied as a function of forest age, with C:N decreasing by approximately 25% from young to old growth forests while the background enrichment of ^{15}N increased by a similar magnitude. These values suggest that soils of younger forests accumulate more recent C and the increased availability of N in old growth forests promotes decomposition through greater microbial processing. Our results emphasize the importance of considering the changing balance of N uptake between plants and microbes during forest regrowth, and more broadly the impacts of cutting and forest management on the dynamics of SOM and C sequestration over the long term.

RF.1.2 P.1.33 - Tree diversity effects on fine-root production, distribution and trait values modulated by soil nutrients in young tree communities

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There is growing evidence that mixed-species forests can be more productive than monocultures. This positive diversity-productivity relationship has been explained by interspecific interactions (i.e. competitive reduction and facilitation), which can be quantified by functional traits of the constituent species in a community. However, while numerous studies have investigated the mixture effects on aboveground ecosystem properties and processes, our understanding about how tree diversity influences belowground organs of trees is still limited. Moreover, little is known about the influence of abiotic environmental gradients on below-ground tree diversity effects. In our study, we aimed at identifying tree diversity effects on fine-root production, distribution and trait values and their modulation by nutrient availability. Here we present results from a young tree diversity experiment established in 2013 in Freiburg, Germany. Tree seedlings of six European species representing a wide range of functional diversity independent of species richness were planted at high density, comprising monocultures of six species, six combinations of two-species mixtures and six combinations of four-species mixtures. Each community has both fertilized and unfertilized plots. Soil cores were extracted to a depth of 30 cm in each plot, sectioned in 10 cm layers, and roots were separated from the soil by washing and sorted by species. Fine roots of each species at each depth were divided into absorptive and transport roots, and separately weighed and scanned to determine vertical distribution of root length and mass and specific root length of both categories. Vertical distribution of mycorrhizal colonization intensity was recorded on absorptive roots. This study explores the following hypotheses: 1) tree diversity positively impacts on root production, distribution and traits related to soil resource acquisition; 2) functional diversity is a better predictor of these changes than species richness; 3) fertilization reduces the magnitude of diversity effects on fine-root overyielding, distribution and traits.

RF.1.3 P.1.34 - Fine-root responses to changing tree species diversity in mature forest stands across Europe

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In addition to water and nutrient uptake, fine roots play a key role in carbon (C) and nutrient cycling and thereby in overall ecosystem functioning. Mixed-species forests have often been shown to enhance above-ground ecosystem properties and functions. However, the role of tree species diversity for below-ground functions driven by fine roots such as nutrient exploitation and C sequestration has been studied for a few species only and remains largely unknown. To fill this gap, we conducted a comprehensive study assessing the influence of tree species diversity (from one to three species) on fine-root soil exploration and exploitation by taking advantage of an existing network of comparative sites in four major European forest types. Our main hypothesis was that – owing to niche differentiation among species – the overall exploration and exploitation of soil volume by fine roots would be higher in mixed species stands than in monospecific forest stands. To test this, soil cores were taken at the level of tree neighborhoods in 64 tree species mixtures and corresponding monospecific forest plots. Fine roots were sorted by species and divided into absorptive and transport roots according to the functional classification approach. Total fine-root biomass and a variety of fine-root traits including morphological, architectural and chemical traits as well as mycorrhizal colonization intensity were measured.
Our analysis will compare measures of fine-root soil exploration and exploitation among mixed and

monospecific stands in four contrasting dominant forest types across Europe. This work should bring important new insights into the mechanisms by which tree species diversity influences fine-root systems and their interactions with several ecosystem functions.

RF.1.4 P.1.35 - Soil water balance of a harvested opening in a dry forest and tree seedling establishment

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Tree seedling survival in dry forests of the Southern Interior of British Columbia, Canada, is largely dependent on the level of competition for soil water from rhizomatous grasses, soil properties, and year to year variation in weather. We investigated how variations in weather and soil properties influence temporal soil water dynamics with respect to the establishment of tree seedlings when they are planted in the first, second, and third growing season post-harvest. The site has a loam soil with around 30% coarse fragments through the soil profile (0-100 cm). The amount of available water was constrained to approximately 126 mm in the 60 cm rooting depth. The first year (2015) was dry with soil water deficit conditions starting at the end of June in the adjacent mature Douglas fir stand, while soil water in the harvested opening was not in deficit throughout the entire growing season. A relatively wet year in 2016 (April-Nov; 376 mm) had 80 days of water deficit in the mature stand, compared to 25 days in the opening. Seedling survival was over 80% during the first two years post-harvest. In 2017, March to June precipitation was 180 mm, but June to September was only 30 mm. As a result, both the opening and the mature stand had 110 of 215 days during the growing season in deficit conditions and spring planted seedlings experienced significant mortality. The greater demand for water by competing plants likely affected seedling survival. Hence, even in a dry year, successful seedling establishment can be achieved when planted immediately after harvest and before understory vegetation becomes overly competitive for resources. With climate change, the location and timing of harvest in dry forest systems will need to consider specific soil conditions and the dynamics of soil water availability for successful reforestation.

RF.2.1 P.2.11 - The Deleaves drone – A tool for fast and easy sampling of foliage from large trees

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Foliar nutrient data of large trees are often sought by forest soil scientists for various studies, but the considerable efforts associated with the sampling of upper canopy branches often leads to reduced sample sizes. Current techniques for sampling upper canopy foliage of large trees include the use of a telescopic pole pruner, a shotgun or climbing the tree to remove a small branch, or felling the tree entirely. These techniques are not optimal for different reasons. For example, the pole pruner cannot reach very far (10 m at most), the use of a shotgun may be limited in some areas, tree climbing requires safety precautions but remains dangerous, and felling trees is an issue in conservation areas. Except

perhaps for the shotgun approach, these techniques are also time-consuming. The Deleaves drone can be used by two operators, i.e. one drone pilot and another controlling the sampler, to collect branches in upper canopies very efficiently and in a timely manner. It was tested in poplar and maple stands in Quebec and was shown to be effective for sampling branches up to 10 mm in diameter, with lengths varying from 20 to 100 cm and holding as much as 24 leaves. The drone can operate under a moderate breeze (i.e. wind speed less than 28 km/h). Under good flying conditions, the operators can take off, collect a sample from a tree at 25 m and land in about 180 seconds. The onboard cameras allow sampling beyond visual line of sight at distances up to 200 m. Longer distances could be achieved with more powerful radio transmitters. Work is currently underway to automate various flight aspects, increase the operating conditions and reduce the sampling time. All in all, the Deleaves drone is a very promising tool for forest soil scientists.

THEME 2: Technological advances in forest soils research

Keynote 2 - Technological advances and challenges in forest soils research: environmental microbiology perspectives

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Soil microbes directly and indirectly mediate key processes in forest soils and support forest ecosystem services. These include facilitating nutrient availability for primary production, cycling and storage of soil carbon, building and maintaining soil structure, and controlling the fluxes of greenhouse gases, among many others. Nucleic-acid based fingerprinting (e.g. marker gene or transcript amplicon sequencing, environmental genomics) and coarse-scale physiological assays (e.g. in vitro extracellular enzyme activity characterization, incubations measuring substrate and product concentrations) have taught us much about the scope of communities and functioning in the past 25 years; though owing to the size, number, and diversity of the targets, we still have a fundamentally poor understanding of the bacteria, archaea, and fungi in forest soils. One important issue is the poor representation of relevant cultured strains of soil microbes: unknown taxa are easily detectable in soils via isolation of marker gene sequences, but little can be accurately inferred about their physiology and metabolism. Fundamental ecological patterns and processes that have been well established for macro-organismal communities are also still not well understood in the microbial realm. For example, competing hypotheses still exist regarding what controls soil microbial community structure, including if microbial distributional constraints, per se, ever meaningfully influence communities. Further, definitive linkages between microbial biodiversity and ecosystem processes or rates are uncertain. This presentation will give an overview of contemporary approaches to understanding forest soil microbial communities in light of the major epistemological challenges broadly faced in the field of environmental microbiology. It will also showcase recent student-led research from colleagues' and my research groups exploring soil microbial dynamics in managed north temperate and boreal Canadian forests, notably highlighting 1) intensified biomass harvests for enhanced bioenergy production and 2) solutions to potential impacts of harvesting by way of returning bioenergy by-products (wood ash and biochar) to soils.

O.2.1 - Slope exposure effects on chemical and microbiological properties of Norway spruce deadwood and the underlying soil

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High-altitude ecosystems represent unique scenarios for the study of climate impact due to their sensitivity and responsiveness to environmental changes. Topographic features, particularly the slope

exposure and the land-use management (e.g. conversion of grassland to forest) are the dominant factors affecting the vegetation composition as well as the soil functionality with implications for carbon (C) turnover. Deadwood represents an important global C stock and as woody material decays a succession of microbial communities occurs according to their biochemical requirements. However, to date scarce information is available about how slope exposure influences the wood-inhabiting microbiota over the complex decomposition process in an Alpine setting. Therefore, a field mesocosm experiment was set up in the Italian Alps to evaluate the impact of exposure (North (N)- *vs.* South (S)-facing slope) on physico-chemical and microbiological properties (microbial biomass: double stranded DNA; microbial abundance based on real-time PCR: fungi, dinitrogen reductase ("nifH"); and hydrolytic enzyme activities of the main nutrient cycles) of *Picea abies* wood blocks with equal size (2×5×5 cm) and the underlying soil (in direct contact with the wood blocks) over a 3-year period. Overall, our findings showed that the abundance of fungi and nitrogen-fixing bacteria in the deadwood did not significantly vary in terms of exposure, while an increase in their abundance was observed with progressing wood decay at both slopes along with more acidic conditions. In contrast, for the soil we found an exposure effect. At the N-facing site, where cooler and moister conditions prevail, a higher abundance of both fungi and nitrogen-fixing bacteria was evident. Moreover, the impact of exposure was enzyme-specific and time-dependent for both the *P. abies* wood blocks and the underlying soil. These results will represent the base to set up future forest soil C sink managements in relation to the attended climate change effects.

O.2.2 - Nitrogen isotopes to predict forest ecosystem responses to fertilization

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Nitrogen is one of the primary constraints to forest productivity globally. As a result, nitrogen fertilization is a common practice in managed plantations. Yet, the efficiency and widespread adoption of fertilization is limited by uncertainty in the fate of added nitrogen, including retention and partitioning within the ecosystem, and associated responses in forest productivity. Here we synthesize information from region-wide fertilization experiments across three managed forest systems: Douglas-fir (*Pseudotsuga menziesii*) in the US Pacific northwest, loblolly pine (*Pinus taeda*) in the US southeast, and radiata pine (*Pinus radiata*) in New Zealand. Results indicate that stand-level properties, like patterns in the natural abundance of nitrogen stable isotopes, characterize the openness of the ecosystem nitrogen cycle. In particular, foliar isotopic signatures and the enrichment factor (EF = foliage - soil) were the strongest predictors. Such measures relate to ecosystem nitrogen retention and could be further used to scale predictions of nitrogen dynamics in response to fertilization. In the case of foliar predictors, hyperspectral approaches have also shown to correlate with stable isotope values in ways that were decoupled form foliar nitrogen concentration alone, suggesting the potential utility of airborne assessments. Such approaches can serve as important management tools to identify landscapes that are sensitive to nitrogen additions, thereby improving the economic efficiency and environmental sustainability of nitrogen fertilization in forest ecosystems.

O.2.3 - Soil degradation caused by forestry machinery – an assessment scheme for soil ecology and trafficability of skid trails

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This study combines the results of different research projects concerning classification and quantification of soil strength and trafficability during timber harvesting in order to develop an assessment scheme for soil degradation processes caused by forestry machinery on skid trails. Six different machine types were tested on seven different study sites in Lower Saxony between 2012 – 2014 and in Baden Württemberg since 2016, Germany. During these studies, disturbed and undisturbed soil samples were taken in 20 cm, 40 cm and 60 cm soil depth to determine physical soil parameters like precompression stress (Pc), shear resistance (τr), total pore volume (TPV), air capacity (AC), bulk density (ρt), saturated hydraulic conductivity (ks) and air conductivity (ka) as well as texture, pH-value and content of organic matter. Furthermore, major principal stress (σ1) and shear stresses (τs) caused by the tested forestry machinery were measured with the stress state transducer system (SST). As a result of theses measurements an assessment scheme was developed, which can be divided into two levels. The first level distinguishes internal and external soil parameters influencing soil stability. Internal soil parameters are processes and elements which strengthen soil and soil stability describing parameters (Pc and τr), for example clay migration and matric potential. External parameters are elements like wheel load or contact area finally resulting in stress impacts (describing parameters: σ1 and τs). The comparison of internal and external soil parameters lead to the second level of this assessment scheme describing four different processes of soil degradation and deformation: elastic deformation, plastic deformation, failure of bearing capacity and homogenization of soil structure. The consequences for a sustainable land use includes the option to define site and climate specific machines for timber harvesting and trafficability without negative impact for soil physical, chemical and biological functions.

O.2.4 - Digital mapping of soil properties for the Province of Quebec using legacy soil data

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There is a growing need for detailed and quantitative information about the spatial variability of soil properties to be used as inputs in forest biophysical process models. Here, we propose a new 3D gridded soil dataset for the Province of Quebec, Canada. This new dataset provides the spatial distribution for 5 soil properties (sand, silt, clay, organic carbon content, and pH) at a horizontal resolution of 250m and for 6 soil depths. Digital soil maps were generated by combining soil observations from georeferenced legacy datasets (N=9658) with spatially explicit covariates that express the functional relationships between soil properties and conditioning factors. These covariates were derived from sources such as digital elevation model, time series of satellite imagery, gridded climatological variables, and geophysical data. All models were built using a subset of soil profiles as a training dataset (N=6760). This subset was used to train random regression trees using the Random

Forests algorithm. The performance of each model was evaluated using cross-validation based on an independent dataset (N=2898). Results from the cross-validation showed that our current models account for 40–50% of the overall variance across Quebec. Also, a visual comparison of spatial patterns between our products and a geomorphological map showed a fair agreement between both datasets. This implicitly reveals the important contributions of topography and parent material in explaining soil spatial heterogeneity. Our dataset provides a unique portrait of the spatial distribution of soil properties across the Province of Quebec. These new maps of soil properties will be a valuable addition to spatially-explicit forest productivity models and could be used, for example, to study the effect of pedoclimatic conditions on tree growth and productivity. Ongoing work aims at refining the spatial resolution of our product at 100m and at providing a spatial assessment of pixel-level uncertainty.

THEME 1 and THEME 2: Poster Session

P.1.1 - Belowground wood stake decomposition in forested wetlands with varying levels of restoration

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In 2012, we started a cross-site study to evaluate belowground decomposition in a variety of forested sites in the eastern US, with the goal of improving our understanding of belowground carbon cycling. One of these sites was located in forested wetlands in Somerset County, on the eastern shore of Maryland. The study site is located in the Coastal Plain Physiographic Province within the Chesapeake Bay Watershed, with an average maximum yearly temperature of 19.7°C and an average annual rainfall of 1124 mm. There is little topographic variability (≤5% slope) and the majority of the site was historically palustrine forested wetland. Wood stakes of 3 species (*Pinus taeda*, *Populus tremuloides*, and *Acer rubrum*) were installed in the mineral soil and on the surface of the soil in 3 replications of the following treatments: Restored to Saturation, Restored to Inundation, Non-restored, and an Upland reference site. The microbial communities of the soil were characterized at the time wood stakes were installed. Wood stakes were extracted from the mineral soil and surface annually. Decomposition of the mineral stakes varied among the treatments; the community composition of the microbiota also varied. In general, the mineral wood stakes in the Upland treatment decomposed most quickly, with relatively small differences among the restoration treatments. Decomposition on the Upland site may have been aided by the occurrence of termites, which were lacking in the wetter sites. The upland site was also characterized by greater incidence of arbuscular ectomycorrhizal fungi. First year mass loss of the species decreased from Aspen > red maple > loblolly pine. Further work to elucidate differences among the restoration treatments is ongoing.

P.1.2 - Do we know how much carbon is in Maine, USA forest soils?

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Soil organic carbon (SOC) is one of the largest terrestrial carbon pools on Earth. This pool plays a key role in ecosystem processes and in climate regulation. It is increasingly important to identify suitable data on the magnitude of SOC stocks, and use that information in support of managing changes in SOC. In the state of Maine, the land base is nearly 90% covered by forests, and information on C in forest soils will be increasingly important in support of public policy and forest management. However, multiple sources of soils data exist that include information on SOC, and understanding how these data compare is a complex challenge for stakeholders. This research aims to evaluate estimates of forest soil C from three different but complementary data sources: (1) the USDA Forest Service Forest Inventory and Analysis

(FIA) data, (2) the USDA NRCS SSURGO data, and (3) the USDA Rapid Carbon Assessment (RaCA) data. The FIA program is widely recognized as the primary forest monitoring program in the USA that has been measuring soil attributes since 1995, providing a long-term inventory of SOC in forest land. We used forest soil C data of 214 soil plots measured from 1995 to 2015 by FIA across Maine to calculate SOC stocks in Maine forest soils. These data showed overall Maine forest soils had an average of 243.9 ± 0.46 Mg C ha^{-1}, with 188.52 ± 0.21 Mg C ha^{-1} in surface organic (0 - 20 cm) and 55.38 ± 0.25 Mg C ha^{-1} in mineral soils (5 - 20 cm). This research will compare these estimates with the other data sources on soil C, and identify strengths and weaknesses of each source to guide future soil C data utilization.

P.1.3 - Sugar maple litter decomposition and nutrient release rates in southern Quebec: Influence of forest species composition and other environmental factors at various scales

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Recent research on forest litter dynamics suggests that micro-environmental conditions exert a larger control on decomposition and nutrient release rates than climatic differences expressed at the landscape scale, highlighting a need for finer scale studies. We therefore investigated litter dynamics of sugar maple (*Acer saccharum* Marsh.) leaves under hardwoods, mixed-woods and coniferous stands at four locations in southern Quebec to evaluate maple's 'conditioning' ability of acidic and nutrient-poor boreal soils in the context of climate change and species redistribution. A total of 200 litter bags in 22 plots were left to decompose on the forest floor and then retrieved regularly over 2 years for determination of mass loss and nutrient contents. Soil conditions (i.e. temperature, moisture, pH, and nutrients) were recorded in each plot. The results indicate a larger influence of landscape on decomposition relative to micro-environmental conditions. Soil moisture was found to be the most robust predictor of decomposition rate constants, with sites characterized by higher soil moisture showing faster decomposition. No clear generalized effect of forest species composition and forest floor type on litter dynamics was found between sites. The litter at the two sites with higher soil moisture decomposed faster and resulted in a lower mass of leaf material under hardwoods than under coniferous stands. These sites were also the only ones showing significant differences in soil moisture between forest types, i.e. hardwoods being higher than coniferous stands. While litter N showed a relatively stable release rate between sites and forest types, litter C and macronutrient contents showed trends similar to those of mass loss. This study provides further insights on the environmental factors controlling litter decomposition and nutrient release rates of sugar maple and suggests that moisture availability will likely be an important variable for predicting litter dynamics under climate change.

P.1.4 - Fine root turnover of a north boreal *Betula pendula* forest

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On a global scale, about one-third of forest annual net primary production (NPP) belongs to belowground ecosystems, thus fine root turnover has a critical role in the forest ecosystem carbon (C) flux. In boreal forests, even minor temperature changes can affect the amount of greenhouse gas emissions. In Finnish forests, silver birch (*Betula pendula*. Roth) is the main deciduous tree species; covering 16% of the standing volume. We aimed to quantify the fine root biomass and turnover and the annual above- and belowground C input of silver birch and understory in a 73-year-old north boreal forest in northern Finland. We also compared the birch stand to an adjacent Norway spruce stand (Leppälammi-Kujansuu, et al. 2014), which was established after clear-cutting the originally same spruce forest. Birch fine root biomass was 1.4-fold higher than that of understory fine roots and rhizomes (234 ± 22, 171 ± 19 g m^{-2}, respectively). Fine root longevity of birch (372 days) was significantly ($P < 0.05$) shorter than that of understory vegetation (643 days). Our results showed the birch fine root longevity was positively related to root diameter and soil depth. The fine roots born in the late-growing season had a relative lower hazard ratio. Our study proved that the total annual belowground litter production was greater than that of the aboveground litter in a boreal deciduous forest stand. The proportion of the understory annual C input was 35% of the total. The total annual belowground C input was 1.4-fold greater than that of the aboveground.

P.1.5 - Soil microbial responses to changing climate and nitrogen availability – implications for carbon sequestration

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There is a new combination of environmental change over Europe during the last decade - nitrogen (N) deposition declines whilst air temperature is increasing. Soil microbial functional groups and enzyme activities are sensitive to these environmental factors, they affect the decomposers carbon (C) use efficiency and may therefore have implications for C sequestration in forest soils. The first aim of this soil transplant experiment is to assess the responses of soil microbial functional groups and activity to i) change in climate, ii) change in N availability and iii) the combined change of both climate and N availability. The second aim is to discuss possible implication for the decomposition of young and old soil organic matter. The soil transplant experiment was carried out in three Norway spruce field sites; Stråsan (central Sweden), Skogaby (SW-Sweden), and Certovo (south Czech Republic) on Podzolic soils. The mean annual temperature is 3, 8 and 5 °C and the current N deposition is 3, 15 and 15 kgN/ha in Stråsan, Skogaby and Certovo respectively. In addition, there were N fertilization treatments at both Swedish sites. Intact soil cores were sampled (length 35 cm) and installed in 2013, after being divided into humus and mineral soil, and recollected 2017. Cores were exchanged between each site and treatment (n =4) plus two internal controls. Changes in climate were mimicked by transplants Skogaby-Certovo, change in N availability by transplants Swedish sites control and N treatment, and combined changes by transplants Stråsan-Certovo. The soil microbial variables, measured as C and N biomass, enzymatic activities and Phospholipid Fatty Acids (PLFA), of recollected soil cores were compared with those at start of experiment (Rappe George et al., 2017). We hypothesize that transplants' microbial variables are more similar to those of their host than their origin environment and discuss implications for C sequestration.

P.1.6 - European forest soil microorganisms in the face of drought: the influence of tree diversity

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Climate change models predict increased drought frequency and severity for a significant part of Europe, which may affect the activity of the forest microbial communities who control much of the carbon and nutrient cycling. This may alter biogeochemical cycles with potential feedbacks on forest productivity. The resistance and resilience of forest microbes will depend upon several abiotic and biotic factors, among which tree community diversity and composition may be particularly important. We investigated (1) the effects of drying-rewetting (DRW) cycles on European forest soil functioning along a latitudinal gradient ranging from Mediterranean to boreal forests, and (2) the influence of tree species mixtures on soil microbial resistance and resilience during these events. We sampled soil from either natural mature forest monocultures or polycultures in four European countries and subjected them to two DRW cycles, measuring CO_2 and N_2O fluxes before, during, and after each event. Higher tree diversity in mixed forest stands is predicted to harbor higher soil microbial abundance and diversity, which positively influences soil microbe resistance and resilience to drought. We expect that CO_2 and N_2O fluxes in monoculture soils fluctuate more strongly in response to DRW events due to less resistant and resilient microbial communities compared to mixed tree stands. Moreover, biomass, activity, and the capacity to efficiently use a variety of C-substrates are more impaired in soil microbial communities from mono-specific forests than mixed forests after two DRW cycles. Likewise, losses of CO_2 and N_2O into the atmosphere are higher and DOC/DON leaching greater from mono-specific forest soils. These results could help predict changes in forest microbial functioning under climate change based on tree community composition and possibly predict changes in forest productivity. However, a better understanding of how microbial community composition changes during DRW events is still required.

P.1.7 - Assessment of dead roots biomass in German forests

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The estimation of carbon storage in deadwood is an important element of the German greenhouse gas reporting of forests. Currently, there are some shortcomings in the reporting of deadwood regarding the completeness and level of detail. Until now, there is no information about dead roots and only limited information about rootstocks. The assessment of dead coarse roots is a very tedious, time consuming and complex process. So far, there are no methods to systematically assess dead coarse roots on a national level. Therefore, the main focus of this project is the development of an approach to assess and

estimate dead coarse roots volume and (carbon) biomass as well as the implementation of this approach into a nationwide field inventory. The assessment will be conducted based on indirect non-destructive methods for the dominating tree species, i.e. *Picea abies*, *Fagus sylvatica*, *Pinus sylvestris* and *Quercus sp*. and dependent on the main soil types in Germany. With this approach we aim to provide a basis for an improved and advanced greenhouse gas reporting.

P.1.8 - Silicon dynamics in hardwood and conifer trees of temperate forests with a focus on interactions with lignin and tannin metabolism

Roxane Jaffray[1], Benoit Cote[1]
[1]CFR-McGill

Silicates, comprised of silicon (Si) and oxygen, are ubiquitous in natural systems. Si in the form of biogenic silica in plants is known to provide structural, physiological, and protective benefits to plants. While being 10-20 times energetically cheaper than lignin, Si could therefore confer a competitive advantage to Si-accumulating plants. This study examines how foliar Si concentration varies among 17 hardwood and conifer tree species in relation to leaf chemical properties (lignin, cellulose, condensed tannins and Ca). I hypothesized that trees that are high in leaf Si (beech and sugar maple) have lower leaf lignin and Ca, but higher condensed tannin concentrations. The study was conducted at the International Diversity Experiment Network with Trees (IDENT) plantation on the Macdonald Campus in Sainte-Anne-de-Bellevue, QC. Tree leaves were sampled from four blocks of monoculture plots in the summer of 2014 and 2015. Leaf Si was extracted with a NaOH digestion, lignin as Acid Detergent Lignin (ADL) and Ca in concentrated HNO_3. Condensed tannins were extracted with methanol, followed by a proanthocyanidins assay with acid butanol. My results indicate that hardwoods can be active Si accumulators (beech), passive accumulators (maples) and Si excluders (all other hardwoods), whereas conifers are mainly Si excluders. My study suggests a different metabolic role for Si in hardwoods and conifers with Si being negatively associated with lignin and calcium in hardwoods, and Si being positively associated with condensed tannins in conifers. Both relationships are in agreement with my hypothesis but the role of Si in trees seem to be species specific. Understanding these differences amongst species can contribute to forest management. Further research is necessary to determine the underlying mechanisms and functions of Si and how it is intertwined with phenol metabolism, Ca nutrition and plant cell wall components in different tree species.

P.1.9 - Soil-water retention and saturated hydraulic conductivity of near-surface forest soils in topographically complex terrain

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Few studies have quantified soil hydraulic properties on steep topography to understand how slope morphology and soil depth influence soil-water retention and saturated hydraulic conductivity. Our objective was to understand how local soil hydraulic properties interact with hillslope morphological characteristics that affect landscape evolution. Specifically, we asked: 1) How local slope and upslope drainage area relate to total depth to bedrock; 2) Does the interaction of local slope, upslope accumulated area, and soil depth create differences in shallow soil hydraulic properties (soil-water retention and saturated hydraulic conductivity)? We collected soils on north-facing convergent and divergent slope morphologies of a 0.1 km^2 sub-catchment within the H.J. Andrews Experimental Forest in Oregon, USA. We measured soil depth to bedrock at 38 locations, with two measurements per location (<5 m apart). Soil cores were collected at a subset of these locations to characterize soil water-retention and saturated hydraulic conductivity at 15 and 45 cm depth. Upslope drainage area ranged from 8 to 3,278 m^2, local slope ranged from 27 to 44°, and depth to bedrock ranged from 0.26 m to >5.15 m among measurement locations. Preliminary results suggest that depth to bedrock may be highly variable within short distances (<5 m). The average and standard deviation for the difference in depth to bedrock between location replicates was 0.90 ± 0.83 m. Average depth to bedrock was greater on convergent (2.74 ± 1.35 m) compared to divergent (1.77 ± 1.06 m) slope morphologies ($p<0.001$). A mechanistic link between topography, soil depth, and soil hydraulic properties has the potential to improve predictive modelling of time and space variability of soil water storage dynamics. This understanding may better inform forest management strategies aimed to reduce vegetation water stress.

