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Applying wood ash waste to soil: contributing to sustainable forest management in Canada

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Canada

Acknowledgements

Forest Ecosystem Risk and Assessment Team (FERAT) – group of researchers, field and laboratory technicians, students and interns based at the Great Lakes Forestry Centre in Sault Ste. Marie

AshNet collaborators – universities, provinces/territories, industry (forest, energy)

Kirsten Hannam, Agriculture and Agri-Food Canada
Dave Morris, Ontario Ministry of Natural Resources and Forestry
Trevor Jones, Canadian Wood Fibre Centre (OMNRF)

Office of Energy Research and Development (OERD)/Program of Energy Research and Development (PERD), Canadian Wood Fibre Centre (CWFC) Fibre Solutions program, CFS Sustainable Forest Management (SFM) program

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Outline

- background
- AshNet I - first stage
- barriers and knowledge gaps
- current work
- future directions AshNet II

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Bioenergy production in Canada

TABLE 1 — **National Energy Board. 2017**

Electric Capacity and Generation in Canada

	Capacity in MW and %			Generation in GW.h and %		
	2005	2015	2016	2005	2015	2016
Oil and Diesel	4 795	3 842	3 837	10 608	4 041	3 436
	3.9%	2.7%	2.6%	1.8%	0.6%	0.5%
Natural Gas	13 191	22 006	21 499	40 875	66 060	62 512
	10.8%	15.2%	14.7%	6.8%	10.2%	9.6%
Coal	16 003	9 661	9 661	96 750	62 256	60 374
	13.1%	6.7%	6.6%	16.1%	9.6%	9.3%
Nuclear	12 805	14 273	14 273	86 669	95 682	95 418
	10.5%	9.9%	9.7%	14.4%	14.8%	14.6%
Solar	17	2 135	2 310	0	3 001	3 568
	<0.1%	1.5%	1.6%	0.0%	0.5%	0.5%
Biomass	1 804	2 414	2 702	7 688	12 511	13 214
	1.5%	1.7%	1.8%	1.3%	1.9%	2.0%
Wind	557	11 072	11 902	1 453	28 314	30 462
	0.5%	7.6%	8.1%	0.2%	4.4%	4.7%
Hydro	72 890	79 434	80 403	358 387	374 116	383 392
	59.7%	54.8%	54.8%	59.5%	57.9%	58.8%
All renewable sources	75 268	95 056	97 317	367 528	417 942	430 636
	61.7%	65.6%	66.4%	61.0%	64.7%	66.0%
All sources	122 061	144 838	146 588	602 430	645 981	652 375

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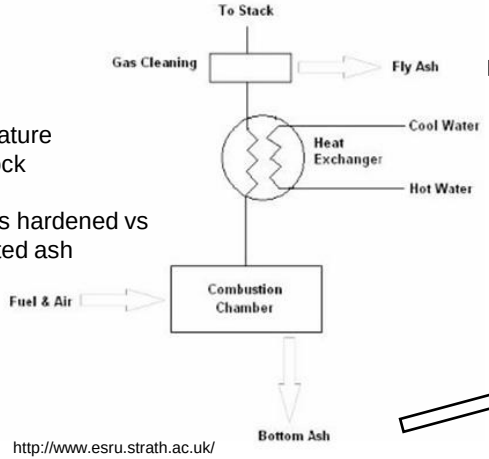
DANGER

2/3 of the wood ash produced in Canada is landfilled

Biomass boiler ash – high pH (8-13)



http://www.esru.strath.ac.uk/

Temperature
Feedstock

Loose vs hardened vs granulated ash

Fly ash
Reactive, small grain size,

High in Ca, Mg, K, Na salts and oxides
Low in N and C

Bottom ash
Less reactive, large grain size,

		Fly	Bottom
As	mg/kg	13.5	20.9
Cd	mg/kg	8.9	2.8
Cu	mg/kg	83.5	62.0
Pb	mg/kg	20.3	55.7
Zn	mg/kg	1178.9	439.2

Canadian Wood Ash Chemistry Database
https://www.nrcan.gc.ca/forests/research-centres/glfc/ashnet/20288

Ash research in Scandinavia

Soil

- higher pH, BS, increased microbial activity, decomposition and N min
- initial impacts in the forest floor, later in mineral soil, long-lasting effect, larger dose = larger impact