P.1.10 - Does increasing *Pinus echinata* in mixed *Quercus* forests increase above- and below-ground carbon stocks?

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There is increasing interest in restoring *Pinus echinata* (shortleaf pine) in the Ozark Highlands where it was once abundant in pure stands or in mixtures with *Quercus* (oaks) and other hardwoods prior to widespread logging during the early 1900s. Restoring shortleaf pine in this region is viewed as an adaptive strategy for climate change because of projected favorable growth under modeled emissions scenarios. It may also be a climate change mitigation strategy because softwoods generally store more carbon in the forest floor and in the underlying mineral soil than do hardwood forests. Despite these generalities, it remained unknown whether carbon storage differs between oak and shortleaf pine forests in the Ozark Highlands or how increases in shortleaf pine abundance will affect the quantity of carbon stored in the forest floor and mineral soil. Study objectives were to examine the effect of increasing the shortleaf pine component on above-and below ground carbon storage in mature stands. At the Sinkin Experimental Forests in Missouri, USA, we inventoried vegetation, sampled the forest floor, and sampled the mineral soil to a 1-m depth in 130, 0.05-ha plots having a range of shortleaf pine from 0 to 99% relative stocking. Carbon in the trees and roots were estimated using allometric equations, forest floor carbon was estimated as a percentage of its mass, and carbon in the mineral soil was determined by combustion. The forest floor carbon increased significantly with increasing pine stocking. There were no significant increases in the above-ground, root, and mineral soil carbon storage as a function of composition. Regardless of the composition, twice as much carbon is stored in trees than in the mineral soil or forest floor. Managers seeking to enhance carbon storage in these systems should focus on increasing the stand density and biomass of the pine—oak mixtures.

P.1.11 - Thin skin – forest soil dynamics in Karst environments

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Karst catchments supply almost half of Austria's population with drinking water. These areas are located in the Calcareous Alps, where forests dominate the montane and subalpine vegetation belts. Disturbances by windthrow and bark beetle have intensified in the last decades, posing a significant threat to forest and soil functions. Vulnerable Lithic and Rendzic Leptosols and Folic Histosols, the latter sometimes comprised solely of organic surface layers (Tangel), cover ca. 40 % of the Karst area. Investigations along a salvage logged disturbance chronosequence revealed a 60 % carbon loss from organic soil layers and an increase in visible bare rock outcrops within a few years post-disturbance. CO_2-flux measurements at the soil surface of windthrow sites suggested a significant increase in heterotrophic soil respiration when compared to intact control stands. A calculated net carbon loss was in the same order of magnitude as changes in soil carbon stocks along the chronosequence. The soil C losses were accelerated on the one hand by increased soil temperatures and on the other hand by limited ecosystem resilience in the region. Despite successional increases in herb and grass vegetation cover, tree regeneration was restricted. Eddy covariance measurements confirmed net CO_2 losses even eight years after windthrow. A main factor driving insufficient tree regeneration in Austrian mountain forests is ungulate herbivory. Ungulate exclosures at windthrow sites resulted in a distinct difference in vegetation cover and soil climate between fenced and non-fenced plots. Non-fenced sites, dominated by grasses, showed particularly high soil CO_2 efflux rates, while under established tree regeneration a recovery of the litter layer was observed. The studies indicate that proactive forest management promoting tree regeneration is necessary to alleviate negative effects of forest disturbances on soil functions.

P.1.12 - Impact of tree species on C stocks and C sequestration in German forest soils

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In face of climate change, an appropriate forest management is necessary, to sustain robust forest ecosystems, but also timber yield. The selection of appropriate tree species is among the relevant challenges regarding this issue. The aim of our study is to analyze the effect of different tree species on C sequestration and stabilization of organic matter in forests soils of Southern Germany. The conversion of old monocultures of *Picea abies* to mixed forests which was initialized in many forests about 40 years ago provides today a unique opportunity to analyze and quantify the influence of tree species on soil properties. For the conversion young trees (today > 30 years old) of the intended species were planted below the old spruce trees. We analyzed soil C stocks and C stabilization of clusters with natural spruce regeneration, of clusters planted with *Fagus sylvatica*, and of *Abies alba* at five different sites with widely differing site characteristics. We analyzed the depth distribution of soil organic carbon down to 40 cm soil depth under the different tree species as well as the distribution of organic C within light fraction, occluded light fraction and heavy fraction. Furthermore, we analyzed aggregate stability using dynamic digital image analysis. The C stocks of the forest soils ranged between 62 and 213 $Mg \cdot ha^{-1}$ at the different sites. The effect of tree species was significant at 4 out of 5 sites, yet with different magnitude and direction. Interestingly, the first results of density fractionation indicate higher amount of organic matter in the fraction of occluded light fraction under those tree species, which provided more stable soil aggregates. Based on the results from all study sites we will develop/present a concept on controls and mechanisms of C sequestration in forest soils.

P.1.13 - A multi-site approach to assessing the effect of thinning on soil carbon contents in pine, oak, and larch forests in South Korea

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Karst catchments supply almost half of Austria's population with drinking water. These areas are located in the Calcareous Alps, where forests dominate the montane and subalpine vegetation belts. Disturbances by windthrow and bark beetle have intensified in the last decades, posing a significant threat to forest and soil functions. Vulnerable Lithic and Rendzic Leptosols and Folic Histosols, the latter sometimes comprised solely of organic surface layers (Tangel), cover ca. 40 % of the Karst area. Investigations along a salvage logged disturbance chronosequence revealed a 60 % carbon loss from organic soil layers and an increase in visible bare rock outcrops within a few years post-disturbance. CO_2-flux measurements at the soil surface of windthrow sites suggested a significant increase in heterotrophic soil respiration when compared to intact control stands. A calculated net carbon loss was in the same order of magnitude as changes in soil carbon stocks along the chronosequence. The soil C losses were accelerated on the one hand by increased soil temperatures and on the other hand by limited ecosystem resilience in the region. Despite successional increases in herb and grass vegetation cover, tree regeneration was restricted. Eddy covariance measurements confirmed net CO_2 losses even eight years after windthrow. A main factor driving insufficient tree regeneration in Austrian mountain forests is ungulate herbivory. Ungulate exclosures at windthrow sites resulted in a distinct difference in vegetation cover and soil climate between fenced and non-fenced plots. Non-fenced sites, dominated by grasses, showed particularly high soil CO_2 efflux rates, while under established tree regeneration a recovery of the litter layer was observed. The studies indicate that proactive forest management promoting tree regeneration is necessary to alleviate negative effects of forest disturbances on soil functions.

P.1.14 - Cutting edge northern peatland research at the SPRUCE experiment: early results

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The Spruce and Peatland Responses Under Changing Environments experiment, or SPRUCE, is an ambitious ecosystem-level experiment that is testing the response of high-carbon northern peatland ecosystems to increased temperatures and elevated carbon dioxide. The experiment is being conducted in a black spruce peatland in northern Minnesota, USA, at the USDA Forest Service's Marcell Experimental Forest (MEF). SPRUCE is supported by the US Department of Energy and is a collaboration

between Oak Ridge National Lab, the USDA Forest Service and numerous other scientists from across the globe. Northern peatlands are an ecosystem considered especially vulnerable to climate change, and anticipated to be near their tipping point with respect to their carbon balance, especially at the southern margin of their range at MEF. Responses to warming and interactions with increased atmospheric CO_2 concentration are anticipated to have important feedbacks on the atmosphere and climate. The manipulation is evaluating the response of the existing communities to a range of warming levels from ambient to +9°C, with and without elevated CO_2, provided via large, open-top chambers. Belowground heating began in 2014, aboveground heating in 2015, and elevated CO_2 treatments commenced in June 2016. We anticipate running the experiment for 10 years. I will give an overview of SPRUCE and some initial results, including pre-treatment characterization of the peatland and some early findings following the establishment of the treatments.

P.1.15 - Increasing soil carbon content with diminishing exchangeable manganese in temperate coastal forests of Vancouver Island, British Columbia

Marty Kranabetter
BC Ministry of Forests, Lands and Natural Resources

Recent publications have highlighted an intriguing relationship in forest soils where carbon (C) content, particularly the amount of forest floor, increases exponentially with declines in exchangeable manganese (Mn). The mechanism behind this observation is thought to be the key role of Mn in peroxidase enzymes, which are produced by saprophytic and mycorrhizal fungi to facilitate the breakdown of recalcitrant organic matter. I searched for corroborating evidence of a correlation in exch. Mn and soil C over an edaphic gradient of temperate coastal forests across southern Vancouver Island. The study is composed of fourteen sites with a single tree species (coastal Douglas-fir, Pseudotsuga menziesii), between 40-60 years in age, that span a podzolization gradient between very dry to very wet temperate forests. Forest floor accumulation was greatest on strongly podzolized soils, particularly sites with seepage, and these plots also had the lowest concentrations of exch. Mn (approx. 0.2 and 0.015 cmol kg^{-1} for forest floor and mineral soil, respectively) of the study. Consequently, total soil C content and exch. Mn content of the upper soil profile (forest floor + 0-20 cm mineral soil) were well correlated in an inverse power function, similar to patterns reported elsewhere. Foliar Mn concentrations of both Douglas-fir foliage and mushrooms (saprophytic and ectomycorrhizal species) collected from these study sites will be assessed to confirm a similar decline in bioavailable Mn on heavily podzolized soils that would be consistent with diminished peroxidase activity. The results of this and related studies highlight a potentially critical bottleneck in organic matter turnover that would likely improve upon current forest carbon models focused exclusively on macroclimate, productivity and litter quality parameters.

P.1.16 - Is the turnover of soil organic matter in European beech forests P limited?

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Carbon sequestration and the magnitude of C stocks in forest soils depend on the complex interaction of climate, soil, and vegetation, in addition to microbial activity. Ongoing N deposition into forests of central Europe is assumed to have strong effects on microbial activity and thus to aggravate possible P limitation of forest ecosystems. To study the impact of N and P input on SOM turnover, we established a factorial NXP application experiment at three study sites on silicate rock differing in total P stocks (160 – 900 g P m-2, down to 1 m depth). Fertilizers were applied in dissolved form with garden sprayers directly on the forest floor (50 kg P ha^{-1} as KH_2PO_4, 90 kg N ha^{-1} as NH_4NO_3 at three different dates). We sampled the forest floor as well as the mineral soil (0-5, 5-15 and 15-30 cm) before the experiment started and after 6 and 12 months. Soil pH, water-extractable DOC, total C-, N- and P-contents in bulk soil and in soil aggregates (< 2mm), as well as forest floor stocks were analyzed. Already after 6 months a significant increase of DOC concentration in water extracts of Oi and Oe layer was found at all three sites treated with N and P, while the N treatment induces a decrease in DOC at all sites. P application increased DOC concentrations at the sites with higher P availability but showed no effect at the P poor site. Results for density fractionation 12 month after fertilization will be presented at the conference to analyze effects of N and P application on C sequestration. So far our results indicate that DOC production at the studied beech forest ecosystems is P limited even at the P rich sites.

P.1.17 - Effects of litter manipulation on soil-atmosphere greenhouse gas exchange in a subtropical secondary forest

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Forest soils are generally net sources of CO_2 and N_2O as well as net sinks of CH_4 that could play a role in governing future climate change. Variations in the amount of litterfall in response to changing atmospheric CO_2 levels might also alter soil-atmosphere greenhouse gas (GHG) exchange in forests through various physical and biogeochemical feedbacks. We carried out weekly measurement of soil GHG fluxes in four replicate plots for each of the three experimental treatments (i.e. controls, litter addition, litter removal) in a subtropical secondary forest in Hong Kong from 2015 to 2017. We found a positive impact of litter addition on soil CO_2 emissions only after two years, while litter addition significantly suppressed CH_4 uptake by 33% over the study period. The removal of litter enhanced N_2O emissions by over 90% in the initial year but had no significant effects on N_2O fluxes in subsequent years. Our results showed that forest litter could act as a physical barrier in affecting soil-atmosphere GHG exchange particularly at the initial stage, while the biogeochemical changes induced by litterfall could play a role on GHG dynamics when given more time.

P.1.18 - Novel peatland management practices - key for sustainable bioeconomy and climate change mitigation

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Peat soil of croplands and forests is currently the largest emission source in the LULUCF sector and climate-smart peatland management has large potential to mitigate emissions. We aim to develop ecologically and economically sustainable climate change mitigation options for forest and cropland

management. The emissions from managed peat soils may be mitigated by limiting depth of actively decomposing peat layer by raising the soil water table closer to soil surface. In managed peatland forests we test continuous cover forestry with elevated water table as an alternative to rotation forestry with clear-cutting and ditch network maintenance. On croplands, other potential means to mitigate emissions are no-till, catch crops and addition of biochar. We will measure GHG exchange on experimental study sites and develop dynamic models for predicting GHG exchange for different management practices. The data will feed economic analyses, i.e., static gross margin and profitability calculations. Microeconomic dynamic models with optimization will be used to quantify the required incentives for a farmer to choose climate-smart management options. For forest sites, cost-efficiency of mitigation options is assessed by comparing net present value - GHG ratios of the management alternatives. We will compile GHG emission scenarios needed for evaluation of the climate policy options in Finland. Our results will have an important impact on the economic optimization of climate change mitigation in the agriculture and LULUCF sectors and they help to meet the agreed emission reduction targets.

P.1.19 - Effects of environmental change on long term tree growth and water use efficiency in Tiantong National Forest Park, Ningbo, China

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It has been well observed in many studies globally that the increased atmospheric CO_2 concentration has acted positively to the plants growth rate in the past century. However, it is crucial to understand how long the forest growing trend will remain towards the elevating CO_2 concentration before it declines. In this paper, we will be focusing on researching the long term tree growth respond to CO_2 rise, in combining with other environmental facts, and its influences on climate change in the future.
This study has sampled tree species, *Pseudolarix amabilis* and *Cryptomeria japonica*, from Tiantong National Forest Park, a subtropical forest located in the east of China. The long-term tree-ring chronologies established and basal area increment (BAI) of the samples has been calculated according to the tree ring width. Additionally, using isotope analysis to determine intrinsic water-use efficiency (iWUE), and analyse the relationships among BAI, CO_2, and iWUE. Through the tree cores of target samples, obvious results can be obtained that BAI values continuously increased in both tree species with the rise of CO_2 concentration till mid-nineteenth century, and the CO_2 critical points were found at 365.07 ppm (around year 1997) and 363.02 ppm (around year 1996) of *Pseudolarix amabilis* and *Cryptomeria japonica*, respectively, where tree growth started to decline even with CO_2 increase. Furthermore, iWUE exerted a continuous increase trend with the increasing of CO_2 concentration while the critical points are also clearly visible. The reason for the critical points appear was found that tree growth was more CO_2 driven before reaching the critical points, while more water stress driven after the critical points. The critical points vary from diverse tree species and different environmental conditions, and air relative humidity plays an important role in this process.

P.1.20- Variation of soils properties across forest - agricultural field ecotones of SLP Masaryk Forest Kritiny in the Czech Republic

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Transitional zones between biomes are clearly noticeable changes in vegetation structure and pattern. However, little is understood of the key soil factors that permit these changes in vegetation seen at ecotone regions and how soil properties vary across ectones. This study sought to analyse how key soil properties vary across clearly defined ecotones at the study plots of SLP Masaryk Forest Kritiny from the forest stand and agricultural field. Soil samples from four study plots at the SLP Masaryk Forest, Krtiny were obtained monthly starting from early Spring to late Autumn for two consecutive years. On each of the study plots, there were thirteen sampling sets at a depth of 5 cm: one spot clearly marked as ecotone, six into forested stand and six into agricultural field. With respect to laboratory work, soil samples collected were tested for: maximal capillary water capacity, minimal air capacity, pH in water (actual soil reaction) and pH in chlorides (potential soil reaction). The results show a pattern of soil acidity decreasing from the forest stand towards the agricultural field. The maximal capillary water capacity for both the forest stand and agricultural field averaged between 30 – 40 percent. However, there was a sharp decrease in the minimal air capacity from the forest stand towards the agricultural field thus the minimal air capacity of the forest stand averaged between 10 – 20 percent where as that of the agricultural field averaged between 5 – 10 percent. The outcome of this study supports the ecotone concept of diverse species being able to survive at ecotone regions as well as confirming the accession that ecotones serve as ecological limits for dominant species of adjoining biomes. This is because the critical soil factors required for the survival of the dominant species of adjoining biomes cease to exist at ecotone regions.

P.1.21 - Evaluation of the mitigation potential of climate change following afforestation of open woodlands

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The speed at which climate change is occurring today is alarming and strategies for adapting and mitigating these changes are at the heart of international debates. Emissions of anthropogenic GHGs, especially carbon dioxide, are one of the main causes of global warming. The role of forests in carbon sequestration is well known, and the addition of the substitution and sequestration effect of wood products helps to increase the amount of carbon sequestered and decrease the effect of carbon dioxide emissions. The forest sector plays a key role in mitigating climate change through forest management scenarios, such as afforestation, to increase forest sequestration capacity. This project aims to evaluate the mitigation potential of climate change through afforestation of open woodlands and poorly regenerated burns. Specifically, the amount of carbon sequestered by ecosystems will be modeled and the substitution and sequestration effect of wood products from harvesting forest stands will be added. The effects of climate change will also be included in the modeling to determine changes in carbon

stocks in different pools over the long term. The modeling will be done using the Forest Carbon Accounting Model CBM-CFS3, created by the carbon accounting team at Natural Resources Canada's, Canadian Forest Service. Expected results from modeling of afforestation scenarios will provide a better understanding of forest carbon interactions. Also, this study will verify the contribution of wood products and their substitution effect in the calculation of the total carbon budget in the context of an increase in forest area in the province of Quebec. The expected results will enable us to guide political institutions to better steer climate change mitigation measures and policies.

P.1.22 - Soil carbon sequestration in long term managed grassland and broadleaf forest

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It is increasingly important to adequately understand and quantify the change in terrestrial carbon sinks under native woodland compared to common agricultural land uses. This study has employed deep soil sampling (1.1m) by depth and horizon in a long term *Quercus robur* forest, where a 27 site chronosequence was divided into young (<47 year), mature (110> >70 year) and ancient forest (>220 year) stands, and a paired grassland site in Southern England, together with physical fractionation of soil carbon. It aims to quantify differences in soil carbon accumulation by depth and soil horizon, and quantify the distribution of carbon in fractions of different recalcitrance. The known forest and agricultural land use history allows us to hypothesise that land has reached steady state with respect to carbon and nitrogen. The results therefore provide insights into the potential benefits of future forest management and grassland afforestation on a seasonally waterlogged clay soils in a maritime temperate climate.

P.1.23 - Modelled soil carbon losses after harvesting oak forest on a seasonally waterlogged clay

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Forest management affects not only above ground biomass, but also soil organic carbon dynamics. Modelling can be used to supply a more nuanced understanding of soil organic carbon dynamics during tree growth and harvesting events. This study uses a well-known soil organic matter model, RothC. Input data is provided from an oak forest chronosequence and grassland in Southern England. Physical fractionation of soil organic matter from the oldest forest and grassland sites was used to provide fractions that could be assigned to pools in RothC with different turnover times. The dynamic simulation starts using soil organic matter pools and plant inputs initialised using the oldest, steady state forest sites. The youngest sites are assigned the same plant inputs as the grassland site, which is assumed to be in a steady state. After canopy closure sites are assigned the same plant inputs as in the oldest sites. Plant inputs are distributed through time using the forest growth model, 3PGN. Every site is checked separately as marked differences in soil properties exist. This approach allows the decline in forest soil carbon after harvesting and gradual accumulation during stand development to be simulated.

P.1.24 - The Canadian Peatland Carbon Modelling Project

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Canada contains the world's second largest area of peatlands, covering approximately 13% of the Canadian land area and storing 103 to 184 Pg carbon (C) of which more than half is found in the Boreal region. Canadian peatland soils store 60% more C than is stored in forest biomass and soils. The importance of peatlands in the C balance of Canada has been recognized for a long time but our ability to estimate their net greenhouse gas balance has not been possible due to the lack of an adequate peatland type mapping across the nation and an appropriate model to estimate the net C flux. Over the last three years the Canadian Forest Service has undertaken a project to estimate greenhouse gas emissions from peatlands in Canada's forested area. The project has produced a national map for the distribution of nine peatland types, preliminary estimates of emissions based on combining the map with emission rates reported in the literature, a model (the Canadian Model for Peatlands [CaMP]) for spatially explicit estimation of emissions at 1 ha resolution, along with a database for model parameterization (NPP, decay rates) and a digital update to "A wetland data base for the western boreal, subarctic and arctic regions of Canada" (Zoltai et al. 2000). Challenges and achievements of the project are described along with plans for expansion of the model's capabilities in the future.

P.1.25 - Long-term changes in soil carbon stocks after afforestation of cropland in Denmark

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Afforested soils are thought to become carbon sinks for climate change mitigation after conversion from cropland. This hypothesis was examined by Barcena et al. (2014) in a chronosequesce on clayey soils in Denmark, 0-40 years after afforestation with Norway spruce and oak, respectively. They found indications of a soil organic carbon (SOC) loss during the first decades, followed by a recovery phase of yet unknown duration. The present study aims to compare differences in SOC stocks between afforested and cropland soils in a longer term. A chronosequence of nineteen afforested stands with adjacent croplands were identified throughout Denmark, where afforestation had taken place 37-137 years ago. The forest floor was sampled, as well as mineral soil from the layers 5-10, 10-15, 15-30, 30-60, 60-80, 80-100 cm. We measured soil carbon concentrations and bulk densities, and estimated the SOC stock in different layers after correction by the equivalent soil mass method. We hypothesized that SOC stocks in forest soils are higher compared to adjacent cropland and that the difference between the two land uses increases with time since conversion. Apart from built up forest floors, preliminary results indicate an average increase in SOC stocks in upper mineral soil layers, and, for some sites, also in deeper layers. Further analyses will be made to examine the relationships between SOC stocks and tree species group, soil type and other soil parameters. The results will be discussed in the light of the land use and management history, based on available information from state forest achieves and farm owners.

P.1.26 - Microtopography and rainfall exclusion effects on sugar maple and bitternut hickory fine roots vertical distribution

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The aim of this project is to understand the link between fine roots production and physical characteristics of the environment at tree level, under drought conditions. Preliminary results from 171 plots in Montérégie showed that micro-topographical position influenced tree mortality, which is more important in pits than on mounds. We hypothesize that fine rooting depth, biomass, growth rate and resistance to water shortage vary between pits and mounds micro-topographical positions. To test this hypothesis, we set up 16 sites in Vallée-du-Haut-Saint-Laurent, Qc, Canada with contrasted exposures and soil textures. Four mature sugar maple and four bitternut hickory tree were selected in each site, half in pits and half on mounds. To simulate drought, half of the sampled individuals were isolated from rainfall by plastic covers of 3.65m radius during 1 month. This setup reduced soil moisture and increased water tension significantly. At the base of each tree, root growth-chamber in a soil pit let us monitor the fine root production through the summer while soil cores were used to evaluate biomass, both according to soil depth. Our results show an important effect of micro-topographical position on the vertical distribution of the fine root (biomass and production), whatever the species.

P.1.27 - Afforestation aid forest soil carbon sequestration

Elena Vanguelova
Forest Research UK

Growing trees can help to mitigate climate change by sequestering carbon (C), making a significant contribution to meeting the UK Government's Greenhouse Gas (GHG) emission reduction targets, as well as offering an alternative fuel source to fossil fuels. On average, up to 75% of the overall forest C could be stored in the soil to 1 m depth. However, different soil types have different levels of C and respond differently to forest establishment. For example, organic soils, which tend to be upland, peaty soils, store twice the C of mineral soils, yet need more intensive preparation for afforestation. As a result, it is beneficial to know where best to focus efforts on future afforestation for GHG balance purposes. This can then be reflected in policies to support woodland creation targets and land use change to forestry. This presentation will review up to date research and monitoring quantifying soil C changes due to afforestation and subsequent forest rotations. It will cover results from repeated soil surveys, long term soil monitoring and forest chronosequence studies.

P.1.28 - Wood decomposition in forest soils: the role of subterranean termites

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Coarse woody debris is an important structural and functional component of forest ecosystems, and is an important terrestrial C sink because of its slow decomposition rate. Consequently, land managers and climate change modelers need to understand how forest management practices may alter both surface and belowground wood decay and resultant soil C sequestration. Numerous wood decomposition studies have shown that fungi are the main biological drivers, but subterranean termites also have an important role in the decay process, as well as soil aeration and nutrient cycling, in many forest ecosystems. Much information is available on mound-building termites in tropical ecosystems, but less is known on subterranean termites in temperate forests. Subterranean termites are found in a wide variety of U.S. soils, in which their distribution and population density are generally controlled by food availability, but also by soil microclimate (temperature and moisture), as termites are less abundant in soils that freeze annually. Extensive research has been conducted on the life cycle, community structure, and destructive impacts of subterranean termites on wooden structures in urban areas. In contrast, relatively little is known on the impact of management in non-urban forest ecosystems on subterranean termite activity, especially on wood decomposition, organic matter cycling, and carbon sequestration in mineral soil. As part of the North American Long-Term Soil Productivity Study (LTSP), standard wood stakes used as an index of organic matter decomposition were found to have termite-feeding damage in many soils of the LTSP network. The results of our studies show the effect subterranean termites can have on wood decomposition in the litter layer and mineral soil across a range of soils and climatic conditions, and the effect of LTSP treatments (soil compaction and organic matter removal) on termite activity and subsequent wood decomposition.

P.1.29 - Three years of experimental warming increased heterotrophic respiration and decreased root-dependent respiration in a subtropical plantation

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The most advanced global land models remain highly uncertain in their predictions of the magnitude and direction of the effects of global warming on soil respiration. To better understand how soil respiration responds to warming, we conducted a three-year soil warming experiment in a subtropical Castanopsis hystrix plantation. Soil respiration (Rs) is considered the sum of root-dependent respiration (Rrd) and heterotrophic respiration (Rh). We estimated root-dependent respiration using the difference in soil respiration between trenched (100 cm deep) and non-trenched plots. Our results showed that soil moisture was significantly higher in the trenched than non-trenched subplots in the second year, but not in the third year. Soil warming increased Rh, and suppressed Rrd. The responses of Rh and Rrd to soil warming varied with the seasons, being greater in the dry–cool than in the wet–warm season. The elevated Rh levels may have resulted from the increased soil temperature and decreased soil moisture due to warming. The decline in soil total nitrogen (STN) content attributed to soil warming decreased arbuscular mycorrhizal fungi (AMF) biomass, which led to the reduced Rrd. The decreased Rrd and increased Rh appear to have offset each other, resulting in unaltered Rs levels under the warming

treatment. Our study shows that mycorrhizal colonization can have similar effects on soil carbon as it does abiotic environmental factors such as temperature and moisture, and affects Rs dynamics.

P.1.30 - Greenhouse gas exchange affected by *Alnus glutinosa* when used to recover compacted anaerobic forest soils

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Mechanized logging leads to soil compaction and deformation on around 10-20 % of the forest area when dedicated skid trails are implemented in distances of 20-40 m to each other. Such soil-physical alterations often produce more or less pronounced anaerobic conditions with the possible consequence of less CH_4 oxidation and an increased N_2O efflux. Planting black alder (*Alnus glutinosa*) is regarded as one option to accelerate the regeneration of soil structure due to its ability to grow roots under anaerobic soil conditions. We compared GHG exchanges on skid trails replanted with alder 10 and 17 years ago to disturbed and undisturbed references, partially replanted with *Fagus sylvatica*. On all skid trails, we observed increased N_2O emissions and decreased CH_4 oxidation rates. Even though there was evidence for a better soil aeration on skid trails under alder, neither a positive effect on CH_4 uptake nor lower N_2O emissions were found. On the undisturbed reference sites with alder, we observed higher N_2O emissions and lower CH_4 oxidation rates than under other tree species. Both can possibly be attributed to symbiotic nitrogen accumulation by *Frankia alni*. In case of CH_4, this effect could be explained by the inhibition of the enzyme monooxygenase by ammonium. Obviously *Alnus glutinosa* is able to develop a vital root system under skid trails promoting the regeneration of soil structure. While the effects of alders on GHG exchange in the undisturbed stand are very pronounced, they are unclear and most probably weak on the skid trails.

P.1.31 - A continental - scale investigation of factors affecting soil organic matter vulnerability to decomposition

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Soil organic matter (SOM) is the largest actively-cycled terrestrial carbon (C) pool and is linked to atmospheric C and climate through soil respiration, one of the largest terrestrial C fluxes. Consequently, due to potential carbon-climate feedbacks, understanding SOM dynamics is critical to predicting the effects of global change drivers, such as climate and land use change. However, there is an ongoing paradigm shift in regards to controls on SOM dynamics with SOM molecular recalcitrance playing a

lesser role than soil and other ecosystem properties, which has led to a knowledge gap in being able to predict SOM vulnerability to environmental change. In an effort to address this knowledge gap, a year-long, two-way factorial laboratory soil incubation is currently underway. The experiment involves incubating samples from two horizons (A and uppermost B) from 30 National Ecological Observatory Network (NEON) sites spanning a wide range of climates, ecosystems, and soil types under two temperature levels (site mean summer temperature (MST) and MST + 5 ºC) and three moisture levels (-33 kPa, -150 kPa, and -400 kPa). Over the course of the incubation, headspace CO_2 concentrations are being periodically measured to calculate cumulative C respired. A vulnerability metric will be calculated by normalizing cumulative C respired to total sample organic C, and this metric will be combined with additional data streams in a multivariate analysis to determine which factors are significant in controlling SOM vulnerability to decomposition. Insights gained from this project have the potential to improve our ability to predict the degree of vulnerability of SOM in a given soil and could thus inform broader climate change adaptation and mitigation efforts.

P.2.1 - Determining a wildfire-induced forest soil erosion index using remotely sensed images and the Terrestrial Ecosystem Information data

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During the summer 2017, the province of British Columbia, Canada experienced its worst recorded wildfire season with more than 1.2 Million hectares burned. The large extent of burned forest exposed soil to erosion. Some areas are more at risk and identifying the most vulnerable areas to erosion can improve remediation and protection efforts. The objective is to use burn intensity information derived from remotely sensed images, soil characteristic data, and slope information to create a potential erosion index and a robust methodology to answer specific question about landscape dynamics and prioritizing conservation intervention. The goal of this study is to develop a workflow and to provide a tool to determining the most sensitive areas for erosion. The tool can support prioritization critical areas for remediation. The study area is the Elephant Hill wildfire extend (~140,000 ha), which is located in central BC. The Burned Area Reflectance Classification (BARC), a satellite-derived image of post-fire vegetation, uses near infrared and mid infrared light to differentiate the spectral reflectivity of forest impacted by wildfires and differences burned severity. Soil characteristics (texture, parent material, and drainage) were obtained from the Terrestrial Ecosystem Information (TEI) database– Soil survey of the BC Ministry of Environment, and slope information was derived from Terrain Resource Information Management (TRIM) 25m DEM. Each dataset was reclassified according to their level of impacts on soil erosion. The classes were assigned to each raster layers, based on expert knowledge. Each classified raster layer was overlay and the erosion index was calculated for each raster grid cell.
The index shows that 54,000 ha are at higher risk of erosion, 62,000 ha at medium and 30,000 ha at lower risk. The information can be used to prioritize remediation sites and water body protection.

P.2.2 - Predicting soil properties in the Canadian boreal forest with limited data: comparison of spatial and non-spatial statistical approaches.

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Digital soil mapping (DSM) involves the use of georeferenced information and statistical models to map predictions and uncertainties related to soil properties. Many remote regions of the globe, such as boreal forest ecosystems, are characterized by low sampling efforts and limited availability of field soil data. Although DSM is an expanding topic in soil science, little guidance currently exists to select the appropriate combination of statistical methods and model formulation in the context of limited data availability. Using the Canadian managed forest as a case study, the main objective of this study was to investigate to which extent the choice of statistical method and model specification could improve the spatial prediction of soil properties with limited data. More specifically, we compared the cross-product performance of eight statistical approaches (linear, additive and geostatistical models, and four machine-learning techniques) and three model formulations ("covariates only": a suite of environmental covariates only; "spatial only": a function of geographic coordinates only; and "covariates + spatial": a combination of both covariates and spatial functions) to predict five key forest soil properties in the organic layer (thickness and C:N ratio) and in the top 15 cm of the mineral horizon (carbon concentration, percentage of sand, and bulk density). Our results show that 1) although strong differences in predictive performance occurred across all statistical approaches and model formulations, spatially explicit models consistently had higher R2 and lower RMSE values than non-spatial models for all soil properties, except for the C:N ratio; 2) Bayesian geostatistical models were among the best methods, followed by ordinary kriging and machine-learning methods; and 3) comparative analyses made it possible to identify the more performant models and statistical methods to predict specific soil properties. Our work supports existing efforts toward the production of improved digital soil products with limited data.

P.2.3 - Ecological classification on the White Mountain National Forest using the Soil Inference Engine

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Terrestrial Ecological Unit (TEU) is a taxonomic land survey system implemented by the US Forest Service to produce natural resource information that can be used by the forest for project level planning activities. However, traditional Terrestrial Ecological Unit Inventory (TEU) survey methods are cost and time prohibitive with today's budgets. This study identified and tested light detection and ranging (LiDAR) derived data products and employed robust sampling methods to improve soil-site-vegetation

mapping efficiencies. A 20,000-acre watershed in western New Hampshire was selected as representative of the full range of soil parent material, elevation, and moisture-nutrient gradients of the White Mountain National Forest. LiDAR data were subjected to Natural Resource Conservation Services' (NRCS) knowledge-based raster "Soil Inference Engine" to create preliminary ecological map units. Arc Soil Inference Engine (ArcSIE) is a knowledge-based approach to develop and implement automated soil mapping. These preliminary ecological map units, in turn, served as a basis for stratified, random sampling of 171 plots measuring overstory trees and understory vegetation, as well as describing a soil profile description and soil samples. Nonmetric multidimensional scaling (NMDS) results showed a three-dimensional ordination explaining 89.1% of cumulative understory vegetation variation. This test strongly correlated eight soil properties and five LiDAR-derived topographic metrics with 26 of total 252 understory vegetation species. This study highlights the utility and application of LiDAR for delineating preliminary ecological map units to support Land Type Phase (LTP) scale mapping using the knowledge-based raster "Soil Inference Engine."

P.2.4 - Forest management and land-use change alter the radiocarbon age, fluorescence characteristics, and lability of dissolved organic matter

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The age of carbon exported from major rivers increases as human disturbance in the watershed increases, suggesting that deep soil carbon has been mobilized on a global scale. Pre-aged organic matter that is exported to freshwater systems is rapidly degraded and consumed, creating an additional source of fossil C to the atmosphere as CO_2. Consequently, it is critical to understand how changes in land management drive the release of organic matter into solution and alter the composition of dissolved organic matter (DOM). This study examines the composition of DOM across gradients of land use change and intensive forest management in São Paulo State, Brazil and in Oregon, USA. Water extractable organic matter (WEOM) was obtained from 6 profiles to a depth of 1.5 m. The bulk soil organic matter was characterized by Fourier Transform Infrared (FTIR) spectroscopy and the WEOM by fluorescence spectroscopy to understand how shifts in land use, depth, and soil pedogenic development influence the composition, radiocarbon age, and biolability of organic matter across the solid-solution interface. Microbial biomass decreased much more quickly with depth than WEOM, suggesting that C released into solution from deeper horizons may be less likely to be intercepted, and thus preferentially leached to groundwater. The difference between bulk soil radiocarbon age and WEOM age was much greater in Cerrado forests compared to adjacent, industrially managed Eucalyptus plantations. Radiocarbon age across all sites and samples corresponded with a fluorescence region associated with microbial by-products and biomass, with younger WEOM corresponding with greater fluorescence in that region. Processes operating at the interface between solid and liquid, terrestrial and aquatic are a key unknown in the global carbon cycle. This research permits a unique snapshot into the relationship between DOM and SOM and the response of these pools to land-use change and forest management.

P.2.5 - Estimating mineral surface area and acid sensitivity of forest soils

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In 2012, the Rio Tinto aluminum smelter in Kitimat, British Columbia increased sulphur dioxide (SO_2) emissions from 27 to 42 tonnes/day. An initial study was conducted to investigate the effect of the increased deposition on forest soils. A key uncertainty of the initial study was mineral surface area estimations that were applied to critical load calculations. The current study investigates the ability to predict mineral surface area using pedotransfer functions (PTFs). Mineral surface area was measured on bulk soil samples using BET gas-adsorption. Particle-size based PTFs developed from other regions were not found to be significantly correlated with measured surface area. A regionally-specific particle-size based function had stronger predictive value of surface area measurements (adjusted R2=0.82). The PTF that best reflected surface area measurements of bulk soil for the Kitimat area used particle-size data as well as kaolinite, the most abundant clay mineral in the region. Surface areas estimated using the particle-size PTF were applied to the PROFILE model to calculate weathering rates. Weathering rates were then input to critical load calculations using steady-state mass balance. These estimates predicted that zero of the 24 measured sites are receiving SO_2 deposition in exceedance of their critical load.

P.2.6 - Predictive mapping of paludification in black spruce forests of eastern Canada using remote sensing and a Random Forest approach

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Spatial prediction of paludification is of particular importance in forest management given its negative effect on forest productivity. Paludification is the accumulation of partially decomposed organic matter over saturated mineral soils, thus reducing tree regeneration and growth. In this study, we used the Random Forest (RF) approach as a machine-learning tool for predicting the organic layer thickness (OLT) as a proxy of the paludification process. We used the RF as regression and classification models in the northeastern region of Canada where the forests tend to paludify naturally, using a suite of 20 environmental predictors. Models performances were evaluated using cross-validation as well as independent dataset from ecological survey maps. Importance measures of the predictors indicated that Slope, TPI, Landsat Band4 and Band5, the latitude and the Palsar_HH are the most important variables in explaining the spatial distributions of OLT. Cross-validated root mean square error (RMSE) for the regression model is estimated at 20.70% ±0.476 with an R2 at 0.41 ±0.021 whereas the average out-of-bag (OOB) error for the classification model is estimated at 44.75%. With values ranging from 4.25, 44.07, 102.58, and cm for the min, mean, and max respectively, spatial patterns of predicted values of OLT are in accordance with previous studies realized at the national and regional scale. Our results confirm that ecological types RE39 and RE38 are particularly risky in terms of paludification (>40cm), while the MS20 and RS20 remain at low risk. Limitations of the model and applications for decision making in forest management are discussed.

P.2.7 - Effects of forest harvesting and Hemlock Looper infestations on boreal forest soils: a microbiome perspective

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Disturbances affect forest nutrient cycling through modifications of organic matter and nutrient inputs to the soil, as well as changes in light and water supplies. Microbes play central roles in soil biogeochemical cycles and are known to respond to changes in soil physico-chemical conditions, therefore being potential indicators of soil perturbation. While forest ecosystems nutrient cycling generally recovers rapidly following disturbance, little is known on the impact of disturbance type nor of combinations of disturbances on the soil microbiome. In this study, we evaluated the effects of (1) hemlock looper (*Lambdina fiscellaria*) forest infestation, (2) forest harvesting, and (3) both disturbances, on forest soil microorganisms using a high-throughput metabarcoding approach targeting the bacterial 16S rRNA gene and the fungal ITS2 gene. Soil samples were collected in a boreal balsam fir forest, Québec, Canada, following a rare hemlock looper infestation that led to extended tree death in 2012-2013. Several soil characteristics were assessed and linked to bacterial and fungal community diversity, structure and composition. Fungal communities in soils of undisturbed forest stands were clearly distinct from those of disturbed ones, and perturbations were associated with higher levels of fungal diversity. The impact of disturbances on bacterial communities was much lower, underlining the higher resilience of bacterial communities to perturbations and the potentially better suitability of fungi as indicators of perturbation in forest soils. Concentrations of soil nitrogenous compounds (NH_4 for fungi, dissolved organic nitrogen for bacteria) were identified as main drivers of community structure. Microbial communities in sites impacted by both disturbances were not clearly distinct from those of sites impacted by a single disturbance, indicating that combinations of disturbances do not necessarily lead to cumulative effects in forest soils.

P.2.8 - Lichens contribute to open woodland stability in the boreal forest through detrimental effects on pine growth and root ectomycorrhizal development

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In the boreal forest, open lichen woodlands have been described as an alternative stable state to the closed-crown feather moss forest. In this study, we addressed the role of terricolous lichens in stabilizing open woodlands by hindering tree regeneration and/or growth. The objective was to determine the

effects of ground cover composition on the growth of 6 month-old jack pine seedlings (*Pinus banksiana*). In a first greenhouse experiment, seeds were sown on (i) sand covered by a layer of feather mosses (primarily *Pleurozium schreberi*), (ii) sand covered by terricolous lichens (primarily *Cladonia stellaris*), and (iii) bare sand (control). In a second experiment, pine seedlings were not directly grown in the different ground cover types but submitted to their leachates. Pine root ectomycorrhizal colonization and diversity were examined at the end of each experiment. Early seedling growth was much better in feather mosses than in lichens and bare soil. Compared to feather moss, lichen cover was associated with reduced abundance and modified composition of the ectomycorrhizal community, thus potentially contributing to reduced pine growth. Feather moss and lichen leachates had no differential effects on pine growth and ectomycorrhizal colonization. These results suggest that feather mosses provide more favorable conditions than lichens for jack pine growth by promoting the development of ectomycorrhizal association. Our results support the hypothesis that the effects of terricolous lichens on soil contribute to maintaining open woodlands within the closed-crown boreal forest region.

P.2.9 - Evaluating a solid phase fluorescence approach to the study of soil organic matter

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Fluorescence spectroscopy is a well-established technique to investigate the composition of organic matter in aquatic systems and is increasingly applied to soil organic matter (SOM). Current methods require that SOM be extracted into a liquid prior to analysis by fluorescence spectroscopy. Soil extractions introduce an additional layer of complexity as the composition of the organic matter dissolved into solution varies based upon the selected extractant. Water is one of the most commonly used extractants, but only extracts the water-soluble fraction of the SOM with the insoluble SOM fluorescence remaining in the soil matrix. We propose the use of solid phase fluorescence on whole soils as a potential tool to look at the composition of organic matter without the extraction bias and gain a more complete understand of the potential for fluorescence as a tool in terrestrial studies. To date, the limited applications of solid phase fluorescence have ranged from food and agriculture to pharmaceutical with no clearly defined methods and limitations available. We are aware of no other studies that use solid phase fluorescence and thus no clear methods to look at SOM across a diverse set of soil types and ecosystems. With this new approach to fluorescence spectroscopy there are new challenges, such as blank correction, inner filter effect corrections, and sample preparation. This work outlines a novel method for analyzing soil organic matter using solid phase fluorescence across a wide range of soils collected from the National Ecological Observatory Network (NEON) eco-domains. This method has shown that organic matter content in soils must be diluted to 2% to reduce backscattering and oversaturation of the detector in forested soils. In mineral horizons (A) there is observed fluorescence quenching, which is likely a result of organo-mineral complexation. Finally, we present preliminary comparisons between solid and liquid phase fluorescence, which provide new insights into fluorescence studies in terrestrial systems.

P.2.10 - Evaluating CENTURY, Yasso07, and Yasso15 soil carbon models against boreal forest soil CO_2 emissions and soil organic carbon stocks

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To improve management decisions of the soil organic carbon (SOC) pool, the most significant terrestrial carbon stock, and curb climate change we need confidence in predictions of future soil CO_2 emissions. However, evaluating the performance of soil carbon models in comparison to observed soil CO_2 fluxes and SOC stocks is rare. We measured soil CO_2 emissions, temperature and moisture in four intensively monitored forest sites in Finland for approximately two years (2015 and 2016) in weekly intervals during the vegetative season (April – November). We up-scaled the momentary measurements to monthly levels with nonlinear least squared regression models and compared them with predictions of soil carbon models (Yasso07, Yasso15, and CENTURY). The Yasso07, Yasso15, and CENTURY predictions strongly correlated with measured heterotrophic respiration on a monthly level. The models showed a significant correlation to observation during the spring, autumn, and winter months but not in summer. However, the models on average underestimated measured soil CO_2 fluxes by 43%. The predictions of the Yasso models showed less underestimation and stronger correlations with measured soil respiration, and a closer match with the measured SOC stocks, than the predictions of CENTURY. The temperature dependence of decomposition determined how well CENTURY could reproduce the observed CO_2 fluxes in spring and autumn. Improving estimation of summer CO_2 fluxes for Yasso models and CENTURY models, which could reflect their missing representation of microbial processes, might be decisive for accurate projection of SOC stock changes and CO_2 emissions.

THEME 3: Management practices, land-use change and soil-forest productivity

Keynote 3 - Decomposition, transformation, humification, and soil organic matter formation: how can we reverse land degradation?

Cindy Prescott
University of British Columbia

The restoration of degraded soils is one of the most pressing environmental challenges we face in the next decade. The restoration of levels of soil organic matter and carbon are essential for repairing lands degraded by large disturbances such as mining and for combatting land degradation, desertification and climate change. Trees and forests are a vital part of the restoration toolbox, as evident in the numerous ambitious Forest and Landscape Restoration programs initiated in recent years to reverse land degradation around the world. The urgent need to increase levels of organic matter in soils provides an opportunity to put to the test our understanding of the processes involved in the formation and decomposition of soil organic matter, and how we might be able to foster accumulation of soil organic matter. In this talk, I will discuss some of the important and sometime counter-intuitive recent discoveries that have transformed our thinking about decomposition, humification and soil organic matter formation. Based on our current understanding I will suggest land use changes and management practices that have the potential to assist us in improving the fertility and productivity of forest soils.

O.3.1 - Soil productivity drivers in New Zealand planted forests

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Soil fertility is known to be one of a number of key drivers of forest productivity. However, our ability to determine the importance of soil fertility to *Pinus radiata* productivity has been limited by the lack of a nationally representative sampling framework. In New Zealand the national planted forest inventory plot network (part of the Land Use and Carbon Analysis System, LUCAS) was used to explore variation in a stand productivity index in relation to climate and soil factors. The stand productivity index used in this case is a measure of the mean annual increment in stem volume at age 30 years for stands growing at a final crop stocking of 300 trees per hectare (the "300 index"). Climate data (normalised average temperature and rainfall), solar radiation (corrected for slope and aspect using a digital terrain model), tree health scores, soil measures of fertility (including soil chemistry and categorical information such as soil type and land use history) were included in the analysis of variation in the 300 Index across the range of planted forest environments in New Zealand. Land that was previously managed for agricultural production resulted in a 20% gain in overall forest productivity, which is known as the "farm effect". The soil chemistry data showed that the adjusted C/N ratio (an index of nitrogen fertility) and total phosphorus in the topsoil were the dominant drivers of productivity. These soil fertility drivers were also assessed at several long term trial sites to examine temporal variation in these soil drivers, in conjunction with foliar

chemistry monitoring. The findings add to the knowledge of soil productivity drivers and further support site specific precision soil management.

O.3.2 - 50 plus years of base cation depletions in forest soils, following stand conversion of old growth tolerant hardwoods to managed conifer plantations in southcentral Ontario, Canada

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Although there are only a few long-term studies, rapid base cation declines in forest soils have been documented between 1950 -1980; more recent short-term studies suggest that these declines have continued into the 21st century despite reductions in sulphate deposition rates. A number of external contributing factors, including forest management practices, have been implicated although their potential cumulative effects remain poorly described. The current study was established in the early 1960s in southcentral Ontario, Canada. An old growth hardwood stand was clearcut harvested, and planted and managed as a conifer plantation. Repeated soil sampling was undertaken on the converted stand, in an adjacent uncut old growth hardwood forest and in a nearby old growth red spruce stand in 1963, 1983, 1993, 2003, and 2016 to describe the temporal patterns of base cation decline and potential recovery associated with lower sulphate deposition rates. Results show rapid declines in exchangeable Ca pools from the 1963 to 1983 sampling period, further declines up to 2003 but with slower rates of loss, and partial recovery by 2016. The temporal patterns differed depending on stand type: 1) greater losses occurred in the old growth hardwood stand (39% of original) compared to the old growth conifer stand (81%), 2) recovery between 2003-2016 was more pronounced in the old growth hardwood stand (back to 63%) compared to the conifer stand (88%), and 3) the managed conifer plantation (now almost 60 years old) showed the greatest depletion of exchangeable Ca compared to the undisturbed 'controls' and these losses continued to 2016 (14% of original). These long-term results illustrate the cumulative effects that prolonged acid deposition and climate change have had on soil base cation levels (i.e., declines in the undisturbed 'controls'), but also indicate the potential exacerbating effects that forest management can have on soil base cation levels.

O.3.3 - Retention trees slow post-harvest fine-root decomposition in coastal temperate rainforests

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Fine roots are a dominant carbon input in forest soils and decomposition of this material has important consequences for belowground carbon storage and turnover. By modifying soil physicochemical properties and microbial communities, forest harvesting may influence fine-root decomposition.

Relative to clearcut harvesting, variable-retention harvesting (VRH), where some trees are left on site after harvest, typically reduces soil nitrate availability, soil temperature and moisture, and maintains fungal communities similar to those found in uncut stands. Here, we determined how VRH and clearcut harvesting modify fine-root decomposition rates, whether any effect of harvesting persisted as stands age, and how decomposition rates changed with distance from retention trees or patches. We also determined which soil physicochemical properties were the best predictors of fine-root carbon mass loss. Douglas-fir (*Pseudotusga menziesii*) fine roots (<2mm) were placed in litterbags and buried in clearcut and variable-retention treatments (aggregate and dispersed retention), as well as in uncut stands. The experiment was replicated at two sites harvested in 2008 (6 years post-harvest) or 2001 (13-years post-harvest), on Vancouver Island, Canada. After 2 years of decomposition at the 6-year site, fine roots decomposed faster under clearcut harvesting, with carbon mass loss 15-19% lower near retention trees and patches, and in uncut stands. Fine roots decomposed faster with distance from retention trees or patches. Nitrate availability correlated with decomposition rates, so management practices that reduce nitrate availability (like VRH), may result in lower carbon losses. The influence of harvesting on fine-root decomposition was not persistent as fine-roots decomposed at similar rates at the 13-year post-harvest site. Fine-root biomass, and nitrate, potassium, and sulphate availability explained 37% of variation in fine-root carbon mass loss after 2-years of decomposition. Overall, the results indicate that fine roots decompose slower with increasing tree coverage, but these findings need to be tested in other forest ecosystems.

O.3.4 - Wood stakes: an index of soil properties and conditions affecting organic matter decomposition

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Organic matter decomposition has a key role in maintaining soil productivity, and is controlled by some of the same factors that affect plant growth: water, nutrients, pH, and temperature. Various studies have shown the effect of forest management practices on OM decomposition and its impact on subsequent soil productivity. Decomposition studies often use OM (leaves, branches) from a particular location and provide appropriate site-specific information. However, differences in OM quality (e.g., lignin content, C:N ratio) make it difficult to compare decomposition study results between sites. When the same OM ("standard") is used on different sites, organic quality is held relatively constant, and decomposition becomes a function of soil abiotic (moisture, temperature, etc.) and biotic (microbial biomass, etc.) conditions. When these soil properties are measured during the decomposition process, they can be used in cross-site decomposition comparisons, and as parameters in soil C cycling models. Many studies have used standard litter bags placed on the soil surface, but little information is available on OM decomposition in the mineral soil. Therefore, we used standard wood stakes of two wood species (*Populus tremuloides* and *Pinus taeda*) as an "index" to assess soil biotic and abiotic properties

during decomposition on 50+ study sites across North America, Europe, Asia, and Africa. These sites encompass a wide range of forest types, soil properties, and climatic regimes. This presentation will give an overview of the wood stake method, and how it was used to assess the impacts of forest management (harvesting, site-preparation), fire (wild, prescribed), and climate gradients on wood decomposition, and on associated changes in soil biotic and abiotic properties in the surface litter layer and in the mineral soil.

O.3.5 - Recent key findings in crop tree and site biota response to soil compaction and site organic matter removal (Long-term Soil Productivity study) in central British Columbia

Marty Kranabetter[1], Erica Lilles[1], Brendan Miller[1]
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An installation of the Long-term Soil Productivity study (LTSP) in sub-boreal forests of central British Columbia has recently reached 20 years in age, and we present some key findings related to crop tree and biotic responses to soil compaction and site organic matter removal. There were strongly contrasting responses in the growth of lodgepole pine (*Pinus contorta*) and hybrid white spruce (*Picea glauca* x *engelmannii*) among disturbance treatments. Growth had been stable for lodgepole pine, averaging a 6% difference across treatments, whereas white spruce has had large growth increases on forest floor retained – compacted plots (average of 63% gain), but significant reductions in productivity on the forest floor removed – compacted plots (40% decline). Some key differences in species traits were suggested by foliar $\delta^{15}N$ and foliar $\delta^{13}C$, underlining how productivity response to disturbance is likely contingent upon tree autecology. The ecological integrity of disturbed soils was also assessed via three biotic indicators of epigeic beetles, understory plants, and ectomycorrhizal fungi. Removal of forest floors and, to a lesser degree, compaction significantly altered plant and fungal communities, but with little effect of soil disturbance on beetles. None of the guilds after 20 years showed an effect of retaining logging slash. Collectively these biotic communities changed by small amount overall (4-6% dissimilarity) with each level of treatment severity, demonstrating a high degree of resilience to soil disturbance. There was, however, greater spread of invasive plants (particularly hawkweed ["Hieracium" spp.], with disturbance that merit concern. On-going evaluation of crop tree and site biotic responses, along with related data from the network of LTSP sites in North America, will greatly enhance our understanding of full ecosystem responses to gradations in soil disturbance.

O.3.6 - Loss and recovery patterns in soil carbon and nutrient reserves following different levels of biomass removal in boreal, conifer-dominated site types in northern Ontario, Canada

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With a growing interest in using forest biomass for energy production, concerns regarding soil nutrient supply and tree productivity have been heightened. In this context, the objectives of this long-term study were to evaluate temporal changes in soil carbon and nutrient reserves resulting from different

biomass harvest intensities conducted on boreal jack pine and black spruce site types. Fourteen sites were established on coarse-textured outwash sand deposits and shallow to bedrock, coarse loamy morainal tills. Sites were experimentally harvested (stem only, whole-tree, whole-tree + forest floor removal) in 1994/5. At four sites herbicide was applied in a split plot design. Organic and mineral soil horizons were sampled on replicated treatment plots periodically through to year 20. Soils were also sampled in associated mature reference stands at each site. Total C and N, extractable P, and exchangeable Ca, Mg and K reserves were determined for each treatment. Application of all biomass removal treatments resulted in initial declines in soil C and nutrient reserves (SO = WT < WT + FFR). Recovery was more rapid on the richer loam sites, particularly for N. In general, the magnitude of soil nutrient loss was greater and the rate of recovery slower on the infertile sandy sites. Similarly, P and K losses were greater and recovery times extended compared to N, except for the bladed treatment. Clearcut harvesting generally resulted in lower long-term (20 year) soil C and nutrient reserves compared to the pre-harvest levels in the mature, reference stands. Whole-tree and stem only treatment organic, mineral and total reserves were not significantly different. Declines in organic horizon reserves with forest floor removal resulted in decreases in total soil C and nutrient reserves with the exception of P. Retaining understory vegetation on site increased organic horizon concentrations and reserves of some nutrients.