Foliage

- increased Ca, K, P, B; metals have low bioavailability (increased pH = decreased availability)

Tree growth

- peatland sites - increased pH, increased decomposition, increased growth, K and P fertilizer
- upland sites - N limited (high C:N), no significant effect - N rich sites (low C:N), increased growth

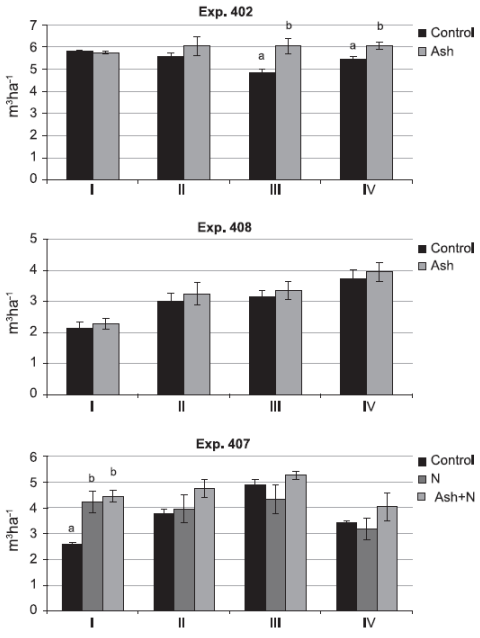


Fig. 3. Mean annual volume growth of tree stands on the upland sites during the first-, second-, third- and fourth 5-year period after treatments. Mean of three replicate plots. Mean values with different letters differ significantly from each other ($p < 0.05$). Standard error of the mean is marked on the columns by bars. Results for the first and second 5-year periods have been published earlier (Saarsalmi et al., 2004).

Saarsalmi et al., 2014

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Recycling bioenergy ash in forests – PERD funded project

Amelioration of biomass harvested sites with wood ash waste: improving Canadian forest productivity and sustainability through an alternative approach to bioenergy waste management

Objectives:

1. Scientific and regulation/guideline synthesis
2. Techno-economic analysis
3. Network of researchers and knowledge
4. Monitor ongoing and new experiments

Partners: Ontario Power Generation, Wood Pellet Association of Canada, Tembec/RYAM, CanFor Pulp, J.D. Irving, Resolute Forest Products, OMNRF, BC Ministry of Forests, FP Innovations

University of Northern British Columbia, University of Saskatchewan, University of Manitoba, Lakehead University, Laurentian University, Trent University, University of Toronto, University of Quebec en Abitibi-Témiscamingue, University of Quebec TÉLUQ

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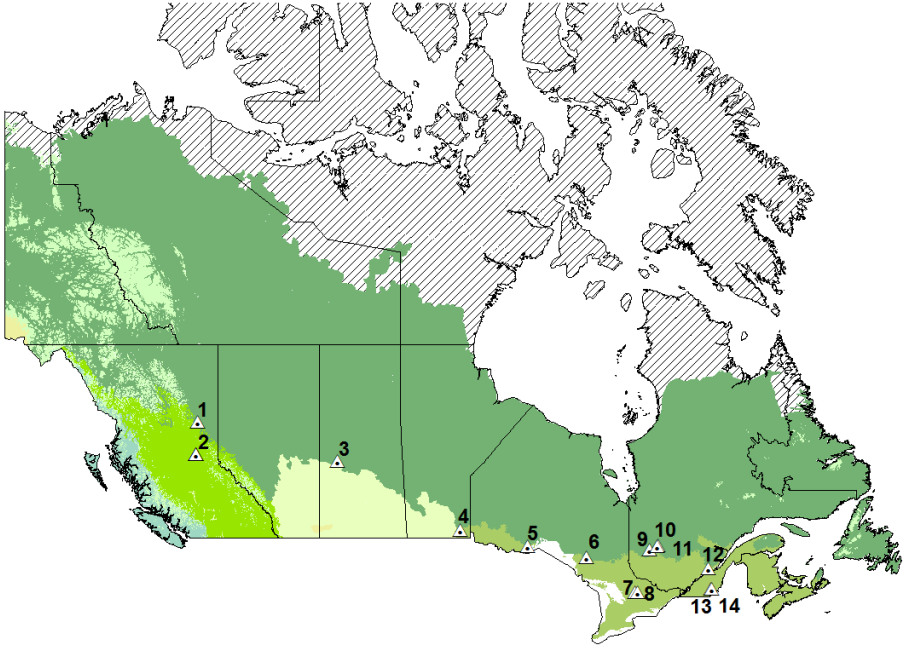
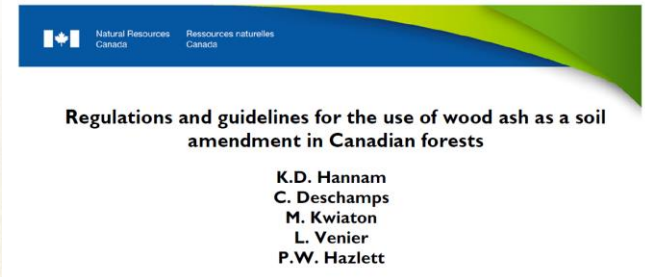
Network Development - AshNet