O.3.7 - End of rotation impact of harvest removals and fertiliser addition on soil nutrients and productivity in *Pinus radiata* forest, New Zealand

Loretta Garrett[1], Peter Beets[1], Mark Kimberley[1], Simeon Smaill[1], Peter Clinton[1]
[1]Scion

Planted forests in New Zealand receive either no or very little nutrient inputs from fertiliser application, largely relying on inherent soil fertility. Some planted forests are now entering their third or even fourth rotation. Consequently, the long-term productivity of New Zealand's planted forests depends on soil fertility being maintained over successive harvests. To investigate the potential for harvest management practices to promote a decline in the productive capacity of planted forests over successive rotations, two long-term trials have been sampled at the end of their second rotation to determine the impact of harvest residue removal and fertiliser addition on nutrient pools and forest productivity. The results show that the removal of the whole tree plus forest floor at harvest negatively impacted soil nutrient pools and tree productivity. The addition of fertiliser was beneficial to soil and forest floor nutrient pools and increased tree productivity. However, fertiliser addition did not replace the soil nutrients lost to whole tree and forest floor removal during the harvest of the previous rotation. Site soil factors were also demonstrated to reduce the extent of growth responses to fertiliser addition. The end of rotation results from this long-term study are rare, nationally important, and significantly contribute towards the international understanding of long-term planted forest nutrient sustainability.

THEME 3: Rapid Fire

RF.3.1 P.3.40 - A second fertilization with biosolids and wood ash near canopy closure shows significant benefits in hybrid poplar plantations

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Tree plantation productivity is expected to decline during canopy closure as soil resources become scarcer with increasing intraspecific competition and as the effects of a pre-panting fertilization dissipate. Thus, fertilizers are sometimes reapplied near canopy closure to sustain growth rates. We tested this strategy in 3- to 6-year-old hybrid poplar plantations in southern Quebec. The first fertilization (pre-planting) consisted of paper biosolids (140 $t.ha^{-1}$) and lime mud (10 $t.ha^{-1}$), while the second fertilization (pre-canopy closure) consisted of paper biosolids (100 $t.ha^{-1}$) and wood ash (15 $t.ha^{-1}$). We hypothesized that soil nutrient availability would increase after the second fertilization, resulting in enhanced tree growth. By applying glyphosate in a 1.5-m radius around a subset of poplars, we also tested whether understorey vegetation would negatively impact target trees by competing for soil resources. After 1.5 growing seasons, annual height growth of poplars receiving two fertilization treatments was ~25% higher than poplars receiving only one treatment (1.9 m vs 1.5 m, respectively; $p = 0.002$). Soil N and K bioavailability as measured by ion-exchange resins incubated for 6 weeks in midsummer in plots receiving two fertilization treatments increased respectively by 49% and 45% compared to plots with one fertilization. Soil P remained unchanged by the second fertilization. The removal of understorey vegetation increased soil N (+82%) but decreased soil P (-30%). There were significant interactions between the two treatments: highest levels of soil N were found under the combination of two fertilizations without competition, for soil P it was one fertilization with competition present, and for soil K, two fertilizations with competition. Our results suggest that the effects of a second fertilization are beneficial for poplar growth. It is also generally beneficial for soil nutrient availability, but the response differs depending on the nutrient and the levels of understorey competition.

RF.3.2 P.3.41 - Long-term nitrogen addition decreases organic matter decomposition and increases soil carbon in a temperate deciduous forest

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We examined chronic N deposition effects on forest soil processes in a 100-year-old temperate deciduous forest. After nearly two decades of N-additions (100 kg N $ha^{-1}y^{-1}$), soils were collected from

the O-, A-, and B-horizons. Soil C (14.20+0.73 kg m^{-2}) was 17% greater in fertilized than control soils. There was no increase in aboveground biomass growth between control (7.9±1.0 Mg $ha^{-1}y^{-1}$) and fertilized plots (7.3±3.7 Mg $ha^{-1}y^{-1}$), nor in aboveground litter production (Control: 492+42 g $m^{-2}y^{-1}$); Fertilized: 478+35 g $m^{-2}y^{-1}$). Root biomass did not differ between treatments, although root productivity was not measured. Decreased organic matter decomposition appears to explain soil C increases. One-year decomposition rates of black cherry, sugar maple, and mixed cherry-maple leaf litter were 6.2, 5.6, and 10.6% lower in fertilized than control plots. Root decomposition did not differ by treatment. Total soil respiration was lower (6.3%) due to fertilization. Biochemical indicators also suggest lower rates of soil organic matter decomposition. In the O-horizon, autumnal peroxidase activity in fertilized plots was only 29% of activity in control plots. In the A-horizon, there was no difference in peroxidase activity between treatments, but β-glucosidase activity in the fertilized plots was 37% of the control. N-fertilization resulted in selective preservation of a range of plant-derived soil organic matter compounds including steroids, and lignin-, cutin-, and suberin-derived compounds. In the A-horizon, there was more light fraction (density < 1.85 g m^{-3}), mainly from plant residues, and less heavy fraction (density > 2.4 g m^{-3}) with N-fertilization, indicating that plant-derived residue was less processed. Long-term N additions for forest soils reduce enzyme activity, thus reducing decomposition and increasing fractions of less-decomposed organic matter. Reduced decomposition may reduce energy available to microbial fauna, and lower forest productivity due to diminished nutrient availability.

RF.3.3 P.3.42 - The effects of management and disturbance on forest soil properties in Sierra Nevada forest ecosystems – a synthesis.

Seth Myrick[1], Garret Liles[1]
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This project will present an evolving data synthesis targeting soil physical, chemical, and biological properties and functions associated with management and disturbance of Sierra Nevada forest ecosystems. These data will provide the baseline and range of conditions to support Life Cycle Assessment (LCA) modeling of forest wood utilization for biopower production – California Biopower Impacts Project (CBIP). The CBIP is a California Energy Commission funded project tasked with producing a GHG emissions accounting tool to evaluate the impacts of different bioenergy policy and technology pathways. Current forest stand conditions across much of the Sierra Nevada (and Western North America) are being impacted by overstocking and drought leading to declining tree health and mortality associated with Bark Beetle infestation. These landscapes will require stand management and harvest, to support ecosystem resilience and health, producing new biomass streams far above existing levels with large portions not suitable for traditional timber and wood products. The effects of disturbance (forest management, harvest, and wildfire) on soil properties and functions are variable depending on the mode of disturbance and its intensity. Considerable investigation of management and disturbance effects on soil biogeochemical properties has occurred across California, other Mediterranean forest ecosystems, and temperate forests of North America. This work spans traditional silviculture to disturbance ecology and will provide the foundation for this synthesis. The final data synthesis and LCA model tool will provide an important linkage between management and GHG production in California forests to help guide policy and management leading to enhanced forest health.

RF.3.4 P.3.43 - Can salvage harvesting speed up the recovery of nutrient cycling in insect killed stands?

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[1]Natural Resources Canada

Disturbances affect forest nutrient cycling through the modifications of organic matter and nutrient inputs to the soil, as well as through changes in the amount of light, energy and water reaching the soil. Little is known on the impact of disturbance type (e.g. natural vs anthropic) nor of the combination of disturbances (insect killed trees+ salvage harvesting) on the soil properties and on the recovery of nutrient cycles. In this study, we evaluated the effects of (1) hemlock looper (*Lambdina fiscellaria*) forest infestation, (2) forest harvesting, and (3) both disturbances, on forest soil physico-chemical properties. Soil samples were collected in a factorial experiment located in a boreal balsam fir forest, Québec, Canada, following a rare hemlock looper infestation that led to extended tree death in 2012-2013. Disturbances had an impact on several of the soil characteristics, with generally higher concentrations of soluble N compounds (i.e. $N\text{-}NH_4$, $N\text{-}NO_3$, DON) but lower concentrations in K and Na in disturbed soils when compared to undisturbed soils (control sites). Highest soluble N concentrations were detected in plots affected by hemlock looper alone, while intermediate values were identified both in harvested sites and in sites affected by both disturbances. Interestingly, while harvesting tended to increase soluble N in uninfested sites, it also generally decreased their concentrations in soils of sites infested by hemlock looper. These results indicated that the effects of cumulative disturbances are not necessarily additive and may lead to compensatory effects. In this particular case, these interactions between hemlock looper and forest harvesting were reflected in the vegetation status of the regenerating stands, with a much faster vegetation recovery in sites affected by both disturbances than by hemlock looper alone.

RF.3.5 P.3.44 - Building more productive, higher quality forests for the future

Simeon Smaill[1], Peter Beets[1], Loretta Garrett[1], Dean Meason[1], Peter Clinton[1]
[1]Scion

The forestry sector has set the ambitious target of increasing the value of New Zealand's forest exports to $12 billion by 2022. Meeting this goal will require investment and development across all components of the supply chain, but will ultimately rely on the ability of New Zealand forest soils to support long term increases in the productivity of the radiata pine estate. The 'accelerator trial series' has been established with a focus on the development and implementation of edge of the envelope forest science to increase the productivity of any given radiata pine plantation, pushing towards the biological potential of the site. The trial series will provide the basis for future detailed studies on tree growth and wood formation across a range of tree genotypes, sites, and site specific treatments intended to make trees grow sustainably faster. Six sites have been installed at locations with particular limitations to productivity, predominantly relating to soil factors. Given the wide range of potential limitations to productivity, the removal of one limitation will only promote the next; consequently multiple treatments are planned. These trials are intended to serve as both a long-term source of information for researchers and as demonstration sites for industry. The trial data will improve understanding of how to achieve the goal of increasing the productivity of future forests and what the implications for wood quality and sustainability might be. In this poster we provide details around the

range of sites and soil properties being studied in this trial series, the rationale for the inclusions of these sites, and treatments that are being tested in the trials themselves.

THEME 4: Societal change and forest soil: a balancing act

Keynote 4 - Societal change: a balancing act

Ellen Bergfeld
Soil Science Society of America

In a world that depends on soil to sustain life, most humans know little about soil's role and why we need this precious resource. The demand for clean water, food, and energy is expected to rise sharply as the global population expands toward 10 billion by 2050, while at the same time standards of living are increasing for much of the world. Meeting this demand will be difficult enough in itself, but the challenge is even greater in the context of global climate change and the pressing need to reduce the environmental impacts of human activities. Additionally, the challenge of balancing the changing expectations of society with scientific knowledge to form policies, regulations and practices for sustainable forest soil management continues to grow. The Soil Science Society of America has a critical role to play in this arena. The International Year of Soils (2015) provided a unique forum for communication, outreach and policy strategies to educate the public and inform elected members of government and their staff to meet current and future needs. The need is ongoing to advocate for research funding on critical issues and provide access to voices important to writing and implementing policy. We must also play a role in educating, recruiting and retaining talented individuals into the soils disciplines to ensure a dedicated workforce capable of addressing these and future needs. Collaboration and partnerships form a large component of our work and include building knowledge through public engagement.

O.4.1 - State of policy for forest soil conservation in Canada

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[1]Canadian Forest Service, Natural Resources Canada
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[3]Saskatchewan Research Council

We examine the current policy context for forest soil conservation in Canada to address the questions: 1) How does forest soil conservation contribute to land stewardship?, and 2) Do stewardship-driven policies lead to forest soil conservation? The current policy context in Canada includes governmental (provincial, federal) and non-governmental (e.g. national and international certification standards; criteria and indicators frameworks) initiatives. The cross-cutting and cross-jurisdictional role of soils in land management results in a diversity of land managers, soil management objectives, and agencies responsible for implementation. We examine current programs and initiatives in Canada that explicitly address forest soil conservation, including why they were created, how they are structured, and how they are administered. We consider the following: How is success measured in approaches to conserving soil resources? What criteria for selecting and implementing conservation practices will facilitate effectiveness? How can relevant and enduring soil management practices best be incorporated into policy today, to serve tomorrow? How can forest soil conservation accommodate changing societal values related to the ecosystem services provided by soil? What are the implications of inadequate policy? How can research be directed towards policy development?

O.4.2 - Silviculture, soils, syphilis, and social events

Ronald Taskey
Cal Poly, San Luis Obispo

In 1935 Ludwik Fleck, a medical microbiologist and scientific philosopher, published "Genesis and Development of a Scientific Fact" in which he argued that doing research science is a social activity conducted within and among thought collectives that exhibit contrasting, culturally conditioned thought styles; thus, facts are as much created by the process as they are discovered. Fleck used the development of the Wassermann reaction to carry his argument. As a series of social events, the scientific process engenders anomalies, theory conflicts, and cognitive conditioning on its way to generating facts. Despite some shortcomings, Fleck's ideas can be extrapolated to the evolution of forestry and forest soil science in North America. Recognizing that knowledge of forest soils developed to serve forestry (primarily its emphasis on trees as a harvestable crop), this paper sketches forestry's historical background and presents two key figures—Franklin Hough and Bernhard Fernow—who cut the path into the most pivotal period in North American natural-resource history: the bookend decades of 1900. Then, in place of the Wassermann test, it employs three iconic figures—John Muir, Gifford Pinchot, and Richard Ballinger—to represent the competing thought styles and collectives that shaped natural resource philosophies, policies, research directions, and (ultimately) knowledge for the next century. What we know today and how we came to know it is not merely the result of objective inquiry but also the legacy of past thought collectives combined with the products of our own culturally conditioned thought styles.

THEME 3 and THEME 4: Poster Session

P.3.1 - Soil organic matter stocks and formation pathways in bark-beetle infested lodgepole pine: implications for salvage logging and residue management

Bethany Avera[1], Charles Rhoades[2], Francisco Calderon[3], M. Francesca Cotrufo[1]
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Continent-scale forest disturbance caused by bark beetle outbreaks and associated salvage logging has renewed concern about the implications of forest management on soil organic matter (SOM) stocks. The objective of this study was to investigate how salvage logging and residue management influence SOM fractions in beetle-infested lodgepole pine (*Pinus contorta*) forests and to identify dominant sources of soil carbon (C). We quantified the C inventory of downed wood and organic and mineral soils at four

sites in Colorado, each with three blocks of the following treatments: (1) uncut beetle-infested forest and, adjacent stands that were logged seven years ago with either residue (2) retention or (3) removal. Soil C increased with salvage logging, but was unrelated to woody residue inputs. For example, soil C was 5.5 Mg ha^{-1} higher where logging residues were removed compared to where 35 Mg C ha^{-1} of residues were retained. Increases in soil C were in the light (<1.85 g/cm^{-3}) and sand-sized (> 53 µm) SOM fractions. Differences in $\delta^{13}C$ between the organic soil and SOM fractions suggest that C in the mineral soil may not originate from surface organic layers, but from belowground plant inputs. Analyses of the SOM fractions and plant tissue using Fourier-transform infrared spectroscopy are under way to better elucidate the C composition of each and the pathways of SOM formation. Salvage logging and residue management have multiple consequences for ecosystem processes and biodiversity but our study suggests in lodgepole forests these treatments can increase rather than decrease soil C and that belowground C inputs from residual and newly-established vegetation are crucial to SOM formation.

P.3.2 - Nutrient bioavailability is related to microbial functions in reclamation soils: an incubation experiment

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[2]Department of Renewable Resources, University of Alberta

Nutrient bioavailability is critical for vegetation growth and organic matter cycling, especially where the belowground system is completely restructured such as with reclaimed oil sands mine sites in northern Alberta, Canada. Peat mineral mix (PMM) and forest floor mineral mix (FFMM) are currently being used as cover soils in oil sands reclamation. There is great interest in understanding the mechanisms that drive nutrient bioavailability in these soils. In this six-month incubation experiment, we used 12 different soils (PMM, FFMM, Sub-Soil and mixtures of these along with a natural post-fire soil), and examined the relationships between nutrient bioavailability, microbial biomass and community level physiological profiles (CLPP), organic matter quality, and other basic soil properties (e.g. pH and EC). We hypothesized that organic matter quality and microbial substrate mineralization efficiency would drive nutrient bioavailability, and that intermixing reclamation soils would change the drivers of nutrients. Significant differences were observed in nutrient bioavailability among soil types and preliminary analyses showed that the differences in microbial biomass and substrate mineralization patterns drive nutrient bioavailability. Long-chain polymers and carboxylic and ketonic acids were the key drivers of nutrients in PMM, whereas amino acids and carbohydrates were more associated with FFMM, sub-soil, and post-fire soil. Intermixing changed the drivers of nutrients in the composite reclamation soils but a shift in nutrient-profile was observed only in sub-soil mixed with FFMM. Our findings show that mixing FFMM with low-nutrient sub-soil may yield more ecologically favourable results.

P.3.3 - Using soils information and mapping to inform land management planning in the Pacific Northwest

Cara Farr
USDA-FS Pacific Northwest Region

As one of the largest land managers in the Pacific Northwest, the Forest Service is a leader in developing and maintain forestry practices. Several soil mapping techniques and philosophies have been applied throughout the region giving us a wide range of soils data. This poster shows how the soil scientists in the region have used soils and landscape data to inform land management in the face of climate change for long-term resiliency of soils and landscapes for forest production and habitat management. Case studies include large-scale landform information in hydropower mitigation planning to look at the long-term gravel augmentation needed for salmon recovery in the North Umpqua River in OR; using soils and climate data to discuss instream flow potential during forest land management planning on the Colville National Forest in WA; the incorporation of soils information to design and balance a project for hazardous fuels and mule deer winter range on the Sisters Ranger District in OR; and mapping potential actions in the Blue Mountains of OR based on the baseline data provided in soil mapping.

P.3.4 - USDA national forest soil interpretations from the National Cooperative Soil Survey for the USA – updates, revisions and new interpretations.

Cara Farr[1], Olga Vargas[2], Nicole Jacobsen[3], Robert Dobos[2], Steve Campbell[2], Bart Lawrence[2], Tony Jenkins[2]
[1]USDA Forest Service
[2]USDA NRCS
[3]WA DNR

The United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) has established a 3-year schedule to update all National Forest Soil Interpretations. Updates will standardize application of the "fuzzy logic" system to "best express the degree of membership of a soil in a particular interpretive class (SSD 2017)." There are currently 16 National Forest soil interpretations. There are approximately 161 forestry-related soil interpretations available on Web Soil Survey (WSS), most of which are state or region specific. NRCS proposes to add four new forest soil interpretations: Ballast Requirement, Mechanical Fuels Treatment Damage Hazard, Soil Drought Potential, and Soil Carbon Storage Potential. In addition to these four, NRCS will accept proposals for the development of new National Forest Soil Interpretations. There are several reasons for these revisions: 1) to account for significant changes in silvicultural and conservation forestry operations throughout the USA; 2) to address new soils and updated national soils maps; 3) to increase awareness and use of National Forest Soil Interpretations to meet complex resource planning needs on public and private lands; and, 4) to improve technical consistency of all National Forest Soil Interpretations as the first step in developing a USDA NRCS National Raster-Based Soil Interpretations tool. This cooperative effort includes multiple partners (e.g. United States Forest Service, US state forest managers, etc.) and USDA NRCS Soils and Forestry specialists. Upon revision of the National Forest Soils Interpretations, United States public and private forest land managers may use and adapt them to their regions or states if needed.

P.3.5 - Root carbon contributions are uniform across intensive biomass removal treatments in a western Oregon Douglas-fir forest

Adrian Gallo[1], Jeff Hatten[1], Scott Holub[2]
[1]Oregon State University

[2]Weyerhaeuser Company

Soil carbon is known to hold at least two times as much carbon as that held in the atmosphere, but the source and fate of soil carbon remains loosely understood. The goal of this study is to determine how the sources of soil carbon shift following varying levels of organic matter removals, and what representative soil organic matter (SOM) pools are most affected by these perturbations. We investigated how lignin biomarkers and stable isotopes changed in soils separated into three density fractions representing ideal pools of SOM from a newly installed (2013) Long-term Soil Productivity (LTSP) site on a Southern Oregon Cascades timber area. There was an overall decrease in the mass of recoverable heavy fraction (>2.60g/cm^3) material 2-years following the forest harvest. The proportion of total soil carbon from the light fraction (<1.85g/cm^3) decreased, with an approximately proportional increase in the soil carbon stored in the intermediate fraction (1.85-2.60g/cm^3). Stable isotope (^{13}C and ^{15}N) and cupric oxidation data on whole soils and SOM pools (density fraction) are forthcoming.

P.3.6 - Soil and plant nutrient reservoirs in a *Pinus montezumae* Lamb. in Tlaxcala, Mexico

Armando Gomez-Guerrero[1], Norma-Fabiola López-Escobar[1], Alejandro Velázquez-Martínez[1], Aurelio Manuel Fierros.González[1], Luis-Ubaldo Castruita-Esparza[2], José-A Vera-Castillo[3]
[1]Colegio de Postgraduados
[2]Universidad Autónoma de Chihuahua
[3]Universidad Autónoma de Chapingo

In this work we evaluated the reservoirs of N, P, K, Ca and Mg in trees, litter and mineral soil of two managed stands of *Pinus montezumae* Lamb. Additionally we estimated the decomposition rate of litter and the annual amount of nutrients required for tree growth. The study was carried out in a natural forests in Nanacamilpa, Tlaxcala México. The soil nutrient reservoirs were estimated from soil analyses information and the depth and bulk density of the soil horizons. The biomass and mass of nutrients in trunk, branches and leaves were estimated with a destructive sampling of 10 trees. Dasometric data, reservoirs and nutrient dynamics were similar in both stands (t, $P > 0.05$). In mineral soil, the contents of N, P, K, Ca and Mg were 5 419, 68, 1 245, 9 163 and 2 029 kg·ha^{-1}, respectively. The estimated mass of nutrients in biomass were 242, 12, 28, 167 and 118 kg·ha^{-1}, in the same order. The decomposition rate of leaf-litter was -0.335 y^{-1}. The annual requirements for the studied stands were 73 to 81 kg·ha^{-1} of N, 5.2 to 5.3 kg·ha^{-1} of P and 9.4 to 10 kg·ha^{-1} of K. Soil nutrients could maintain forest growth for 256 years, but P could be a limiting factor if sustainable harvest practices change.

P.3.7 - Changing the dynamics of agricultural soils by introducing trees into agricultural landscapes

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Agroforestry is the incorporation of trees into farm landscapes, and tree-based intercropping (TBI) is an agroforestry practice whereby trees and annual crops are grown together. In 1987, the University of

Guelph (UG) initiated a long-term TBI research project on 30-ha at the UG Agroforestry Research Station, Guelph, Ontario. Ten tree species (8 hardwoods and 2 conifers) were planted and annually intercropped with corn, soybean and winter wheat or barley. Tree rows were spaced at 12.5m or 15 m apart with a within-row spacing of either 3m or 6 m. Soil type is sandy loam (Typic Hapludalf). Crops were planted between the tree rows every year according to standard cultural practices. Since inception, as the tree component aged, numerous long-term studies have been undertaken including ones on changes in biodiversity (avian, insect, plant, earthworm), and aspects of nutrient cycling and carbon dynamics. Here we present 32-year long changes in soil properties that have occurred as a result of the introduction of TBI. 7 years after establishment, soil organic carbon (SOC) levels next to tree rows had increased from 2.5% to 3.5% (35% relative increase); 5 years later, as tree crowns grew and litterfall inputs increased, these same changes could be found across the 15 m wide alley. In 2006, (trees in the ground 19 years), soil C pools were almost 80 t C ha^{-1} in TBI systems compared to 65 t ha^{-1} in adjacent monocropped systems. In 2010, there was 12% more SOC in the TBI system compared to an adjacent conventional agroecosystem, and after 25 years, total C pools to 40 cm were substantially greater in TBI systems than in adjacent monocropped systems (maximum 113 t C ha^{-1} (TBI) vs. 71 t C ha^{-1} (mono)). Additional data on soil pH and macronutrients will also be presented.

P.3.8 – Digging deeper: How do introduced deer affect soils and carbon storage on Haida Gwaii?

Sue Grayston[1], Catriona Catomeris[1], Morgane Maillard[1], Dylan Mendenhall[1], Simon Chollet[1], Jean-Louis Martin[1]
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The introduction of non-native species into ecosystems is altering the world's natural communities and their ecological character at an unprecedented rate, is threatening the services our ecosystems provide, and is now on par with atmospheric and land-use change as a major human-induced driver of climate change. Sitka black-tailed deer were introduced to Haida Gwaii in the 1870's and in the absence of predators, the deer population has grown exponentially to the current estimate of 13-30 deer Km^{-2} and has had major impacts on the plant and songbird communities of these islands. Whilst the impacts of deer aboveground is fairly well established, in comparison there is a paucity of knowledge on the effects of deer on belowground organisms and processes. The vital role that soil organisms play in soil carbon storage and nutrient cycling processes and consequent known feedbacks to plant nutrition and growth means such investigations are critical. Deer can reduce the quantity and quality of litter entering the soil, change plant C allocation, transform plant nutrients into more labile forms as urine and dung and compact soil through trampling. In this presentation I will discuss new research being conducted in Gwaii Haanas on islands with and without deer to address these knowledge gaps. Forest floor depth, root biomass, soil pH and soil microbial biomass were significantly higher on islands lacking deer than on islands with deer present. On islands with deer soils were more compacted, had higher soil moisture and NH4 and Al concentrations. Deer populations should be managed to prevent the cascade of effects on forest community composition and ecosystem processes.

P.3.9 - Root zone hydrology in and around wheel tracks on boreal forest clear-cuts: 2D modelling and vegetation inventory

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Rutting (wheel tracks) and/or soil compaction are common disturbances after forestry operations on unprotected, moist soils. Off-road driving can result in decreased porosity and hydraulic conductivity, even on coarse-textured soils (Hansson et al. 2017). Our aim is to assess root zone hydrology and its consequences for vegetation reestablishment, five years after driving. The study is carried out at two forest clearcuts in northern Sweden, each with two slopes/blocks and coarse textured podzolized till soils. Volumetric water content and soil temperature are continuously monitored in different plots along the slopes, in, between, and beside wheel tracks. The reestablishment of vegetation was inventoried in totally 120 plots along the slopes in the summer of 2017, including soil water measurements in each plot with a portable sensor. Root zone hydrology is modelled in and around the wheel tracks as well as in the undisturbed soil in different plots along the slopes using HYDRUS 2D/3D. Five years after driving, the water content was generally higher, and the vegetation cover was still lower in the wheel tracks than in between-tracks and undisturbed areas. The species diversity (Shannon DI) was not significantly different between the tracks and the other areas, but grasses were favored in tracks at the cost of "Ericaceace". The number of self-seeded tree seedlings was highest in the tracks followed by between-tracks and lowest in undisturbed soil. To conclude, the water availability in the wheel tracks was more favorable for seedling establishment and growth than we expected, based on the measured changes in soil physical properties in the previous study. The higher water holding capacity in the tracks might be beneficial for seedling growth during the regeneration phase in these coarse-textured soils.

P.3.10 - Impacts of off-road traffic on soil physical properties of forest clear-cuts: X-ray and laboratory analysis

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Due to the great year-round demand for forest products, off-road forestry traffic occurs even when the ground is susceptible to soil compaction and rutting. We investigated the impacts of repeated passes with a laden forwarder (34 Mg) on the soil physical properties of two clear-cuts on stony till soils in northern Sweden. Core samples (n = 71) were collected from the top 5 cm of mineral soil in and beside wheel tracks, after six passes with the forwarder. Soil physical properties were quantified using classical soil physical analyses and X-ray tomography. The hydraulic conductivity was 70% lower in the wheel tracks than in the soil beside. The X-ray image analysis indicated that this was due to the smaller total volume and lower connectivity of structural pores ($\phi > 60$ µm). Total porosity was 24% and 12% lower in the tracks at the two sites respectively, and mean bulk density was 1.39 g cm^{-3} in the tracks, compared to 1.13 g cm^{-3} beside them. To conclude, traffic changed the soil physical properties in a way that may lead to longer periods of high water content in the wheel tracks, increased risk of surface runoff and

insufficient aeration for optimal seedling growth.

P.3.11 - Soil water quality at a reclaimed mine site 12 years after reclamation

Amir Hass[1], Tigist Geberehiwot[1], Jeffery Skousen[2], Robert Cantrell[1]
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Forestry reclamation approaches (FRA) improved success of reforestation of mine sites in Appalachia by alleviating soil compaction and selecting proper topsoil replacement materials conducive to root growth. Preference and selection of weathered oxidized spoils over non-weathered spoils is expected to lead towards topsoil material with lower levels of dissolved solids released to discharged waters. This study evaluated the effect of FRA practices, namely loose vs. compacted placement of topsoil replacement spoil material, and use of different spoils types (oxidized vs reduced sandstone) on soil water quality of WV mine site, 12 years after reclamation. Experimental plots established in 2005 and shallow wells and zero-tension pan lysimeters (at 30 to 80 cm) installed in the spring of 2017 to collect and monitor water quality. Water samples were taken biweekly since June 2017 and analyzed for elemental composition, total alkalinity, total and organic and inorganic carbon, as well as pH, temperature, and redox potential. Initial results showed levels of alkali and alkaline earth metals within the range of reference surface waters (0.8 – 1.9 times the reference levels) while that of Fe, Mn were much higher (878, and 604 times the reference levels of 0.019, and 0.016 mg L-1, respectively). Levels of heavy metals were elevated as well (1.8, 23, and 37 times the reference levels of 0.0076, 0.0027, and 0.0008 mg L-1, for Ni, Zn, and Cu, respectively). Overall, differences in redox potential and seasonal variation therein seemed to govern metal solubility and nitrogen speciation in the reclaimed soil. Monitoring continue to further assess seasonal changes and mid-term effect of FRA practices on water quality of reclaimed Appalachian mine sites.

P.3.12 - Modern timber harvesting practices have little short-term effect on soil carbon stores in industrial forests of western Oregon and Washington, U.S.A.

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Soil carbon represents a large, but slowly changing pool of carbon in forests and understanding its response to forest management, including harvesting, is critical for determining overall stand/landscape carbon balance. Past studies have observed mixed effects of harvesting on soil carbon possibly due, in part, to imprecise sampling methods and high variability within soils. Weyerhaeuser Company has led a major effort to examine the effect of conventional timber harvesting on long-term soil carbon stores in western Oregon and Washington Douglas-fir forests using a highly-replicated longitudinal study design that enables precise estimation of variability found in these systems. In 2010, we randomly selected nine harvest units from Weyerhaeuser's 2012 harvest plan. Pre-harvest soil samples were collected at 300 sample points from each unit on a fixed square grid, targeting an intensity that would allow detection of >5% change in soil carbon stores. We measured soil carbon concentration and soil bulk density in depth

increments to 1 m to allow for the calculation of total soil carbon per hectare. All units were harvested from late 2011 through mid-year 2012. In 2015, 3-3.5 years post-harvest, we resampled the same areas in an identical manner as the pre-harvest collection to evaluate changes in soil carbon following harvest. Across all sites combined, we estimated a +2% change (-2% to +6%, 95% confidence interval) in mineral soil carbon following harvest, which is consistent with small-to-no change. Individual sites varied in direction of response; only one site showed evidence of a slight decrease in soil carbon, while two sites showed slight gains. These early results indicate that Weyerhaeuser's conventional timber harvesting methods in the Pacific Northwest do not cause substantial short-term losses in soil carbon. Continued monitoring is necessary, however, to document the longer-term trajectory of soil carbon levels through stand development.

P.3.13 - Effects of mixing *Fagus sylvatica* and *Abies alba* on below-ground complementarity at a submontanous site of the Buntsandstein region of Baden-Württemberg, Germany

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The aim of this study was to quantify the effect of mixing European beech (*Fagus sylvatica*) and silver fir (*Abies alba*) on fine-root complementarity to determine the potential of mixtures of these 2 species in face of climate change. We tested several hypotheses: 1) Mixing leads to over-yielding regarding fine-root biomass, 2) fine-root traits differ in mixtures compared to monocultures, 3) mixing leads to a greater fine-root turnover, 4) mixing effects become more pronounced with increasing stand density, 5) mixing leads to a homogenized vertical distribution of fine-roots. The research site is in an approx. 60-year-old stand near Freiburg in southwest Germany. Soil samples were taken with a root soil corer up to 90 cm depth between 30 pairs of trees being 1) two beech trees (pure beech), 2) two fir trees (pure fir), and 3) a beech and a fir tree (mixture) and for each pair, competitors in the neighborhood were measured. Fine-root biomass was highest for the pure fir tree-pairs (ø 2.14 g/cm^3) and fine-root length density was greatest in the pure beech tree-pairs (ø 1.09 cm/cm^3). Specific Root Length of beech was 7 % higher in mixture than in monoculture and silver fir showed a 60 % higher SRL in mixture than in monoculture. The vertical distribution of fine-roots was most homogeneous in pure beech, but the pure fir pairs showed the highest evenness of fine-root distribution. There was no significant effect of stand density on fine-root biomass. It is concluded that mixing of *Abies alba* and *Fagus sylvatica* leads to a higher fine-root growth efficiency, there was no positive effect of mixing on fine-root biomass. This indicates that during drought periods, mixtures of the 2 species may benefit from increased fine-root growth efficiency but not from a better exploitation of soil volume.

P.3.14 - Forest soil and vegetation dynamics following a disturbance - recovery from stump harvesting

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Soil provides the foundation for plant and tree growth in a forested ecosystem. The use of forest-derived biomass has steadily increased in the Nordic countries during the past decades leading to more intensive forest management practices in the region, such as whole-tree harvesting, both above- and belowground. Stump harvest causes severe soil disturbance, such as mixing and relocation of the organic material and the mineral soil within the soil profile potentially leading to decreases in site productivity. Furthermore, decomposing stumps and roots can be a potential source of nutrients for the next generation of trees. Finally, the climate benefits of stump harvesting are uncertain.
The aim of this study was to assess the effects of physical and chemical load on the longevity of soil changes, their long-term ecosystem recovery and factors affecting it. We studied the effects of stump harvesting on soil carbon and nitrogen mineralization, soil surface disturbance, coarse woody debris and vegetation in different clear-felled Norway spruce (*Picea abies*) stands. The sampling was performed 8–13 years after treatments. Site preparation in the form of spot mounding was been carried out in all clear-cut plots, also where the stumps were removed. Logging residues were harvested in all experimental stands and the stands were planted with Norway spruce seedlings following site preparation. The findings of this study indicate that the effects of stump harvesting on soil carbon and nitrogen dynamics, field layer vegetation and coarse woody debris are site-specific but nevertheless existent.

P.3.15 - Artificial groundwater recharge and forest soil - sprinkling infiltration impacts on boreal forest soil, tree growth and understory vegetation

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The artificial recharge of groundwater by infiltrating surface water through forest soil by sprinkling infiltration has been introduced as a groundwater producing practice. As a result, the forest soil, as well as the whole ecosystem, is subjected to extremely high inputs of nutrient and carbon rich lake-water. In this study, we studied the chemical changes in forest soil properties and processes and the effects of infiltration on understory vegetation and tree growth following a 15-year recovery period from sprinkling infiltration.
After a 13-15-year recovery period, soil pH as well as base cation calcium and magnesium concentrations were still significantly higher at the infiltrated plots. The rate of net N mineralization was much higher at the infiltrated plots both in the humus layer and in the mineral soil, whereas net nitrification was negligible. It seems that sprinkling infiltration had induced succession and thus favored early-successional herbs and grasses as well as deciduous shrubs (*Vaccinium myrtillus*) and negatively affected late successional, slow-growing mosses and lichens. After recovery mosses had to some extent recovered from the infiltration. Tree growth indicated a strong short-term response to the added lake water; radial growth of the study trees peaked during and immediately after infiltration. After a few years, this "fertilizing" effect on tree growth had tapered off and the study trees no longer exhibited increased radial growth. Sprinkling infiltration is an environment altering water treatment method which, based on the findings of this study, can have short-term effects on tree growth and long-term effects on soil chemical processes and understory vegetation. As a result, ecosystem recovery will ultimately take much longer than the studied 15 years.

P.3.16 - The role of forests in soil amelioration and securing hydropower needs of Cambodia

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Sediment accumulation remains a major factor in negatively impacting useful lifetime and operation of hydropower dams. Decline in forest cover within a watershed accelerates the rate of soil erosion, thereby soaring the amount of sedimentation in the streams heading to the dam's reservoir. Reducing the rate of deforestation and hence, sedimentation in the rivers positively affects the lifetime and operation of such dams. Ultimately, the appropriate management of the watershed's forest cover and sediment could play an important role in the maintenance of downstream riverine and floodplain ecosystems. The cost associated with conserving forested watersheds can be considered as an investment in betterment of hydropower generation. Payments for ecosystem services (PES), an approach to provide incentives for forest conservation from users of services to their providers, can be used to finance such costs. Using a free, open-source, and widely used computer-aided software, Python, a modelling framework is used to estimate the sedimentation from soil erosion due to deforestation. The associated power generation loss is then calculated, and by relating it to current electricity tariffs we estimated the annualized and present monetary value associated with the benefits of forest conservation to hydropower. Using average climate values and local land-use change projection over 100 years, a general framework is developed and applied to various hydropower dams proposed in the Tonle Sap watershed. This modelling tool is designed to be general and transferable to other river systems around the world where hydropower development is accelerating and creating a great need to maintain a balance between upstream and downstream ecosystem services.

P.3.17 - Use of alkaline-treated biosolids (ATB) as a possible liming amendment on spruce plantations in Nova Scotia, Canada.

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Decades of acid deposition in northeastern North America has resulted in base cation loss and increased Al concentrations in many forest soils across the region. In Nova Scotia, nutrient budget modelling has identified Ca as a potentially limiting nutrient in spruce plantations underlain by slowly weathering soils. To offset current or predicted Ca deficits on these sites, we conducted field trials using alkaline-treated biosolids (ATB) as a plantation soil amendment – the first such use of this product in spruce plantations in the region. We also compared ion fluxes in plantation mineral soils treated with ATB, lime, and fly ash under more controlled greenhouse conditions. The objective was to see if ATB could be used as an effective liming amendment in plantation forest soils while also providing an additional end-use for this waste stream product. Results showed ATB to be as good a source of Ca as lime or fly ash that can significantly increase soil Ca while also increasing forest floor pH and reducing exchangeable Al concentrations. In addition, field treatments did not result in any significant accumulation and/or leaching of trace metals or NO3, nor to any impact on ground vegetation abundance or diversity in the

juvenile plantations assessed. Treatments did, however, improve Ca, K, P, and Mn concentrations in white spruce crop tree foliage, while also slightly increasing diameter increment. On the negative side, use of ATB caused major Ca:Mg imbalances in treated soils due to imbalanced inputs and increased displacement and leaching loss of Mg. This also resulted in no improvement in tree foliage Mg concentrations. Overall results suggest that ATB could be a good source of Ca in Ca-limited plantation soils, but nutrient imbalances may be a problem on sites where significant Mg and K depletion has also occurred, or where N is also limiting.

P.3.18 - Changes in soil carbon abundance and characteristics after converting agricultural fields to bioenergy crops in the lower Mississippi alluvial valley

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We monitored mineral soil C and N to a 30-cm depth at three sites in Arkansas and Louisiana for five years following the establishment of eastern cottonwood (*Populus deltiodes* L.) and switchgrass (*Panicum virgatum* L.) bioenergy crops on marginal agricultural soils. C and N measured in these soils were compared to C and N from soils sampled within a soybean-grain sorghum rotation (control) established at each site. Prior to the study all sites had supported row crop agriculture. However, one site had laid fallow during years with wet springs and another had been converted to a pasture approximately 6 years prior to initiation of the study. Mineral soil C concentrations increased during the five-year study for all cropping treatments. Although the increases did not significantly differ among treatments, increases for the two bioenergy crops were numerically greater than for the control crop. Changes in total N during the study did not significantly differ among cropping treatments. However, at the end of the study soil C:N ratios were significantly higher within the bioenergy crops (13.2-13.9) than in the control (12.1) and greater than that prior to crop establishment (10.6-10.8). Stable C isotope composition ($\delta^{13}C$) of the soils were also impacted by the different crops. At the two sites that had not been converted to pasture, $\delta^{13}C$ was initially low (-25.8 to -26.1 $\delta^{13}C$ ‰) and only switchgrass altered ^{13}C. Switchgrass increased $\delta^{13}C$ by 1.7 to 1.9 ‰ at these two sites. At the other site, switchgrass and the control crop significantly decreased the initial $\delta^{13}C$ from respectively -22.3 and -21.0 ‰ to -24.5 and -25.6 ‰ $\delta^{13}C$. Together, these results indicate that bioenergy crops have the potential to alter C characteristics of these agricultural soils, but land use prior to conversion affects the trajectory and magnitude of these changes.

P.3.19 - Nitrogen deposition, edge effect, sugar maple, soil composition, foliar nutrition

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Atmospheric nitrogen deposition (Natm) from antropogenic source has increased since the beginning of industrial revolution. Current modeled intake rates of Natm in several forests in eastern Canada exceed critical thresholds beyond which many functions and services may be altered. For example, excess Natm

inputs can acidify soils, cause nutritional unbalance and dieback of sugar maple stands, and therefore increase their vulnerability to environmental stresses such as drought. In this study, 11 sugar stands were selected in the MRC of the Vallée-du-Haut-Saint-Laurent, Québec, to test if a gradient of Natm deposition, ranging from the edge of the agricultural field to well within the maple stand (120 m), could be detectable on soil chemical properties (pH, total C and N, extractable P, exchangeable cations, mineralizable N) and on leaf nutrition (N, P, K, Ca, Mg) of mature sugar maple trees. Soil chemistry and foliar macronutrient concentrations of sugar maple did not differ between distances along the measured gradient (10, 20, 30, 50, 70, and 120 m). The large fragmentation of stands in this area may explain the lack of edge effects. The analysis of the nutritional status of the sugar maple through the DRIS indices revealed deficiencies in K and P in all maple stands sampled, at all distances from the field-stand edge. These results make it possible to give better advices to homeowners when they want the best management and fertilization practices in order to improve their maple stands health.

P.3.20 - Nitrogen movement after urea application to a young *Pinus radiata* forest on pumice soil

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One third of the planted forest land area of New Zealand is deficient in at least one of the nutrients required for optimal tree growth. This presents a significant impediment to aspirations to double the productivity of New Zealand's planted forests. Fertiliser use could be a key step towards reaching that goal, but knowing when and how to add fertiliser to maximise crop uptake while minimising drainage losses is an ongoing challenge. Previous nitrogen (N) fertiliser trials in *Pinus radiata* forests using N isotopes (^{15}N) have shown that in years with typical rainfall patterns, movement of fertiliser through the soil can be quite slow and stands could potentially take up high single doses of N. However, other studies have found large losses of fertiliser N. To better understand the effects of N fertiliser addition on leaching and forest productivity, a trial was established in a young *Pinus radiata* stand on a low-fertility pumice soil. In the study area, the *Pinus radiata* Nutrient Balance Model (NuBalM) indicated that 500 kg N ha^{-1} was required to reach target productivity. Nitrogen applications of 0, 250, and 500 kg ha^{-1} in the form of urea were applied in a single dose to a replicated block plot design. Harvest residues from the previous tree crop had been windrowed, so sampling was undertaken both between and below the harvest residues. Movement of N was assessed using soil sampling (^{15}N tracer), as well as resin lysimeters and leachate collectors at depth (1 m and 2 m soil depth). Initial results from this study will be explored with specific attention to the sensitivity of N loss during weather events and the implications for forest management.

P.3.21 - The effects of low-dose chemical control on soil biogeochemistry and tree establishment in a wet longleaf pine savanna of the southern US

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Longleaf pine (*Pinus palustris* Mill.) survival and growth, net nitrogen mineralization, and soil microbial biomass, were evaluated after four growing seasons in a wet Florida flatwoods ecosystem following chemical vegetation control during the first year or second year after planting, or during both years. The four herbicide treatments included sulfometuron methyl at 0.26 ai kg ha^{-1}, hexazinone (0.56 ai kg ha^{-1}), sulfometuron (0.26 ai kg ha^{-1}) + hexazinone (0.56 ai kg ha^{-1}) mix, and imazapyr at 0.21 ai kg ha^{-1}. Imazapyr was the only treatment to significantly improve growth over the control in a single application. Consecutive annual applications of imazapyr and hexazinone over the top of seedlings also improved growth rates compared to the control. Sulfometuron methyl-treated pine trees had lower survival rates and were smaller than pines planted in the control plots after a single application. The survival and growth rates of imazapyr-treated seedlings were improved when the herbicide was applied early during the second growing season after planting. Imazapyr and hexazinone applications increased net nitrogen mineralization rates, but imazapyr was the only treatment to increase ammonification; compared to the control. The overall microbial biomass carbon as well as the fungal component showed no differences between treatments and the control. Imazapyr applied during the second growing season proved to be the best treatment for improving pine growth, controlling competitive vegetation, minimizing pine mortality, and to remain effective during flooding events.

P.3.22 - Exotic Asian pheretimoid earthworms (*Amynthas* spp., *Metaphire* spp.): Potential for colonisation of south-eastern Canada and effects on forest ecosystems

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Exotic species invasions are among the most significant global-scale problems caused by human activities. They can seriously threaten the conservation of biological diversity and of natural resources. Exotic European earthworms have been colonizing forest ecosystems in northeastern USA and southern Canada since the European settlement. By comparison, Asian earthworms began colonizing forests in the northeastern U.S.A. more recently. Since Asian species have biological traits compatible with a greater potential for colonization and disturbance than some European species, apprehension is growing about their dispersal into new territories. Here we review the extent of the current northern range of Asian earthworms in northeastern North America, the factors facilitating or limiting their propagation and colonization, and the potential effects of their invasion on forest ecosystems. Data compilation shows that Asian earthworms are present in all northeastern American states. So far, only one mention has been reported in Canada. Also, data confirm that their distribution has now reached the Canadian border. Studies report that the presence of Asian earthworms is strongly associated with human activities such as horticulture, vermicomposting and the use of worms as fish bait. Some climatic (temperature, soil moisture) and edaphic (soil pH) factors may also influence their distribution. Controlling their dispersal at the source is essential to limiting their spread, as there is currently no effective way to eradicate established earthworm populations without unacceptable non-target effects. Proposed management options in the USA include the prohibition of fish bait disposal and better management of the international trade of horticultural goods, commercial nurseries and vermicomposting industries. We conclude that, although regulations and awareness may delay their expansion, Asian earthworms are likely to spread further north into Canada. They are expected to cause important changes to biodiversity and dynamics of the newly invaded forest ecosystems.

P.3.23 - Soil mediated interactions between southern pine trees and forest insects

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Physical and chemical attributes of soils can have both direct and indirect effects on the incidence and severity of insect damage in southern forests. While unfavorable soil conditions act as a predisposing stress agent, soils also interact with other abiotic and biotic agents to further affect tree health. For example, tree stress associated with drought is often a precursor to outbreaks of bark beetles such as pine engraver beetles (Ips spp.) and the impacts may be more severe in certain soil types. Further, soil conditions typically associated with littleleaf disease (*Phytophthora cinnamomi*) or Heterobasidion root rot (*Heterobasidion irregulare*) also cause increases in forest pests. Soil chemistry may also be important as demonstrated by examples of insect outbreaks in fertilized plots of experimental studies; however, landscape level relationships do not, generally, exist. In this paper we provide state-of-the-art knowledge about the effects of various attributes of soil on insect-tree interactions, describe conceptual relationships between soils and forest insect pest dynamics, and provide gaps in information and future research directions in southern coniferous forests.

P.3.24 - Soil organic matter from southern pine biofuel feedstocks under different soil types and management systems

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Biofuels have the potential to reduce our dependence on fossil fuels and lower CO2 emissions.
The use of loblolly pine plantations to produce biofuels, using pre-commercial thinnings instead of commercial timber, can potentially deliver sustainable biofuels. However, the removal of additional biomass from these plantations could reduce carbon (C) inputs belowground and therefore decrease overall ecosystem C storage. Additionally, very few studies have analyzed soil C dynamics in pine plantations managed for biofuel production. This study analyzes soil C stocks as a function of soil type and different pine plantation management systems. We hypothesized that plantations with heavier pre-commercial thinning and a more intensive silvicultural regime would have lower soil C stocks than plantations with less intensive overall management, especially in plantations with well-drained soils compared to poorly-drained soils. We specifically expected to see these differences in soil organic matter (OM) fractions that are not mineral-associated (i.e. light fraction and particulate organic matter) and therefore less persistent. We found there were no significant differences in bulk soil C stocks across management intensities or soil type. The pre-commercial thinning treatment had no effect on the %C found in each soil organic matter fraction. However, proportionally more C was found in mineral-associated OM and less in particulate OM in the more intensive silvicultural regime treatment, possibly due to higher below ground inputs and microbial activities in these more fertile stands. Contrary to our hypothesis, our results suggest that management intensification to support biofuel production from loblolly pine plantations will not affect soil carbon stocks, but possibly increase their persistence.

P.3.25 - Characterization of soil fertility in lichen woodlands and adjacent black spruce-feathermoss stands in the continuous boreal forest

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We investigated old lichen–spruce woodlands (LW) and adjacent spruce–feather moss (FM) stands growing under similar soil conditions in the continuous boreal forest zone in Quebec. A total of six pairs of stands were investigated by profile sampling. Stem density, basal area, and biomass were about four times greater in FM than in LW on an area basis. The humus also was on average twice as thick in FM compared to LW. Soil pH tended to be 0.17 ± 0.1 unit lower in FM than in LW stands, and this difference was apparent both throughout the humus and the mineral soil profile. Humus C/N ratios were similar between stand types. The stocks of total C and N, and of exchangeable K, Ca, Mg, Al, and Na in the humus were 1.4 to 2.3 greater in FM than in LW soils. In the first 30 cm of the mineral soil, only total C and exchangeable Al stocks were about 2.7 times greater in FM than in LW. There was no difference neither in total N nor in exchangeable base cation stocks on this soil depth. In the first one meter of mineral soil, only total C was 2.4 times higher in FM than in LW soils. For the whole profile (humus + 1 m mineral soil), total C and N, and exchangeable Ca and Mg stocks were 1.3 to 2.6 higher in FM than in LW soils. These results highlight the lower fertility of LW soils, but also the importance of the biological control of C, N, and mineral nutrients on their accumulation in these boreal soils.

P.3.26 - Long-term impacts of slash pile burning on wood decomposition and fungal communities

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Many forest stands in the western United States are in need of restoration for a variety of attributes (e.g "fire regime, watershed health, and insect/disease resilience") after 100 years of fire suppression or lack of harvesting activities. Pre-commercial and commercial thinnings, along with biomass-to-energy harvests, contribute large amounts of slash material, which is commonly disposed of by piling and burning. Belowground soil impacts from slash pile burns can be highly variable because of differences in soil texture, fuel type and loading, and soil moisture during burning. We measured the heat pulse during burning under slash piles and determined changes in soil microbial processes by evaluating wood stake mass loss in and outside recently burned slash piles in western Montana, northern Idaho, and eastern Oregon. Many decomposition studies use native organic matter, but differences among sites are difficult to determine, therefore we used a standard wood stake method that is well-suited for examining fire impacts on multiple sites. From these slash pile burns we determined that, in general, spring pile burning has less impact on belowground stake mass loss as compared to fall burning and all

burn plots had faster mass loss than the unburned control. In addition, soil texture also plays a role in the rate of mass loss. Second, we used the same wood stake method to measure wood decomposition on old (50+ years) burn scars where forest regeneration has not returned (except as invasive grasses and forbs). In these old burn pile scars we also measured changes soil fungal diversity from the center of the burn scar to the surrounding forest edge using metagenomic methods. Both recent and old slash pile burns may alter soil microbial populations to influence long-term forest growth and productivity, depending on burning season, pile size and design, and soil texture.

P.3.27 - Long-term effects of harvest residues on spruce-fir site productivity following whole-tree and stem-only harvesting

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The 1970s spruce budworm epidemic along with energy shortages following the 1973 oil embargo resulted in changes in harvesting system design and associated slash management employed in northern Maine. Proposals to use roadside slash for bioenergy raised concerns regarding potential soil nutrient depletion and reductions in forest productivity. As a result, from 1979-2015, 25 permanent study plots were established across three soil drainage classes in uncut (reference) and clearcut watersheds at the Weymouth Point Study Area in north-central Maine to evaluate residue treatment effects on forest productivity. Twelve 20x20 m plots were treated in 1981 with three harvesting residue treatments: whole-tree harvesting (WTH), de-limbing residues lopped and scattered (LOP), and de-limbing residues chipped and spread (CHP). Residue treated plots were subsequently treated with triclopyr in 1985 to release conifer crop trees from hardwood competition. The CHP residue treatment significantly ($\alpha = 0.1$) affected DBH, height and biomass of the naturally regenerated trees. Tree growth was significantly affected by stand density in the CHP treatment; but not by other residue treatments, soil drainage class or soil stone volume. Stand density variation across treatments suggested that chipped residue application reduced advanced natural regeneration seedlings by 600 stems per ha on CHP sites which, in turn, significantly enhanced growth of surviving trees. The 100 fastest-growing trees per plot (equivalent to 2500 stems per ha) were also significantly larger on CHP treated plots due to lower stand density. Analysis of differential N, P, K, Ca and Mg loading associated with residue removal (WTH) or addition (CHP, LOP) 35-years after harvest suggests that whole-tree harvesting has not reduced stand growth at this study area.

P.3.28 - Long-term bioavailability and plant uptake of fertilizer nitrogen in managed coniferous ecosystems of the southeastern United States

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Nitrogen (N) is generally considered the most limiting nutrient to productivity in managed pine plantations across the southeastern United States. To ameliorate N deficiencies in managed pine plantations, N fertilization, generally in the form of urea, is applied at various times during the stand rotation. Yet large amounts of urea N can be lost from the system dependent on the weather at the time of urea fertilization, with remaining fertilizer N partitioned among various ecosystem components. The primary objective of this research was to refine our understanding of nitrogen (N) dynamics in managed coniferous ecosystems across the southeastern United States after N fertilization. We enriched four fertilizer treatments (urea, urea+NBPT (NBPT), MAP coated urea (CUF), polymer coated urea (PCU)) with 15N (0.5 atom %). Each treatment was applied to a single 100m2 circular plot at three sites (AR, AL, VA) in the spring and summer of 2011 at a rate of 224 kg ha^{-1} N. Six years after application, all vegetation was removed from the plot and surrounding area. Eighteen loblolly pine (*Pinus taeda* L.) seedlings of the same genetic material were planted in each plot. Additionally, three intact cores were removed from each plot and planted with a single loblolly pine seedling for a laboratory experiment. One loblolly pine seedling and different species of competing vegetation were sampled from both the field and laboratory experiments at the end of a single growing season to assess differences among treatments specific to the bioavailability and plant uptake of residual fertilizer N. Preliminary sample analysis indicates residual fertilizer is bioavailable for plant uptake six years after fertilization, although it is uncertain at this time whether differences exist among treatments and between seasons.

P.3.29 - Long-term effects of whole-tree harvesting and residue management on spruce-fir soil quality in central Maine

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Soils support plant growth and development, making the management of this resource a cornerstone for successful forest conservation. A growing demand for forest biomass has encouraged foresters to intensify management practices including the use of whole-tree harvesting (WTH), where minimal residues are sometimes left on site. When analysing nutrient fluxes, researchers have found that WTH results in significantly greater loss of N, P, K, and B compared to both stem-only harvesting (SOH) and no-harvest control scenarios. WTH can result in a net loss of acid-neutralizing capacity due to the loss of base cations such as Ca, Mg, and K that accumulate in the woody biomass. This loss may affect plant development and function through the mobilization of nutrients that can disrupt cell division, respiration, and nutrient uptake. The Weymouth Point Study Area (WPSA) is located in northern Maine, where WTH has been widely utilized following a severe spruce budworm epidemic in the 1970s. To quantify the effects of WTH, a paired watershed study contrasting various forms of WTH and SOH was initiated in 1981. The current analysis examines the long-term effects of WTH versus SOH on soil nutrients 35 years post-harvest. The objective of this research is to quantify the temporal trends in ecosystem C and nutrient availability that could be used to develop criteria and indicators of sustainable forest management that informs forest policy and certification systems. Data have been generated from forest floor and mineral soil samples, that have been air-dried and sieved, and will be analyzed to estimate the concentrations of total C and exchangeable nutrients across treatments and controls.

Based on trends observed 17 years post-harvest, it is hypothesized that WTH could result in long-term negative consequences in terms of soil acidification, nutrient losses, and soil C storage 35 years post-harvest.

P.3.30 - Microbial community diversity in biochar amended forest soils in the Pacific Northwest, USA

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Overstocked forests occur in the western United States due to fire suppression and lack of harvesting. Overstocking stress can be alleviated by forest thinning. Thinning residue can be converted and returned to the forest as biochar to compensate nutrient losses. Biochar has the potential to sequester carbon and improve soil quality when used as a soil amendment. Biochar affects soil chemical and physical properties, which could affect microbial community diversity. The study objective was to determine if forest soil bacterial and fungal communities are affected by biochar amendment. Biochar was applied to the soil surface at three rates (0, 2.5, and 25 Mg ha^{-1}) in the northwestern USA. DNA was extracted from soil samples collected from three depths, three to five years following amendment (dependent on site). Double-barcoded 16s rRNA (bacteria) and LSU (fungi) amplicons were sequenced on an Illumina MiSeq platform. Bacterial sequencing data represented 33 phyla. The most common genera were Gp4 of the Acidobacteria phylum and *Spartobacteria* genera incertae sedis of the Verrucomicrobia phylum. Biochar amendment, dependent on soil depth, affected the amount of Acidiobacteria and Gemmatimonadetes in the soil. Bacterial community diversity (Shannon-Weaver Index) and richness (Chao Index) were not affected by biochar amendment. For fungi, sequencing data represented six phyla and the most common genus was *Umbelopsis*, a ubiquitous soil zygomycete. Biochar amended soil had more Ascomycota while unamended soil had more Basidiomycota. Fungal community richness was significantly higher in soils amended with 25 Mg ha^{-1} biochar, but fungal diversity was unaffected by biochar amendment. Amending forest soils with biochar does not appear to have negative impacts on microbial community diversity. Soil sampling depth significantly affected most variables.

P.3.31 - The Forest Floor Recovery Index: a tool to assess ecosystem recovery using forest floor criteria

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In the oil sands region of Alberta governments and industry are asking for tools to assess the recovery of forest ecosystems after resource extraction and land reclamation. The Forest Floor Recovery Index (FFRI) is a system that uses forest floor characteristics in natural stands as a reference condition to judge success of ecosystem recovery after reclamation. Data collected for nine ecosite types and five stand-age classes in the Central Mixedwood Subregion of Alberta were used to develop the FFRI. Nineteen forest floor classes are described that users can classify on reclaimed sites. Data collected are used to calculate an FFRI score (1–3) that indicates how well the forest floor is recovering by comparison to the reference condition. Recommended application rates of woody material are provided for sites with low

FFRI scores because woody material is important to building forest floors in the region. The FFRI is available as a field manual (2nd edition), and an Android app in English and French. The field manual includes background information on forest floors, guidance and images for ecosite and forest floor classification, instructions on calculating the FFRI score, and woody material application rates. The app includes the same content as the manual and in addition has features that make data entry simple and calculation of an FFRI score automatic. The FFRI has potential for application in other parts of Alberta and Canada to assess recovery of forested land after reclamation.

P.3.32 - Responses of soil microbial community composition and enzyme activities to land-use change in the Eastern Tibetan Plateau, China

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As the second largest forest area, forests in southwestern part of China had been harvested seriously till the end of twenty century. Land-use change is a major determinant influencing ecosystem carbon patterns and nutrient cycling in this area. Structure and function of soil microbial communities following land-use change from old-growth forests (OF) to secondary forests (SF), plantation forests (PF), and grass lands (GL) in subalpine area in the Eastern Tibetan Plateau were studied for assessing the impact of land-use change on soil characteristics. Phospholipid fatty acid profiles and enzyme activity analysis were used to determine soil microbial community composition and activities, respectively. The results showed that soil microbial communities were structurally distinct among land-use types. The anaerobic bacteria were significantly higher in OF and PF when compared to GL. The actinobacteria was increased by 9.4% and decreased by 6.3%, respectively, after the forest conversion from OF to SF and PF. Moreover, land-use changes from OF to PF and GL shifted enzyme production toward a decrease in N-acetylglucosaminidase and β-glucosidase activities, which may reduce nutrient cycling rates and thus decrease nutrient acquisition for metabolism. Although GL decreased the fungi relative abundance, such land-use type dramatically increased the polyphenoloxidase activities, which are typically linked to the depolymerization of soil recalcitrant organic compounds. In addition, correlation analysis showed that anaerobic bacteria and saprotrophic and ectomycorrhizal fungi (SEM) was positively correlated with soil organic carbon (SOC) and total phosphorus (TP), and actinobacteria was correlated with N:P ratio. Our work demonstrates that land-use change has significant influences on microbial community composition and subsequently affected the enzyme activities. The study has important significance on forest management practice for the future in the area.

P.3.33 - Working with soil microbes to build better forests

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Intensifying forest management to enhance productivity has many implications for forest soils and ecosystem functions. Increased demands for nutrients, greater frequency of physical disturbance and changes to the input of organic matter can all substantially alter the nature of soil, and the habitat it provides for the microbial communities that reside within it. Assessing the response of these communities to management-driven changes in soil properties has interest in terms of understanding

microbial community ecology, but of potentially greater significance to forest management are the impacts on the microbial functions that support forest health and growth. To this end, a substantial amount of research has been conducted in New Zealand's planted forests to determine the impact of various management practices on a range of microbial parameters linked to forest performance. These studies initially focussed on a number of long term trials where alterations to soil microbial community properties were incidental. Over time, the research has evolved to include a network of trials in which changes to forest soil microbial community activity is now the principle objective. The research has also expanded to include studies of soil microbial communities in tree nurseries, and the impact of alterations to microbial symbionts on post-nursery performance in the forest. The results of this work have determined that forest soil microbial communities, and the functions they perform, are more sensitive than initially anticipated, with alterations to microbial activity persisting for decades after the application of a management practice. It has also been determined that a number of practices that produce short term growth benefits can produce long term detrimental effects on microbial function that will potentially overwhelm the initial gains. However, some options for enhancing both forest productivity and certain beneficial microbial functions have been identified, and are currently being actively explored.

P.3.34 - Empirical and predicted estimates of balsam fir boreal forest carbon pools following stem-only harvesting in Forêt Montmorency, Quebec, Canada

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Climate change and global wood products demand raise concerns about boreal forest ecosystem resilience to natural disturbances and harvesting. Forêt Montmorency (FM), Quebec, provided an opportunity to use a chronosequence experimental design to evaluate the effects of harvesting on carbon recovery trajectories at the stand level over a period of 77 years in balsam fir-white birch stands. We compared empirical estimates of 19 FM forest carbon pools with those simulated by the Carbon Budget Model (CBM-CFS3) to test model assumptions for predicting carbon dynamics in this eastern boreal forest. The model was initialized using forest inventory data, spatially explicit environmental conditions, and disturbance matrices designed to represent historical spruce budworm epidemics in FM. Over the chronosequence, total ecosystem carbon increased significantly ($p = 0.05$) following harvest, increasing from 211 Mg in year-zero to 279 ± 8 Mg C ha^{-1} in year 67 (mean ± SE); total tree biomass, deadwood, and soil pools accounted for 95 ± 3, 19 ± 2, and 163 ± 9 Mg C ha^{-1}, respectively). Trends in total ecosystem carbon suggest that FM carbon pools were recovering to pre-harvest levels after seven decades. CBM-CFS3 predicted total ecosystem carbon stocks within 10% of the empirical mean at stand maturity; however, several predicted carbon pools deviated from field observations in both C amounts and trends over time. The greatest differences in C stock trends were in deadwood and soil carbon pools, suggesting that the model initialization of dead organic matter pools did not adequately simulate the 1000 year history of C-pool transfers and stand dynamics leading up to the harvest of FM in 1933. This suggests modifications to CBM-CFS3 initialization assumptions and default decay parameters are required to more accurately simulate the long-term effects of natural disturbances on carbon pools over time for this forest region.

P.3.35 - Storage and recycling of residue nutrients on skid trails

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Intensive biomass harvesting extracts and redistributes nutrients within forest stands. More frequently, mechanized processing of stems deposits crown and bark material – and the nutrients therein – onto semi-permanent skid trails. Yet how much nutrients are redistributed to skid trails and their fate has been minimally studied. In this study, we determined the redistribution of base cations and phosphorus onto skid trails from one thinning in an *Abies alba* stand, and from four thinnings in a *Picea abies* stand. We also measured the resulting stand and skid trail nutrient stocks in both the organic layer and mineral soil. In the silver fir stand, 50-60% of harvested nutrients were deposited on skid trails. Five years after thinning though, skid trail cation and phosphorus stocks were the same as the stand's, implying nutrients were recycled back into surrounding vegetation. In comparison, 35-45% of harvested base cations and 60% of harvested P in the Norway spruce stand were deposited on skid trails, and, four years after the last thinning, skid trail cation and phosphorus stocks still accounted for the nutrient deposition after four thinnings. Nutrient concentrations in spruce needles likewise showed no increase closer to the skid trail despite potassium and phosphorus deficiencies. At both sites, soil compaction in skid trails was minimal according to bulk and root densities. In summary, nutrients accumulate on skid trails and can be reused by the surrounding stand depending on disturbance effects from thinning and stand nutrient stoichiometry.

P.3.36 - What do guidelines for forest harvesting residue removals tell us about "sensitive soils"? A review of international guidelines.

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Increased activity in the bioproducts sectors has led to increased concern about the environmental impacts of increased removal of forest harvesting residue from sites for use as feedstock for bioproducts, notably bioenergy. Amongst other issues, there are concerns about the effect of this on soils and subsequent site productivity. There are now 31 guidelines covering 53 jurisdictions in the northern hemisphere that specifically address forest harvesting residue removals for bioproducts. Residue removal guidelines operate at the site level, but can be considered to be nested within landscapes insofar as they are often explicitly stated to operate within sustainable forest management (SFM) and related water and biodiversity regulations. On the other hand, some jurisdictions explicitly choose not to create biomass removal guidelines because they consider it to be already covered under their SFM guidelines. This is especially true in jurisdictions where use of single-pass full-tree harvesting systems that result in residue piles at roadside preceded development of the bioenergy sector and were

implemented for economic reasons. Guidelines typically aim to protect soils from unacceptable degradation of physical (erosion, compaction), biological (soil fauna) or chemical (nutrients) properties and attributes. They are the outcome of a combination of scientific knowledge, forest management planning and operational experience, and sometimes input from other stakeholders. Guidelines are thus the nexus between science and forest operations, between knowledge and the practical application of that knowledge. It is therefore not surprising that definitions of “sensitive soils” requiring some amount of protection during residue removal can vary from detailed descriptions to broad generalisations; for example, operators can be advised to avoid nutrient depletion in general terms – or this may be defined based on detailed soil information or even quantification of potential nutrient removals using nutrient budget models. The various attributes of biomass removal guidelines that are applicable to soils are classified and presented in detail for comparative purposes, and to stimulate discussion on how knowledge can best be applied to ensure the environmental sustainability of this practice.

P.3.37 - The effects of logging residue piles of different tree species on soil nitrogen losses

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Current forest harvesting practices creates logging residue piles that are not evenly distributed on a clear-cut area, which is noticed to accelerate soil nitrogen (N) cycling processes, especially net N mineralization and net nitrification. As a result of this stimulation, N is transformed to more mobile form and risk for N losses as leaching and N_2O emissions from the forest floor may increase.
Our aim was to study how logging residues of Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and silver birch (*Betula pendula*) affect N losses in forest soil after clear-cutting. A spruce-dominated stand was clear-cut in September 2014. Plots with fresh logging residue piles of different tree species, and control plots without logging residues, were subsequently established. Effects of logging residue piles on N losses via leaching were monitored from the soil percolating water. In addition nitrous oxide (N_2O) emissions, collected with closed chamber technic, were determined over two growing season. Denitrification activity and the contribution of nitrification and denitrification to N_2O production were determined once with C_2H_2 inhibition method. Logging residue piles increased total N and nitrate (NO_3-N) concentrations in soil percolation water. In addition logging residues piles tended to stimulate N_2O fluxes, although in general fluxes were low. There were signs of differences between tree species; however, major trends were similar. Currently we study the effects of large logging residue storage piles on N mobilization and losses.

P.3.38 - Impacts of logging practice on base cation budgets of boreal coniferous stands – a sustainability study

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The effects of global warming pose a serious threat to humankind and nature. The increasing use of renewable energy is an important tool of climate change mitigation policy in Europe. Bioenergy, such as forest residues, is regarded as a potential means of substituting conventional fossil fuels, since the use of biomass reduces fossil fuel emissions and replaces non-renewable energy sources. In the intensified harvesting method, whole-tree-harvesting (WTH), forest residues (tree tops, branches, foliage) and sometimes stumps are removed from the site and used as an energy source, while in the conventional stem-only-harvesting (SOH) the logging residues are left on the site. In Finland 2/3 of land area is covered by forest (25 milj ha), therefore opportunities to combine sustainable harvesting of biomass to complement traditional industrial sawlog and pulpwood harvestings are abundant. However, an intensified forest biomass harvesting causes a greater removal of nutrients from the forest ecosystem and can have detrimental effect on the future forest productivity. The major pathways of nutrients into the forest ecosystem are atmospheric deposition and weathering of soil minerals. We simulated the impacts of final felling harvestings on base cation (Ca,K,Mg) budgets in boreal forests under the scenarios of SOH, WTH and WTH+stumps (WTHs). The study included five Scots pine and Norway spruce stands belonging to the UN-ECE ICP-Forests Level-II programme in Finland. A mass balance approach was used: base cations (BC) in total deposition, weathering, leaching, and harvesting removals fluxes were estimated and analysed for the effect of tree species and climate. Soil stocks of exchangeable BC were measured and BC exports in the final fellings were estimated. Results indicated that the amount of BC in the final fellings of all scenarios was larger in spruce than in pine. Harvesting intensity negatively impacted the sustainability of BC. WTHs most severely lowered BC sustainability.

P.3.39 - Quantifying cumulative effects of harvesting traffic and residual slash on aspen regeneration at a harvest block scale

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The effects of harvesting practices on subsequent forest regeneration have typically focused on using sample plots to assess regeneration for large harvested blocks. However, is it possible to scale up the impacts of harvesting on regeneration from using small sample plots to examining an entire block? The objective of this study is to assess the relationship between harvest machine traffic, residual slash, and vegetation regeneration on a block level in the Saskatchewan Duck Mountain Provincial Park. During the winter harvesting in the park, GPS units were placed in skidders to track machine movement. ArcGIS was used to generate a traffic map illustrating the variation in traffic intensity across the block. Residual slash left in the block was quantified from aerial RGB images collected using an unoccupied aerial vehicle (UAV) and spectral supervised image classification. Lastly, multispectral remote sensing with a UAV and vegetation indices were used to assess the level of regeneration across the varying traffic and slash levels. This poster examines the use of multispectral remote sensing as a possibility for scaling up the assessment of regeneration to a block level and its potential use for identifying areas of concern in relation to forest management operations.

THEME 5: Fire effects on forest soils

Keynote 5 - Fire as a dynamic driver of nitrogen cycling in forest soils

Thomas DeLuca
University of Montana

Fire is a natural disturbance in temperate and boreal forest ecosystems; however, changes in fire regimes with changing climatic conditions has created uncertainty in how recurrent fire will influence soil health. Historical fire return intervals and maintained a variable, but suitable soil carbon (C) and nitrogen (N) pools. Changes in fire regimes as a result of anthropogenic climate change could at least temporarily decouple N loss and N accumulation rates. Combustion of litter and humus layers during fire events results in a net loss of N and a temporary increase in net N mineralization and nitrification. Increased mineralization rates facilitates plant N uptake post fire, but also further depletes ecosystem organic N pools. The total N pool lost during fire must be rebuilt through symbiotic and associative N_2 fixation. Relatively low rates of N_2 fixation in boreal and some temperate post fire environs necessitates an extended time period to fully rebuild ecosystem N pools. Retrospective chronosequence studies have helped provide perspective on how N pools change after fire and how total ecosystem N is rebuilt; however, such studies do not readily allow for the assessment of shortened fire return intervals. Recurrent use of fire by humans artificially increases fire occurrence and reduces fire return intervals. Increasing occurrence of fire appears to result in a net decline in vegetative and surface soil C and N in most ecosystems and has implications for long-term changes in soil health. Paleoecological reconstruction fire history combined with soil biochemical assessment indicate that shifts in vegetative composition with increasing use of fire by humans could reduce the capacity of the ecosystem to rebuild N pools and ultimately lead to ecosystem collapse. Such studies help provide insight into the ecosystem level changes in resource availability that may occur in fire maintained forest ecosystems in a changing climate.

O.5.1 - Questioning the concept of soil sterilization: A review of soil heating and biotic thresholds

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Soil heating during a prescribed or wildland fire event is commonly quantified by a single biological threshold of 60°C for the duration of one minute to represent ubiquitous cell death. This metric severely misrepresents the heterogeneity of the soil environment (i.e., biological diversity, chemical substrates, and physical microsites) and the physiological attributes and tolerances of organisms, which act in concert to drive biological community responses to soil heating. Studies that use biological thresholds often cite review papers and, if original research is provided, primary research is conducted in a highly controlled laboratory environment with little attempt to compare field studies. Measurements of biotic death in a simulated laboratory experiment render research findings difficult to extrapolate to forest or grassland soils. A single biological threshold is an inappropriate measure of soil heating effects on plant and microbial communities, yet this oversimplified concept has been widely adopted. The disparity between assumed soil sterilization or biologic death from soil temperature measurements and the variety of biological responses after wildland fire events calls for a thorough review of soil biological heating thresholds. Here we provide results from a literature review of soil biological changes specifically linked to measured soil temperatures during wildfires, prescribed fires, and experimental laboratory heating. We also extrapolate findings to the potential changes in soil biota after an experimental prescribed fire outfitted with 20-cm depth soil temperature measurements in northern Florida ecosystems. The objective of this research is to encourage interdisciplinary research efforts that combine soil biotic changes and soil heating temperatures in order to understand soil biota community responses to wildland fire events.

O.5.2 - Causal relationships among abiotic and biotic drivers explain soil carbon stocks change with time since fire in boreal forest ecosystems

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The fire prone boreal forest ecosystem is an important component of the global carbon (C) cycle. The effect of global warming on soil carbon storage is difficult to predict as climate affects several processes including forest productivity, organic matter decomposition and wildfire regimes (frequency and severity) that may counteract each other. A good understanding of the controls over the pattern of C accumulation following fire is needed to appreciate the effect that a change in fire regime may have on landscape carbon stocks. In our study, we investigate the mechanisms underlying carbon accumulation in boreal forest of Northeastern America with a special focus on soil pools. Using a dataset that included sites that originated from wildfire (from 2 to 314 years ago) and located over a large territory encompassing climatic variability, we used a combination of multivariate causal hypotheses with an information theoretic approach to test the influence of time since fire on terrestrial C pools dynamic and the influence of climate, soil chemistry and bryophyte composition over soil C storage patterns. We showed that time since fire was the main factor influencing live and dead aboveground biomass as well as forest floor C accumulation. Tributary on pH and water balance, organometallic interactions appeared as the main carbon stabilization mechanism in mineral soil. Soils acidified with time since fire and this was conducive to greater organic C stocks, as well as greater metal content. In light of our results, we assume that the maintenance of soil conditions found in mature forests is conducive to enhance soil C sequestration in natural or managed boreal forest.

O.5.3 - Fire effects on soil microbes: burn severity in the boreal forest

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Global fire regimes are changing, with shifts in wildfire duration, frequency, and severity predicted for North American forests over the next 100 years. Fires can result in dramatic changes to C stocks, through the combustion of biomass and organic soil horizons, as well as through the production of pyrogenic organic matter. In addition, fires can restructure plant and microbial communities within the ecosystem, which can have long-lasting effects on ecosystem functions. We investigated the effects of fire on soil microbial communities (bacteria and fungi), plants, and soils in an unprecedentedly extreme fire season in the boreal forest of Canada's Northwest Territories, using field surveys, remote sensing, and high-throughput sequencing. We asked (1) What factors structure the soil microbial communities post-fire? and (2) Which metrics of fire severity best explain soil microbial community composition? We found that pH, vegetation, and fire are strong predictors of soil microbial community composition. In addition, abundant key taxa were identified as fire responders, including the fungus Penicillium sp., and the bacteria *Massilia* sp., and *Arthrobacter* sp. We also found that accounting for burn severity better captures microbial community composition than simply using burned/unburned metrics. In addition, remotely-sensed burn severity metrics capture microbial community composition almost as well as on-the-ground measurements. These results suggest that accounting for burn severity could improve our understanding of soil microbial response to fires, with potentially important implications for ecosystem functions.

O.5.4 - Ecologically novel wildfires impact carbon and nitrogen cycling processes over a decade after disturbance: a tale of two ecosystems

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During the past century, systematic wildfire suppression has decreased fire frequency and increased fire severity in the southwestern US. While this has resulted in large ecological changes aboveground, little is known about the long-term, belowground implications of altered fire regimes, especially on soil biological processes. We used two approaches to study the long-term effect of altered fire regimes on microbial processes: 1) a 44-y high-severity fire chronosequence in the Sierra Nevada and 2) a before-after-control-impact (BACI) design study 1 and 15 y after the high-severity Lake Fork fire in New Mexico, USA. In both cases these forests were historically adapted to frequent, low-severity fire, but were fire suppressed for at least a century. High-severity fire in the Sierra Nevada resulted in a long-term (44+ y) decrease (88-76%; $p < 0.05$) in extracellular enzyme activities and basal respiration (40-38%; $p = 0.008$) compared to unburned control sites. However, nitrogen (N) processes were only affected in the most-recent fire site (4 y post-fire). For example, soil nitrification potential, 30-day net N mineralization, and 30-day net nitrification all increased by over 400% in the most recent fire site, but returned to similar levels as the unburned control in the 12 y site. Similarly, fifteen years after the Lake Fork Fire, extracellular enzyme activities were diminished by 64-77% ($p < 0.001$) compared to the unburned control. However, unlike the Sierra Nevada fire sites, the nitrification potential of the burned soil fifteen

years after the Lake Fork Fire was still 379% higher than the unburned control ($p < 0.001$). Taken together, results from these studies show the large and long-term impacts of high-severity fire in low-severity fire adapted ecosystems. Long-term impacts to the soil biogeochemical environment could result in retarded ecosystem recovery and possible ecosystem state change if altered fire regimes persist.

THEME 5 and THEME 6: Rapid Fire

RF.5.1 P.5.13 - Effects of recent wildfires in the southern Appalachian mountains on soil hydrophobicity and infiltration processes

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A legacy of successful fire suppression in the eastern United States has limited our ability to observe if wildfires in humid hardwood forests cause hydrological effects such as increased soil water repellency (hydrophobicity) or decreased infiltration rates, as have been observed in other forest types. In 2016, intense wildfires occurred throughout the southern Appalachian Mountains region, providing a rare opportunity to study hydrological effects of wildfire in these forests. We therefore evaluated wildfire effects on soil hydrology using sites in Mount Pleasant, Virginia (MP) and Chimney Rock, North Carolina (CR), selecting unburned and burned sites at each location. In situ measurements of soil hydrophobicity (using water drop penetration time tests at 0, 2, and 5 cm depths), soil water content, and infiltration rates were periodically collected for one year, while lab tests explored how hydrophobicity varied during variable wetting/drying cycles. Hydrophobicity was detected after wildfires in both locations, persisting for at least nine months with a gradually fluctuating decline through time. The MP site had the highest hydrophobic layer in surface ash layer (0 cm depth), while the CR site had the highest hydrophobicity at the 2 cm depth. The burned soils in MP had lower infiltration rates than the unburned sites, whereas in CR, infiltration rates did not significantly differ between burned and unburned sites. These different responses may be related to the depth of maximum soil hydrophobicity. Lab tests provided a supplemental result that increasing water content first increased and then decreased hydrophobicity of burned soils, suggesting that a critical moisture content must be exceeded for soils to regain their former hydrological function. Wildfires are projected to increase in this region over the coming decades, meaning that the results generated in this study may be useful to guide future post-fire recovery efforts.

RF.5.2 P.5.14 - A recommendation for a new descriptor for pyrogenic soil horizons in the Canadian Soil Classification System

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The past few decades have seen the steady development of pedoanthracology- the study of soil charcoal. Most studies are initially biased towards fire-affected or fire-prone sites rather than the soil continuum generally. No systematic inventory of charcoal-bearing soil horizons has been done to our knowledge, as the description of pyrogenic features is not a part of the standard soil descriptions. The absence of a specific horizon descriptor (a lowercase suffix) that indicates the presence of charcoal is part of the problem. Our experience indicates that pyrogenic features may be associated with both A and B soil horizons, and even buried layers in C horizons. The features include clusters of charcoal, visible charcoal fragments, heated (reddened) soil mass, and ash accumulations. We propose to use the abbreviation pyr as a lowercase suffix for horizons with visible pyrogenic features, e.g. Ahpyr, AeAhpyr,and Bpyr. The introduction of the lower case suffix 'pyr' will foster the inclusion of fire-related information into soil profile descriptions and enable the systematic collection of fire-related data during soil surveys and other broadly based studies. For example, in a retrospective evaluation of a study of the humic materials of Ah horizons, the presence of significant charcoal in Ah was recorded only in the notes, failing to draw adequate attention to the salient feature of the horizon as determining humic properties. Specific quantitative criteria are to be further developed, but as a starting point we suggest designating horizons as pyrogenic if they contain either clusters of charcoal or dispersed charcoal fragments >2mm visible in a horizon exposed on a vertical surface, or in hand samples. This may be a small addition to the list of lower case suffixes used to describe horizons using the Canadian classification, but will do much to draw attention to pyrogenic features where they do occur.

RF.6.1 P.6.17 - Base cations budgets of forest ecosystems in the UK

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There is growing concern that available base cation pools in soil are declining due to the combined effects of acid deposition and harvesting. To assess these concerns in the UK, elemental mass balances for calcium (Ca), magnesium (Mg), potassium (K), were calculated from more than 10-years monitoring data from the UK's ICP Forest Intensive Monitoring (Level II) plots. On averaged Ca loss through leaching was 42 % of total inputs (deposition + soil weathering) varying between 7 and 86 % depending on sites geology, soil type, tree species and sensitivity to acidification. High Ca removal from sites by tree biomass was measured averaging 68 % of the total inputs, varying from 5 % to over 100 % depending on site. Out of the nine sites investigated negative Ca balances were observed in three sites with the most acid geology and nutrient poor soils, also being heavily acidified in the past. At present, there is sufficient Ca in the soil exchangeable pool to sustain forest growth at most sites, however, continued losses of Ca due to leaching and harvesting at the present rate may ultimately threaten the health and productivity of the forest within just a few decades. Mass balance calculations generally indicated positive Mg and K balance, with the exception of one site with negative Mg balance. Site Ca, Mg and K budgets were significantly ($p<0.01$) positively related to soil exchangeable cations and soil base saturation status. Current soil resampling of the UK Level II sites will provide repeated field measurements of soil exchangeable cations over the last 20 years enabling us to determine if soil cations have been changed at any of the Level II sites.

RF.6.2 P.6.18 - Detecting change over time with depth in forest soils: an example from the Calhoun Critical Zone Observatory, USA.

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Understanding rates of change in storage of carbon and nutrients in soils is essential to global carbon budgets as well as local management decisions. However, change in soils can be slow, and variability in forest soils can make these changes difficult to detect. The purpose of this study is to illustrate an approach to quantifying uncertainty in the detection of soil change, which can inform important decisions regarding soil monitoring designs, such as the needed intensity and time frame of sampling. We analyzed soils collected over almost 50 years from the Calhoun Critical Zone Observatory in South Carolina, USA. Dramatic changes have been observed in soil carbon, nitrogen, acidity, and macro- and micronutrients since the old agricultural field was planted to loblolly pine in 1957. In this study, we conducted power analysis using a dataset of soil carbon and nitrogen concentrations at four soil depths in eight forest plots and eight resampling dates from 1962 to 2008. Surprisingly, the power to detect soil change was high in both surface soils (0-7.5 cm), where concentrations of carbon and nutrients were high, and at great depth (60 cm), where concentrations were uniformly low. At intermediate depths, greater sampling intensity would be required to detect a similar rate of change over time. Nitrogen concentrations were more variable than carbon concentrations except at the 60-cm depth; as a result, smaller changes are detectable for C than N through most of the soil profile, in this study system. Power analysis is a useful tool for reporting uncertainty in long-term change. In cases where changes are not statistically significant, power analysis can tell us whether the changes are small or whether spatial or temporal variability is high, and this can help improve investments in environmental monitoring.

THEME 5 and THEME 6: Poster Session

P.5.1 - In a hot and dry climate, wildfires slow soil respiration through indirect impacts to the surrounding environment

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Soils respond to wildfires in a variety of ways, likely depending on the severity of the fire and, as we suggest here, the climate of the region. We studied forest soils in central Texas where two recent fires have occurred (2011 and 2015) and compared soil respiration in burned and unburned soils as an indicator of recovery after wildfires. Two methods of measuring soil respiration were used as proxies for biological activity: lab-based microcosm incubations and field-based CO2 flux measurements. Other variables such as soil temperature, water content, total C, N, and $\delta^{13}C$ values of total organic matter were measured as indicators of wildfire impacts on soils and predictors of respiration rates. Burned soils had lower total soil organic matter (SOM) than unburned soils, however, lab-based respiration measurements (controlling for temperature and water content) suggest that activity in burned and unburned soils are similar. On the other hand, field measurements show that during hot and dry months

respiration rates in burned soils were much lower than they were in unburned soils due to differences in soil temperature and water content. Soil temperature at 5cm reached 60°C in burned soils and was substantially lower in unburned soils. Increased temperatures in burned soils caused by the removal of canopy cover, the removal of organic matter insulation and the deposition of black ash on the soil surface increased evaporation from the 0-5 cm depth interval as indicated by significantly lower d-excess of water in soils burned in 2015 than unburned soils. We conclude that, although the composition of the soils was not impacted enough to reduce microbial activity where the burns occurred, the surrounding environment was disturbed enough to have severe indirect effects on the soil, most importantly increased heat absorption which led to lower water contents and ultimately lower respiration rates.

P.5.2 - Ashes to ashes: comparing the effects of wildfires and applications of bioenergy ash on soil properties

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As efforts to combat climate change intensify in Canada, there is growing interest in using forest biomass to produce energy and, simultaneously, a greater need to ensure that biomass extraction does not compromise forest ecosystem health. Emulation of natural disturbance (END) is the emerging paradigm for ecosystem-based forest management in Canada. According to the principles of END, management practices in naturally fire-maintained stands should mimic the effects of wildfires on forest structure and composition. However, wildfire-caused changes in soil chemistry are difficult to emulate with conventional management tools. At the same time, the ash produced during bioenergy generation is usually landfilled, placing significant pressure on Canada's waste disposal infrastructure. Given that the chemistries of wildfire ash and bioenergy ash are similar, we explored the potential for diverting bioenergy ash out of the waste stream and using it as a soil amendment to improve wildfire emulation. Employing meta-analysis of data drawn from the published scientific literature, we examined the effects of wildfires and bioenergy ash applications on forest soil chemical properties. We found that both wildfires and ash applications reduce forest floor C and N pools. However, losses of C and N following wildfires are greater and can be detected deeper in the soil profile. Bioenergy ash increases concentrations of available phosphorus in the forest floor; wildfires do not. Both wildfires and ash applications increase soil pH and exchangeable calcium concentrations, but the effects of ash applications on forest floor properties are stronger. From the perspective of maintaining soil C stocks, timber harvesting followed by ash application may be preferable to wildfires. Use of 'stabilized' ash or applications of lower ash doses may improve the utility of bioenergy ash as a tool for emulating the effects of wildfires on forest soil chemical properties on harvested sites.

P.5.3 - The effects of 17 years of repeated prescribed fires on soils in a ponderosa pine forest: do season and interval of burn matter?

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Prescribed fire has been used to reintroduce fire into fire prone forests of the western United States. This management technique is used to reduce fuel loads and return forests to their historical structure and function after a century of fire exclusion. The impact of prescribed burning on ecosystems and soils is dependent on fire severity, which is largely managed by specific prescriptions such as burning in the fall or the spring. Multiple burns are often implemented to maintain low standing fuel and reduce wildfire hazard. The frequency of prescribed fire can affect the time to recover between fires and the cumulative impacts of burning over time, but long-term studies of repeat burning are rare in the western US. The objective of this study was to determine if soil carbon, nutrients, and tree nutrition were impacted by prescribed burning in the fall or the spring at 5- and 15-year intervals. Prescribed burning was initiated in the spring of 1997 and fall of 1997 within the Malheur National Forest of the southern Blue Mountain Ecoregion of eastern Oregon and maintained through 2014. Soils were sampled by major genetic horizon in 2004 and by depth (0-15cm) in 2007, 2012, and 2015. Ponderosa pine foliage was collected in 2015. Soils were analyzed for Total C and N, pH, Bray P, and exchangeable Ca, Mg, K, Na, and Al. Foliar samples were analyzed for the stable isotopes ^{13}C and ^{15}N, as well as total P, Ca, Mg, K, Na, and Al. The effect of fire on soils will be examined using a meta-analytical approach due to the differences in sampling methods, while an ANOVA procedure will be used to examine the effect of repeated fire on ponderosa pine nutrition. Preliminary results suggest that fall burning has increased mineral soil pH and available P, and O-horizons are thinner and have higher C:N. Fall burns had more enriched foliar ^{13}C suggesting that there is a stronger water limitation.

P.5.4 - The effect of fire on the cycling of mercury

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Fire is a disturbance that has important implications for the cycling of mercury (Hg), an important pollutant that bioaccumulates in the aquatic food chain. We have been studying the impacts of fire on mercury cycles in the Boundary Waters Canoe Wilderness Area of the Superior National Forest in northeast Minnesota. In 1999 severe winds damaged 200,000 ha of the Superior National Forest. Over the past decade, the US Forest Service used prescribed fire to reduce fire risk. In addition to prescribed fire, numerous wildfires have also occurred. We have measured mercury in soil, lake water, atmospheric deposition, and fish before and after fire and in unburned control watersheds. Fires lead to large emissions of mercury from the forest floor and additional local deposition shortly after fire. We found a strong relationship between mercury stored in the forest floor and fish mercury. We also found relationships between watershed variables, lake water chemistry, lake water level and climate

parameters with fish mercury. Although we show that fires mobilize mercury in watersheds, our results indicate that light to moderate fires do not lead to additional bioaccumulation in fish.

P.5.5 - Prescribed burning effects on jack pine seeds from high and low serotiny regions: microbial interactions and soil properties

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Wildfire has shaped Midwestern pine barren ecosystems for thousands of years. Within the state of Wisconsin, there is a known gradient of serotiny in *Pinus banksiana* Lamb. (Jack Pine), where more serotinous trees are found in northern portions of the state and less serotinous trees are found in the central and southern portions of the state. However, the effects of burning on microbial populations and soil properties, and their interactions with post-fire plant communities, remain poorly understood. This study investigated the effects of burning on soil (1) on *P. banksiana* germination and success in a 6-month greenhouse trial and (2) microbial communities in the field. We asked: (1) How does burning affect *P. banksiana* seed germination rate and seedling success? (2) Are the soil microbial communities associated with *P. banksiana* different in unburned soils vs. soils subjected to a prescribed burn? Soils from the O and A horizons were collected from Coon Fork Barrens in Eau Claire County, WI before and after a prescribed fire, and O horizon pre-burn soil was burned in the lab for an extreme treatment. Northwest seed lots consistently had a higher survival rate compared to central seed lots ($p<0.001$). There was a significant difference between pre-burn, post-burn, and lab-burn soils for dry root masses ($p=0.02$) and dry shoot masses ($p<0.001$). Prescribed fires are generally lower severity, even compared to naturally occurring barren fires. Thus, any effect on seedling success was not likely driven by soil microbes. Furthermore, initial data do not suggest there were significant changes in microbial community composition after the prescribed fire. Collectively, our data show how biological and chemical properties of soils change after a prescribed fire, with potential implications for pine barrens *P. banksiana* re-establishment for future land management purposes.

P.5.6 - Wood decomposition after wildfires across the western United States

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Organic matter decomposition in soil ecosystems can be altered by wildfire, which affect post-fire management plans and carbon modeling efforts. To better assess and understand this soil-fire relationship, standard wood stakes from two tree species, trembling aspen (*Populus tremuloides* Michx) and loblolly pine (*Pinus taeda* L.), were deployed at four high-severity burn locations in different climate regimes and soil types across the Western U.S: the 2000 Valley Complex Fire (MT), the 2001 Fridley Fire (MT), the 2002 Hayman Fire (CO), and the 2005 School Fire (WA). Post-fire restoration treatments at two sites (School and Hayman Fires) were also included in the study. Wood stakes were placed on surface and inserted to a depth of 20 cm in the mineral soil on all sites. Stakes were also placed on the surface of the litter layer, at the litter-mineral soil interface, and in the mineral soil of adjacent unburned (control) stands. Stakes were extracted annually for five years, and wood moisture content and mass

loss measured. Surface wood stakes decayed more slowly than mineral soil stakes cross all four sites, but mass losses were mixed and few significant differences were found between burned and the unburned soils. In contrast, mass loss of wood stakes in burned mineral soils were greater than in unburned soil. Over all fire sites and stake locations, aspen decomposition rates were consistently higher than with pine. Both soil temperature were and water contents were generally higher in burned than in unburned soil, which had variable impacts on wood decomposition among sites. Results from this study provide information on the response of organic matter decomposition to site-specific changes in soil properties after wildfire, and could help managers plan post-fire restoration activities.

P.5.7 - Forest soil disturbance by wildland fire: Impacts and implications of the severity, scale, fuel loading, slope, infiltration, and rainfall nexus

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Wildfires and prescribed fires cause a range of impacts on forest soils depending on the interactions of a nexus of fire severity, scale of fire, fuel loading, slope, infiltration rates, and post-fire rainfall. These factors determine the degree of impact on forest soils and subsequently the need for post-fire soil management. Fire is a useful tool in landscape management but it can be benign or set off serious deteriorations in soil quality that lead to long-term desertification. If parts of the nexus are absent or not inherently risky, forest soil impacts can be relatively minor or non-existent. A low severity prescribed fire on a small landscape unit with minimal fuel loading, slopes less than 10%, and no water repellency is unlikely to damage soil condition and functions with all but heavy rainfall. On the other hand, a high severity wildfire in a substantial area of heavy fuels with slopes >100% and water repellency may undergo serious soil damage with even moderate rainfall. Soil management is not likely to be needed in the former case but virtually impossible in the latter scenario. This paper examines thresholds in the nexus factors which can raise the risks of wildland fire from low and moderate to high. It documents the interactions of the fire nexus in several case histories and forest soil types in North America to demonstrate different degrees of soil impact.

P.5.8 - Long-term effect of fire severity on soil properties and fungal communities

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Wildfires in southwestern US ponderosa pine (*Pinus ponderosa*) forests have increased in size and severity, often removing large patches of forest for extended periods of time. The loss of mature trees could affect soil properties and fungal communities, such as pine-symbiotic ectomycorrhizal (EM) fungi and saprotrophic fungi. We investigated the long-term effect of: 1) fire severity (high and moderate) on soil properties and the community composition of EM and saprotrophic fruiting fungi, and 2) both fire severity and distance from unburned forest on the colonization and community composition of soil and root-dwelling EM fungi. Our study sites were located on two Arizona wildfires, the 2000 Pumpkin Fire

and the 2002 Rodeo-Chediski Fire. Preliminary results show similar soil nutrient concentrations, EM colonization and EM community composition across different fire severities and unburned areas, but lower soil moisture, EM richness and unique fruiting fungal communities in high-severity burned areas compared to moderate-severity and unburned areas. One site dominated by non-EM host plants had a unique EM community composition compared to two other sites on the Rodeo-Chediski Fire. Our results suggest that high-severity fire has long-term consequences to fruiting fungal communities and EM richness; yet soil properties and EM community composition are quite resilient 12+ years post wildfire. Site-specific changes to EM communities could be a function of the dominant post-wildfire vegetation type. Post-wildfire forest soil restoration may not be necessary on the wildfires we studied; however further research is needed to determine if missing EM taxa could limit ponderosa pine regeneration.

P.5.9 - Evidence of coupled wind-fire natural disturbance in Atlantic Maritime forest soils

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Forests in the Atlantic Maritime Ecozone of North America are subject to intense, periodic windstorms that entail mass tree uprooting and arboturbation of soil. The time for soil formation is limited by the frequency of extreme windstorms, varying from several decades to centuries during the Holocene. In addition, the fires that commonly follow these windthrow events consume both above-ground and below-ground biomass, particularly support roots holding uprooted soil clods. Immense quantities of charcoal are produced during such coupled wind-fire disturbances, much of it sequestered after burial under redeposited soil mass. Moreover, mineral soils exposed in uprooted clods can transform with intense heat creating diagnostic reddened morphons.
Diagnostic features of soil profiles indicative of coupled wind-fire disturbances include: 1) cauldron-like structures with inverted stratigraphy resulting from the redeposition of soil mass, 2) stacked soil profiles with several buried A horizons, 3) lenses and clusters of charcoal in B horizons, 4) morphons of reddened soil mass in B horizons, and 5) charcoalified rootwood in the reddened morphons.
This study uses assessment of soil profile morphology and AMS-radiocarbon dating of buried charcoal to evaluate the frequency of intense wind-fire disturbances in Nova Scotia forests. Our preliminary results show that windthrow affected the soil cover of most upland sites every 300 years in the last 3000 years; the time of stable soil development not exceeding 3ka in the Holocene epoch. Fires occurred less regularly than windthrow, with coupled wind-fire events peaking between 4 and 6ka ago and in the last 500 years. Periods of lower windstorm activity appeared to favor development of Podzolic (Spodosol) horizons, whereas higher frequencies of wind disturbance led to disruption of Podzolic horizons and the formation of Brunisols. In addition to being of pedological interest, such soil assessments can contribute to ecosystem-based forest management planning in the region.

P.5.10 - Magnetic record of forest fire: effect of forest soil type on magnetic enhancement in subtropical region of China

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The effect of forest fire on the soil magnetic susceptibility in subtropical region of China was investigated in both field samples and laboratory experiments. Soil samples affected by sporadic forest fire events were collected and unburnt soils under forest vegetation as controls. Soils that were affected by forest fire exhibited a pronounced magnetic enhancement effect. Rock magnetic measurements indicated the formation of ultra-fine maghemite in the soils, thus increasing the magnetic susceptibility of soils. These results indicated that fire-induced heating caused the poorly crystalline iron oxide minerals of forest soils to convert into a more magnetic, low-coercivity phase maghemite (or maghemite/hematite mixture). In laboratory, forest soil samples from different parent materials were burnt to compare their differences in magnetic properties as a function of fire intensity. Laboratory experiment indicated that burning increased soil magnetic susceptibility several to more than ten times than unburnt soils, depending on soil type and organic carbon content of soil. The ratio of soil magnetic susceptibility after and before burning (Xmax/Xoriginal) could provide complementary parameter for forest soil classification. The ferrimagnetic mineral assemblages produced as a result of forest fire have a significantly finer grain size than those arising from input of soil parent materials. Magnetic measurements were highly sensitive to fire-induced changes in iron oxide mineralogy and provided magnetic signature of forest fire. The transformation of magnetic minerals as a result of forest fire may have important implications for nutrient cycling and pedogenic environment in the forest ecosystem.

P.5.11 - Exploring confusing soil and ecological relationships of the Des Moines Lobe in Minnesota and Iowa, USA

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The Des Moines Lobe of the Wisconsin Glaciation is an expansive and agriculturally important ecoregion consisting of nearly 18 million acres. Predominate soils of the region are classified as Mollisols developed under prairie vegetation, similar to those of the semi-arid northern plains to the west. Still, we estimate at least 2.5 million acres contain soils developed under various treed conditions, ranging from open savannas to closed forests. The majority of these areas were mapped as various transitional soils, having properties of both prairie and forest soils (e.g., dark surfaces, leached horizons, clay-enriched horizons, etc.). Many populations of these soils occur in isolated pockets within the central portion of the Des Moines Lobe, often on the leeward side of fire breaks, such as lakes, stream valleys, or comparatively rough terrain. Based on bearing tree analysis, these areas were primarily oak savanna. In contrast, the majority of these soils are located in the northeastern portion of the region where mesic hardwood forests were the dominant vegetation type (colloquially referred to as “Big Woods” forests). Here, transition to forest soils from the south and west is rather abrupt, where Mollisols (i.e., Typic Hapludolls) apparently abut Alfisols (i.e., Mollic Hapludalfs). Currently, the same soil map units are associated to each of these ecologically contrasting conditions. With interest mounting related to the development of USDA Ecological Site Descriptions, we explore these soil-ecosystem interactions and recommend potential areas for improvement to soil maps.

P.5.12 - Wildfires and slash and burn cultivation as sources of forest soil charcoal

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In the boreal forests the slash and burn cultivation has been widespread, but charcoal in forest soils have paid attention mostly in the context of wildfires. The aim of present paper is to demonstrate, that also slash and burn cultivation have contributed the soil charcoal pool of boreal forest soil. The study area is located in southern Estonia in six protected areas. 19th century land use maps were used to identify the historical land use: permanent arable fields, areas used for rotational slash and burn cultivation and forest land. Macroscopic charcoal were studied in 105 soil pits, including recent forest fire sites and experimental slash and burn fields and in six trenches. The charcoal location and character, soil properties and location in relief were registered and charcoal species composition were identified and 20 charcoal samples were dated. The different uni- and multivariate statistical analyse methods were applied. The results demonstrate, that the location, amount and size of soil charcoal are connected mostly with soil properties, then with historical land use and relief. The rotational slash and burn cultivation have caused the accumulation of humus with sparse charcoal. In the study areas the forest fire events are dated back until about 6000 years, slash and burn cultivation charcoal is connected with 15th-19th century AD. Charcoal location in soil turned out to be better indicator of historical land use than amount of charcoal or size of charcoal. The species composition of soil charcoal is connected with historical land use. Soil profiles consist charcoal from different fire events. The uneven spatial distribution of charcoal both after wildfires and slash and burn cultivation and charcoal translocation in soil complicates the interpretation of charcoal pattern.

P.6.1 - Disentangling soil heterogeneity at multiple spatial scales for long-term monitoring designs

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Soils in the Northern Forest region, as elsewhere in the world, have been subject to a variety of stressors and modifiers, including acid deposition, land use change, and forest harvesting. However, the challenge for implementing forest soil monitoring is disentangling heterogeneity at multiple spatial scales so variation occurring over space is not confounded with change across time. Forty permanent forest soil plots were sampled by genetic horizon at plot center across the White Mountain National Forest (WMNF), NH and ME, USA in 2001-02 and resampled 2-meters away on contour in either direction in 2014. Paired t-tests detected significant differences between the two time periods in exchangeable Al, base cations, and carbon at multiple depths. Although the average change in soil chemistry detected from paired t-tests across all plots was clear, the initial single soil pit per plot design did not allow separating the site-specific changes due to within-site variability. Therefore, a subset of six plots were intensively sampled in 2015 consisting of two more soil pits 2-meters away on contour in both directions of the 2014 soil pit, as well as two more soil pits 2-meters away upslope and downslope. Pooled variances were calculated using all the six intensively, satellite plots from 2015 since variance could not be calculated using one sample from the first sampling in 2001-02. We found that within-site variability was equal to overall regional variability of Spodosols across the WMNF. This approach to estimate the variance components simultaneously at the landscape scale, and at the within-plot or

micro-scale is critical for calculating sample size and quantifying temporal rates of change when designing monitoring systems.

P.6.2 - Quantifying ecosystem classification soil nutrient regimes

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In Canada, most soil classifications for remote forested regions are embedded within provincial and national Forest Ecosystem Classifications (FECs) and/or Ecological Land Classifications (ELCs). These usually include both broad physical characteristics, Soil Moisture Regimes and Soil Nutrient Regimes (SNRs). In Ontario, SNRs are currently inferred using combinations of pedon characteristics, landform type, tree species and understory plants. Our goal is to quantify these regimes in terms of nutrient content and availability to better address soil quality standards and management guidelines. For this analysis, we are collating information from 900 Forest Ecosystem Classification (FEC) plots in northern Ontario with horizon-based soil chemistry information as well as standardized site, soil pedon and vegetation information. We have also identified 600 additional plots in the same region with similar soil chemistry data, and with sufficient site, soil pedon and vegetation information to be accurately FEC-typed. As proof-of-concept we have used several statistical approaches to examine relationships among soil physical and chemical characteristics and Canadian FEC (CFEC) - inferred Soil Nutrient Regimes (SNRs) for an initial data set consisting of 650 northwestern Ontario FEC plots. Overall we found reasonable agreement between SNR categories and a suite of forest floor and/or mineral soil chemistry metrics including total N, C/N ratio, pH, CEC and base saturation as well as soil texture and humus form. Several of these metrics are considered indicators of soil quality and/or suitability for particular forest management practices. We are now analyzing the combined Northern Ontario data sets, which include a broader suite of soil chemistry variables (e.g., P and exchangeable base cations), to identify linkages between soil chemistry attributes, and field-based soil measurements, horizon attributes, vegetation characteristics and SNR typologies.

P.6.3 - Phosphorus fractions along preferential flow pathways in contrasting beech (*Fagus sylvatica* L.) forest soils

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The transport of nutrients in forest soils predominantly occurs along preferential flow pathways (PFP). The presented study investigated the distribution of phosphorus (P) forms in PFPs and soil matrix in temperate zone beech forests in Germany (nation-wide SPP-1685 network). The soil P contents at the contrasting sites followed a sequence in the availability of mineral P from rich to poor. The field experiments included (1) PFPs visualization using the dye tracer Brilliant Blue, (2) digital recording of the pathway distribution, and (3) sampling of stained and unstained soil material. Phosphorus fractions were analyzed by a modified Hedley fractionation method to determine inorganic (P_i) and organically bound (P_o) P in the labile, moderately labile and stable fractions. The results show that labile P was

highest in the O-layer at all sites and had the same range of values (240 – 320 mg kg^{-1}), although total P (TP) differed considerably (530 – 2,330 mg kg^{-1}) from P-poor to rich site. We found a steep depth gradient of all P fractions in the P-poor soil, but a more gradual change with depth in the P-rich soil. The contents of labile and moderately labile P clearly differed in PFPs compared to soil matrix, but not statistically significant. Here, the properties of flow pathways dominantly determined the differences in P contents between PFPs and soil matrix. At sites with high stone contents throughout the profile, water flow dominantly occurred along stone surfaces with low potential for P sorption and therefore no P accumulation in PFPs. In soils with a higher contribution of water flow along biopores (*i.e.*, old root channels), we found indications for an accumulation of labile P_o in PFPs. Furthermore, the C to P_o ratios were clearly increased in such biopores compared to soil matrix because of markedly higher C contents.

P.6.4 - Humusica, humus system, humus forms, topsoil classification, humipedon, diagnostic horizon

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The knowledge of a little number of specific terms is necessary to investigate and describe forest topsoils: diagnostic features lead to the designation of diagnostic organic and organic-mineral horizons. Humus forms, representing five humus systems, are classified based on the vertical arrangement of diagnostic horizons and their attributes. To become a good topsoil diagnostician is only a question of field experience. There is no way around to go to the field with a spade and a good manual and get your hands dirty. It means you have to dig a soil pit and examine a wall of this pit from top to the underlying, detecting the characteristics you find recorded in the manual. At the beginning of your field experience you may be frustrated because of changes from site to site, and there may be also some discrepancy between manual and site characteristics. But after a few days of start-up difficulties, you may be able to diagnose your soil, even without digging a whole soil pit. Be patient and consequently follow what is published in the first eight articles of Humusica (http://intra.tesaf.unipd.it/people/zanella/hmanual.html). Some examples are illustrated in this poster: e.g. diagnostic properties of forest topsoils, and a dichotomous key for classification. A copy of this key will be helpful for field work. There is also a smartphone application (Terrhum) available, which may provide the necessary information for a fast classification of topsoils in the field.

P.6.5 - Ectomycorrhizal response to long-term nitrogen fertilization in a temperate forest: a pilot study in Maine

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Chronic elevated N deposition over the last century has altered the biogeochemistry of temperate forests, with strong influences on belowground biota. The Bear Brook Watershed in Maine (BBWM) is a paired watershed manipulation experiment where one watershed has been treated bi-monthly with nitrogen (N) and sulfur (S) as ammonium sulfate [$(NH_4)_2SO_4$] for 27 years to study the impacts of elevated N and S deposition on forest function. While prior research at BBWM has focused on microbial nutrient transformations, the response of mycorrhizal fungi has received little attention. In 2017 a pilot study was conducted to assess ectomycorrhizal root colonization in red spruce (*Picea rubens*). N addition has been reported in the literature to adversely affect ectomycorrhizal fungi and we hypothesized that long-term N treatment should have caused a decline in mycorrhizal root colonization in the treated watershed. We investigated ectomycorrhizal root colonization by randomly selecting 5 red spruce trees from each watershed with three equidistant soil and root samples from the upper 10cm of O horizon in a 10x10cm template around each tree. Soils were analyzed for pH, total carbon and total nitrogen and these variables will be correlated with root colonization. Fine roots were counted for total mycorrhizal root tips using a gridline intersect method. The percentage of root colonization was significantly different between watersheds with a mean percentage colonization of 80±1.7 and 55 ±4.9 % for the reference and treated watershed respectively, indicating relative loss of ectomycorrhizal fungi as a function of N loading. This pilot study provides evidence of ectomycorrhizal response to multidecadal experimental N enrichment that will guide the development of additional research on N response and ecosystem recovery.

P.6.6 - The origin of soil organic matter controls its composition and bioreactivity across a mesic boreal forest latitudinal gradient

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Warmer climates have been associated with reduced soil organic matter (SOM) bioreactivity, i.e., lower respiration rates at a given temperature, which is typically attributed to the presence of more decomposed SOM. Cross site studies, however, showed that ecosystem regime shifts associated with long-term climate warming can affect SOM properties through changes in vegetation and plant litter inputs to soils. The relative importance of these two controls, diagenesis and inputs, on SOM properties as ecosystems experience climate warming remains poorly understood. To resolve this issue, we characterized the elemental, chemical (nuclear magnetic resonance spectroscopy and total hydrolysable amino acids analysis), and isotopic composition of plant litter and SOM across a well-constrained mesic boreal forest latitudinal transect in Atlantic Canada. Results across forest sites within each of three climate regions indicated that (1) climate history and diagenesis affect distinct parameters of SOM chemistry, (2) increases in SOM bioreactivity with latitude were associated with elevated proportions of carbohydrates relative to plant waxes and lignin, and (3) despite the common forest type across regions, differences in SOM chemistry by climate region were associated with chemically distinct litter inputs and not different degrees of diagenesis. Climate effects on vascular plant litter chemistry explained only part of the regional differences in SOM chemistry, most notably the higher protein content of SOM from warmer regions. Greater proportions of lignin and aliphatic compounds and smaller proportions of carbohydrates in warmer sites' soils were explained by the higher proportion of vascular plant relative

to moss litter in the warmer forests. These results indicate that a climate induced decrease in the proportion of moss inputs will not only impacts SOM chemistry but also increases the resistance of SOM to decomposition, thus significantly altering SOM cycling in these boreal forest soils.

P.6.7 - Long term monitoring of soil organic matter dynamics to address bioenergy sustainability questions

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Despite critical roles played by soil organic matter (SOM) including C sequestration, nutrient provision and moisture retention, SOM dynamics in forests are poorly understood. Inspired from the DIRT (Detrital Input and Removal Treatments) network, a new trial was established in 2017 at the Valcartier Forest Research Station, Québec, Canada, to monitor the long term impact of changing quantity and sources of plant litter inputs with a particular focus on bioenergy sustainability questions. Consistent with standard experiments of the DIRT network, our treatments include control, double litter, no roots, no litter, and no input. In addition, specific treatments include the addition of wood chip, ash and fertilizer as amendments. To limit the high variability associated with natural forests and better isolate the effect of experimental treatments, the trial was set up in a white pine (*Pinus strobus*) plantation established on a site with very homogeneous conditions in term of pH, nutrient content, texture and topography and a near absence of understory vegetation. Here we introduce the experimental design, the hypotheses, the analyses and measurements to be conducted in the coming decades. We welcome researchers interested to contribute to this long term trial that should give us insights on the impacts of global changes, including the intensification of forest practices to meet the growing energy demand, on the fate of SOM in forests.

P.6.8 - Monitoring chemical changes in sandy soils, is it worth the effort?

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The U.S. Geological Survey operates a network of stream water-quality monitoring stations at more than 50 undeveloped watersheds across the nation, some of which have been in operation for 50+ years. From 2011-17, 3 soil chemistry monitoring sites (with 5 to 7 sampling pits per site) were established in each of the watersheds with the plan to sample each site once every 7 years. The goal of the soil monitoring initiative is to track changes in soil chemistry within each watershed. These watersheds are primarily located on lands protected from direct human impacts and therefore serve as references to evaluate environmental change. As we begin our second round of sampling we asked the question: How likely are we to be able to detect changes in soil chemistry in soils with predominantly sandy textures? Nine of the network watersheds are located in the coastal zone from Long Island, NY to southern Louisiana. These soils have a sand texture and are generally characterized by low carbon content, low cation exchange capacity (CEC), and low base saturation (BS). We compared the concentration range and spatial variability among these sites to a variety of loamy textured soils along a similar transect. The sandy soils had lower carbon, CEC, and BS than the loamy soils, but the variability of soil chemical characteristics were of similar magnitude within sites and across watersheds for the two soil types.

Furthermore, the variability within each sampling site in the sandy soils was less than the difference observed in previous studies that detected a statistical change in soil chemistry at several watersheds across the northeastern US and southeastern, Canada. These preliminary results do not indicate whether change could be expected to take place or at what time scale, but do suggest the potential to detect change if it is occurring.

P.6.9 - Multi-decadal evolution of nitrogen dynamics at the Bear Brook Watershed in Maine

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Chronic elevated nitrogen (N) deposition has altered the N status of temperate forest ecosystems in North America, with significant implications for forest productivity, nutrient transformations, ecosystem nutrient retention, and surface water chemistry. The Bear Brook Watershed in Maine (BBWM) is a paired whole watershed manipulation experiment focused on the effects of N and sulfur (S) deposition on ecosystem function. N was added bimonthly as $(NH_4)_2SO_4$ to one watershed (West Bear) from 1989 to 2016. Research at the site has studied the evolution of ecosystem response to both treatments and ambient changes in the chemical and physical climate over time, in particular, declining S and N deposition and warmer, wetter climate in the Northeast. Here, we synthesize results from three decades of research on streams, soils, and vegetation to describe the long-term effect of N deposition at BBWM. While N leaching and export increased almost immediately in West Bear, labile soil N (ammonium, NH_4^+-N and nitrate, NO_3^--N) did not increase in West Bear until the fifth year of treatment. Labile N became increasingly available in West Bear over time, and after 25 years of treatment, West Bear soils had 10X more extractable NH_4^+-N and 100X more extractable NO_3^--N than the reference watershed (East Bear) soils. Stream exports of N from East Bear declined by 95% from 1990 to 2016 to approximately 0.05 kg ha^{-1} yr^{-1}, consistent with declines in ambient N deposition. In comparison, exports from West Bear were approximately 5 kg ha^{-1} yr^{-1} and remained constant. Chronic N additions increased N availability and reduced percent N retention in the ecosystem. The study illustrates how long-term data are essential to capture the evolution of ecosystem response.

P.6.10 - A continental scale assessment of soil moisture monitoring of forest and grassland ecosystems in the United States

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Soil moisture monitoring in forest and grassland ecosystems is often overlooked by national efforts to coordinate soil moisture monitoring, which have mostly included the agriculture and water resource sectors. A workshop held recently by the U.S. Forest Service and Michigan Technological University with

various stakeholders, scientists, and natural resource managers focused on contemporary and emerging research and management issues related to the importance of soil moisture monitoring in forest and grassland ecosystems. The overarching goal of the workshop was to develop a strategic plan to envision a new continental-scale approach of research and monitoring of soil moisture across forest and grassland areas of the United States. Specific objectives were to (1) assess the research and data available to monitor soil moisture for various purposes including the development of indicators, or thresholds, of soil moisture that relate to forest health, draught and water supply; (2) discuss currently available and emerging technology used in measuring soil moisture *in situ* and by remotely sensed platforms; (3) explore opportunities to expand and integrate existing networks to fill spatial and temporal gaps in data; and (4) determine research needs and needed technological advances for measuring soil moisture. Presentations were given on existing soil moisture monitoring networks such as the Soil Climate Analysis Network (SCAN), existing remote sensing platforms such as the Soil Moisture Active Passive (SMAP) mission, and the current effort to develop a National Soil Moisture Network (NSMN).

P.6.11 - Sixteen years into a 150-year soil monitoring study

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Ongoing monitoring of forest soils is essential for detecting, predicting and addressing environmental change. In cooperation with the Forest Ecosystem Monitoring Cooperative of the Northeastern USA, we have established a long-term soil monitoring study in five plots in Vermont. Three are in north-central Vermont around Mt. Mansfield and two are in southwestern Vermont in the Lye Brook Wilderness Area. Elevation ranges from 590 to 1140 m with forest type varying from typical northern hardwood (*Acer saccharum, Betula alleghaniensis* and *Fagus grandifolia*) to high-elevation spruce-fir (*Picea rubens* and *Abies balsamea*). Each 50 x 50 m plot contains 100 5 x 5 m subplots with sampling date assigned randomly (10 per date). The initial sampling of these plots took place in the summer of 2002, and resampling occurred in 2007, 2012, and 2017. Following intensive understory and overstory vegetation inventories, small pits were dug in the center of each plot and the soils were sampled both by genetic horizon and depth increments. These samples are analyzed for a suite of chemical parameters, including exchangeable cations, mercury, carbon and nitrogen. Methodological challenges include the intrinsic variability within and among subplots, which affects our ability to detect temporal changes. Spatial differences in exchangeable calcium pools will be used to highlight this variability. Ongoing challenges of the monitoring study include sustainable funding, robust long-term storage of samples, and continuity of sampling efforts. These plots are on state and federally owned forestland and are reserved solely for soil monitoring purposes. Continued sampling will allow detection of soil change in response to a changing climate, shifting abiotic stressors, and transitions in vegetation, providing an assessment of impacts independent of land management.

P.6.12 - Smart Forests: Insights and lessons learned from a new digital platform for monitoring soil microclimate at USDA experimental forests across the Northeastern US.

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Smart Forests is a new USDA Forest Service initiative deploying a suite of environmental sensors to create an integrated research and monitoring network in experimental forests of the Northeastern United States. The network allows researchers (i) access to forest data in near real time from remote locations and during extreme weather, (ii) tools to address existing research questions and develop new hypotheses, (iii) novel opportunities for education and outreach, and (iv) participation in a new era of networking long term research sites in space and time. The network includes comprehensive monitoring of soil climate, including temperature and soil moisture sensors at multiple depths. A novel insight is the 'Spring Trigger', where soil temperatures rise rapidly (up to 6°C in 24 hours), following snow melt, signaling a rapid onset of spring conditions. Networks are difficult to maintain amidst shifting funding, lack of trained personnel, and staffing turnover. Smart Forests faces many challenges including funding, lack of technical training for managing sensor networks for field staff, and lack of computational training for individuals managing the increasing large data streams from the sensors. The forest soils community needs to come together to discuss the value of integrated long term cyber soil monitoring networks, define a key set of soil variables that could and should be monitored, identify industry and public value for the accumulating data, and establish more formal network goals.
The promise is a new era of integrated cross site research and monitoring of North American Forest soils; the peril is collecting large quantities of poor quality data that no one uses. A road map for the future will be provided.

P.6.13 - Wood decomposition: understanding processes regulating carbon transfer to soil carbon pools using FACE wood at multiple scales

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Dead wood is a significant terrestrial carbon (C) pool, comprising approximately 20% of the forest biomass in the U.S. A major uncertainty in the terrestrial C cycle is the transfer of C from that dead wood into the underlying mineral soil C pool, where it may be incorporated into recalcitrant or protected soil C pools during the decomposition process. Documenting the fate of wood C during the decomposition process is difficult because (1) wood decomposition is inherently slow, (2) C from decomposing wood often cannot be differentiated from C in the soil matrix, and (3) microbial

decomposers with distinct mechanisms can drive distinct outcomes, poorly predicted by climate alone. While Specific wood-decay fungi (brown rot & white rot) and invertebrates, especially termites, are understood to be the principal agents mediating wood decay, little is known about their ecology or their interactions, nor the process and pathways affecting the transfer of wood to the soil. The FACE Wood Decomposition Experiment (FWDE) was established with wood grown under the elevated CO2 in the free-air carbon dioxide enrichment (FACE) experiment. By using that δ13C signature in three species of wood from two FACE sites, we are effectively continuing the FACE experiment by using wood grown under elevated CO2 as the key component to monitor wood decomposition, measure the amounts of wood C incorporated into soil organic matter pools, and determine factors regulating decay processes mediated by fungi and termites within nine major forest – bioclimatic zones within the continental U.S. The FWDE was established in 2011 where ambient and elevated CO2 FACE logs were placed in nine experimental forests, on representative soil types within different bioclimatic zones across the U.S. Assays from year-4 affirm that the δ13C signature of the FACE wood can be traced into the mineral soil. We are building on the early findings to establish what is regulating the amounts of C we are tracing in soil, with specific interest in dominant fungal rot types and termites. Forest DNDC is being provisioned with new capabilities to better reflect the dynamics of wood decomposition, mechanistically, thereby enhancing a proven platform for simulating forest C dynamics at multiple scales under current and future climate conditions and management scenarios.

P.6.14 - Long term trends and effects of nitrogen inputs on forests and soils in the UK

Elena Vanguelova
Forest Research UK

Critical nitrogen load maps currently indicate that the majority of both broadleaf and conifer woodland in the UK exceeds the limits for nutrient nitrogen, although widespread effects of this excess deposition have not been evident, except at woodland edges. Experimental research, long term intensive forest monitoring and spatial soil surveys undertaken by Forest Research during the last 20 years will be presented, summarising the current understanding of the effects of nitrogen deposition on broadleaved and coniferous forests and forest soil biogeochemistry across the UK. Long term trends in nitrogen deposition and soil, soil solution and forest biological responses to deposition changes will be reviewed. The role of forest canopy in nitrogen transformations will be demonstrated through stable isotopes study and the role of tree species and soil type from the spatial forest soil survey BioSoil. The impact of nitrogen inputs on forest growth, water use efficiency, nutrient and carbon cycling will be discussed by presenting results from detailed gradient studies from point sources of nitrogen pollution and regional studies comparisons between forest areas with low and high nitrogen deposition. The likely contribution role and links of nitrogen deposition to tree health and nutritional cycling will also be discussed by presenting examples of current research on the links of current spread of acute oak decline in the UK to deposition chemistry.

P.6.15 - An assessment of traditional chemical indicators of atmospheric pollution in Saskatchewan forest soils

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With increasing industrial development in western Canada there is impetus to establish baseline soil conditions to inform monitoring and modelling studies that are designed to protect ecosystem health. The primary concerns for forest soils are acidification caused by enhanced sulphur (S) and nitrogen (N) deposition; eutrophication also caused by N deposition and metal contamination due to elevated emissions arising from local or regional smelting (Cu and Ni) or from a range of other anthropogenic activities (Hg). Traditional chemical criteria used to assess these effects include soil NO_3, SO_4, soil pH, soil C:N ratios and metal concentration in surface soils. In this study two-hundred upland forest sites spanning the Mid-Boreal Upland, Athabasca Plain, Churchill River Upland, Selwyn Lake Upland and Tazin Lake Upland ecoregions of Saskatchewan were sampled and assessed for a suite of soil chemical properties. The traditional indicators for anthropogenic impacts varied widely (e.g. pH 3.1 – 7.4; Hg 0.6 – 55.3 ppb; Soil C:N 9.3 – 53.7), but in general were unrelated to modelled atmospheric S and N deposition. Surface soil organic matter (or soil C) was the strongest predictor for many of the chemical indicators. For example, soil C was positively correlated with Hg (r=0.9) and extractable SO_4 (r=0.82). Extractable soil nitrate was mostly below detection, and was primarily measured at a concentration >2 ppm in soil samples with a C:N ratio < 25 and a soil C content >2 %. Only Cu and Ni concentrations in surface soils exhibited any relationship with modelled S deposition, which may be indicative of deposition from smelters in Saskatchewan.

P.6.16 - Changing soil characteristics during succession in the Alaskan boreal forest

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Soil change can be measured over multiple time scales, from a decade to a millennium. We examined changes in physical and chemical profile characteristics using both a repeated measures (RM, 23 years) and a chronosequence (200 years) approach in upland and floodplain successional sequences. Dyrness and Van Cleve dug and described soil pits at four locations around each control plot (3 upland and 4 floodplain successional stages replicated 3 times) for the Bonanza Creek LTER research program in interior Alaska during 1988 and 1989. Yarie and Valentine dug and described a second set of pits in 2010 and 2011 within 3 meters of the first pits. Every effort was made to ensure consistency, but changes in the profile descriptions could be ascribed to the background of the scientists, including “lumpers” vs. “splitters”, and the spatial variability of the soil profiles. Soils were sampled by genetic horizon, and the depth profile of pH, bulk density and CEC and the concentration and content of C, N, P, Ca, Mg, and K were compared using the bootstrapped LOESS regression approach (Keith, et al. 2016). Soil carbon concentration in the RM analysis showed no overall change in the upland (UP) profiles between the two sample periods, but there was a small decrease in the quantity of carbon found in the upper profile on the UP1 and UP2 sites with no change on the UP3 site. Carbon concentration and content across the

floodplain (FP) sites for the RM analysis show an increase in the surface (10 to 40 cm) on the FP1 sites, a decrease on the FP2 site, and no change on the FP3 and FP4 sites. The chronosequence displayed no change in carbon concentration and content in the uplands while the floodplain displayed an increase in both features across the sequence.

THEME 6: Forest soil monitoring networks and environmental changes: successes and challenges

Keynote 6 - European forest soil monitoring networks and environmental change: successes and challenges

Bruno De Vos, Nathalie Cools, Tiina Nieminen
Research Institute for Nature and Forest (INBO)

National initiatives for systematic forest soil monitoring started in Sweden and Finland in 1985, when concern was raised about massive forest dieback in Central Europe caused by 'acid rain'. At that time the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP-Forests) was launched under the UNECE Convention on Long-range Transboundary Air Pollution to monitor forest condition at two monitoring intensity levels: a systematic 16 x16 km transnational Level I grid of ~6000 observation plots and ~500 intensively monitored Level II plots representing the major forest ecosystems. By the end of 1996, 23 countries had surveyed their Level I plots, and started analyzing soil solution on 300 Level II plots. Successes of the European-wide monitoring were: (1) installation of the Level I and II plots across Europe, (2) continuation of the intensive monitoring on a substantial number of plots, (3) manuals and protocols resulting from a long harmonization process (1992-2016), (4) a common soil condition database offering free data to the scientific community, and (5) dissemination of the results in scientific journals and reports. ICP-Forests was able to show the positive effects of European and national legislation limiting emissions and decreasing of air pollutants impacts, especially of S and NH4, as in many regions forest soils recover from acidification and eutrophication. Main challenges are: (1) the third repetition of an European forest soil inventory, (2) an integration of the Level I and II data using models linking soil solution and solid soil chemistry, (3) enhanced data up- and downscaling using information from soil maps, inventories and remote sensing, (4) ensuring links to global (forest) soil monitoring networks, (5) enhanced forest soil data elaboration and dissemination of the results and (6) raising political awareness of the importance of forest soil condition and sustainability for healthy forests.

O.6.1 - Decadal restructuring of soil carbon and nitrogen in a regenerating forest on long cultivated land in the southern piedmont of the USA

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At the Calhoun Long-Term Soil-Ecosystem field experiment (1957-present), reforestation of previously cultivated land over fifty years nearly doubled soil organic carbon (SOC) in surface soils (0 to 7.5-cm) but these gains were offset by significant SOC losses in subsoils (35 to 60-cm). Nearly all of the accretions in surface soils amounted to gains in light fraction SOC, whereas losses at depth were associated with silt and clay-sized particles. These changes are quantified in the Calhoun Long-Term Soil-Ecosystem (LTSE) study that resampled soil on eight occasions from 16 plots about every five years and archived all soil samples from four soil layers of the upper 60-cm of mineral soil. We combined soil bulk density, density fractionation, stable isotopes, and radioisotopes to explore changes in SOC and soil organic nitrogen (SON) associated with five decades of the growth of a loblolly pine secondary forest. Isotopic signatures showed relatively large accumulations of contemporary forest-derived carbon in surface soils, and no accumulation of forest-derived carbon in subsoils. We interpret results to indicate that land-use change from cotton fields to secondary pine forests drove soil biogeochemical and hydrological changes that enhanced root and microbial activity and SOM decomposition in subsoils. As pine stands matured and are now transitioning to mixed pines and hardwoods, demands on soil organic matter for nutrients to support aboveground growth has eased due to pine mortality, and bulk SOM and SON and their isotopes in subsoils have stabilized. We anticipate major changes in the next decades as 1957 pine trees transition to hardwoods. This study emphasizes the fundamental importance of long-term soil experiments and deep soil measurements when characterizing SOC and SON responses to land use change. There is a remarkable paucity of long-term soil data deeper than 30 cm.

O.6.2 - Soil and vegetation recovery from acidic deposition to high elevation spruce fir sites in the southern Appalachian Mountains

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Mixed forests of red spruce (*Picea rubens* Sarg.) and Fraser fir (*Abies fraseri* Poir.) (Spruce-fir) are rare in the southern Appalachian mountains, located at elevations above 1300 m. During the 1980s and 1990s these forests declined due to acidic deposition, extended periods of drought, and insect infestation. In 1984 and 1985, Kelly and Mays (1989) described and sampled soils in southern Appalachian TVA spruce-fir inventory plots from North Carolina to Virginia. All plot locations were mapped, vegetation inventories were conducted using a nested circular plot design and a single soil pit, located at the center each plot was described and sampled; all samples were archived. Soils were very acidic, and variable in soil organic matter, base cations, and extractable sulfate. In 2013, we endeavored to relocate 24 plots, conducted vegetation inventories, and dug 3 soil pits for description and sample collection. We used comparable organic and mineral soil horizons from archived (1985) and collected (2013) samples to examine differences between dates using plot as a random effect. Recent vegetation surveys showed considerable regeneration since the 1980s for both Fraser fir and red spruce, 2022 ± 683 and 1496 ± 454 stems ha^{-1}, respectively. Total C and N concentrations increased in the Oa horizon and upper mineral soils; C:N ratios also increased. Total Ca increased and total Al decreased in the Oa horizon but mineral soil NH_4-extractable Ca and Al did not change. Upper mineral soil horizons showed a decline in both native and irreversibly held SO_4. Data suggest that high elevation spruce fir sites are recovering with

evidence of vegetation regeneration, increasing base cations in the O horizons, and declining SO_4 in mineral soils.

O.6.3 - Global change accelerate soil acidification and base cation release over the past 60 years across subtropical China

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Multiple studies have shown that terrestrial soils have experienced significant acidification in past decades, resulting in decreased soil buffering capacity to acid that threatening biodiversity and ecosystem function. Although temporal changes in soil pH have been widely examined, the acidification-induced changes in exchangeable acid and base cations, however, have not been examined across broad spatial scale and over a long time period yet. Based on 2,953 historical observations along soil profiles of 0–150 cm depth from 1955 to 2016, we evaluated the temporal changes in soil acidity and base cations over 200 mountain sites across subtropical China. We found significant overall decreases in soil pH (measured by both water and KCl solutions), accompanied by drastically increasing exchangeable hydrogen ion (H+) and decreasing base cations (Ca2+, Mg2+, Na+) and base saturation during the past 60 years across all soil depths. Along with soil profile, soil pH decreased more rapidly in surface layer than in deeper layer due to significantly increased exchangeable H+ and aluminum ion (Al3+). The temporal trends in soil pH differed among vegetation, soil, parent material types and spatial climate variations, with significantly increased soil acidity for evergreen broadleaf forest and highly weathered Ultisols, granite developed soils and at lower elevations. Our sensitivity analysis suggests that the temporal changes in soil acidity derived from decades of atmospheric nitrogen deposition, sulfur deposition, rising atmospheric CO_2 concentration and regional warming. Our findings revealed that multiple global change drivers have accelerated soil acidification in natural ecosystems across subtropical China for the past six decades and the response of soil acidity to global change drivers are dependent on soil depths, vegetation types, soil types, parent material types and spatial climate variations.

O.6.4 - Soil monitoring provides insights into why decreased nitrogen deposition is having little effect on stream acidification in the Adirondacks of New York, USA

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Effects of nitrogen (N) deposition on N cycling in forest ecosystems have been well studied, often through experimental manipulations. However, an incomplete understanding of how ambient decreases in N deposition are affecting N processes remains and is further complicated by the start of soil recovery from decreased acidic deposition. To address these issues, monitoring data for 1999-2015 were evaluated in North and South Buck Creek watersheds in the western Adirondack region of NY. North

Buck is forested with a mixture of hardwoods and conifers, and has organic-rich soil with a 21-cm thick forest floor, whereas South Buck has mostly hardwood vegetation and an 8-cm forest floor. Concentrations of NO_3^- in 64 streams in the vicinity of these watersheds in 2004 were also compared to values in 2014, and the relationship between soil buffering and stream NO_3^- was investigated with data from over 400 headwater streams throughout the Adirondack region. South Buck N export in stream water was 2-to-3 times higher than for North Buck but no trends were observed in either watershed despite a 45% decrease in N deposition. In North Buck, 72% of N atmospherically deposited in the period 2000-2015 could be accounted for by accumulation in the soil, but South Buck soils lost N over the period. The South Buck response was tied to a loss of forest floor organic carbon, most likely resulting from increased decomposition as these soils responded to lower levels of acidic deposition. In contrast, decomposition in North Buck may have been constrained by naturally high levels of organic acidity. Regional stream sampling results were consistent with Buck Creek results, showing no overall difference in NO_3^- concentrations ($P > 0.10$) between 2004 and 2014, and a significant negative correlation ($P < 0.01$) between NO_3^- concentrations and watershed buffering capacity.

Closing

Keynote Closing – What will environmental change mean for forest soils: will they keep pace with change?

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We have covered numerous examples of soils-forest interactions in changing environments during this conference. There are clearly many implications of both changing social and physical environments for forest soils. Human demand on forests and their soils is increasing in respect of many ecosystem services and benefits provided by forests and at the same time as forest soils are experiencing increased environmental pressures, fire being a good example of this. Management responses and implications thereof will depend on and how forest managers respond to changing social and physical environments The expectations of forests is increasing with respect to the role of forests and forest soils in climate change adaptation and mitigation. At the same time the effects of forest fires on forest soils are of greater consequence due to the intensity and frequency and scale of fires. Losses of forest and greater expectations with respect to climate change adaptation and mitigation are also coinciding with greater demand for forest and wood products from intensively forests which are generally managed as plantations. Competition between land-uses and the need for the provision of other services from forests is increasing the pressure on planted forests and on the productivity of these planted forests. Many bodies such as World Business Council for Sustainable Development are suggesting forest productivity needs to be greatly increased to meet a range of future human needs. Hence the commonly asked question, can we produce more for less? Technological advances and convergence amongst scientific disciplines is opening up such possibilities as researchers are recognising that there are more than one dominant genome in the forest through their studies of the forest soil microbiome. Forest soil monitoring networks are part of understanding the consequences of environmental change and of management activities and are necessary to address the question of how resilient are forest soil resources. It is important more than ever to understand the contribution of forest soils to human wellbeing in the broadest possible sense, accounting for the provision of goods and services and the role of forest soils in feeding and protecting the world. From the perspective of a forest soil scientist we need to start thinking along the forest value chain – linking forest soil properties to the values associated with a particular ecosystem that we are interested in, be it in a high value conservation forest or a highly productive planted forest. What are the values that society are seeking to gain from a particular land use? Is it possible to link soil processes to end product performance – how does our management of soil properties and processes affect the values that we gain from a soil? What impacts to do events such as a mega fire have on our needs and wants and how might we better manage for resilience or recovery of forest soils?