AshNet: a national network of wood ash trials
www.nrcan.gc.ca/forests/research-centres/glfc/ashnet/20279

Scientists, foresters, industry and government (federal and provincial) representatives who are actively investigating the potential for reducing waste and improving forest health by applying wood ash from bioenergy production to forest soils.

Synthesis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Regulations and guidelines for the use of wood ash as a soil amendment in Canadian forests

K.D. Hannam
C. Deschamps
M. Kwiaton
L. Venier
P.W. Hazlett

AshNet: Facilitating the use of wood ash as a forest soil amendment in Canada

by K.D. Hannam[1,*], L. Venier[1], E. Hope[1], D. McKenney[1], D. Allen[1] and P.W. Hazlett[1]

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Synthesis of Current AshNet Study Designs and Methods with Recommendations towards a Standardized Protocol

C.E. Emilson[1], K. Hannam[2], I. Aubin[1], N. Basiliko[3], N. Bélanger[4], S. Brais[5], A. Diochon[6], R. Fleming[1], T. Jones[7], R. Kabzems[8], J. Laganière[9], J. Markham[10], D. Morris[11], P.M. Rutherford[12], K. Van Rees[13], L. Venier[1], K. Webster[1], P. Hazlett[1]

Regulation and guideline support tool to assist ash producers and consumers

Article in Forestry Chronicle/CIF “The national voice of forest practitioners”

Study designs and methods used across AshNet sites with recommendations

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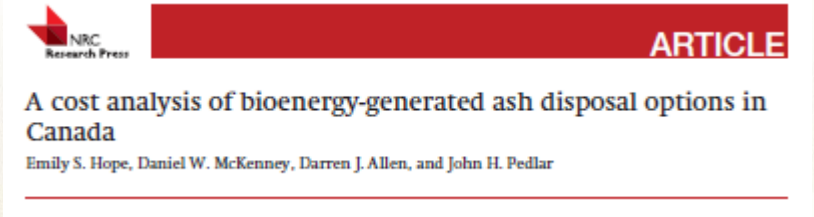
New Knowledge

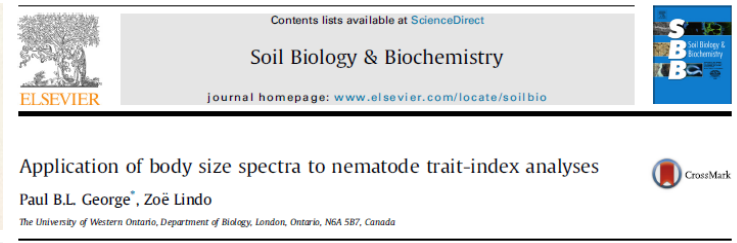


NRC Research Press

ARTICLE

A cost analysis of bioenergy-generated ash disposal options in Canada

Emily S. Hope, Daniel W. McKenney, Darren J. Allen, and John H. Pedlar



Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

ELSEVIER

Application of body size spectra to nematode trait-index analyses

Paul B.L. George*, Zoë Lindo

The University of Western Ontario, Department of Biology, London, Ontario, N6A 5B7, Canada

CrossMark

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

ELSEVIER

Soil microbial responses to wood ash addition and forest fire in managed Ontario forests

Genevieve L. Noyce[a,b,*], Roberta Fulthorpe[b], Adam Gorgolewski[c], Paul Hazlett[d], Honghi Tran[e], Nathan Basiliko[f,g]

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Techno-economic analysis

Environmental impacts research related to forest and soil type, ash type, dosage

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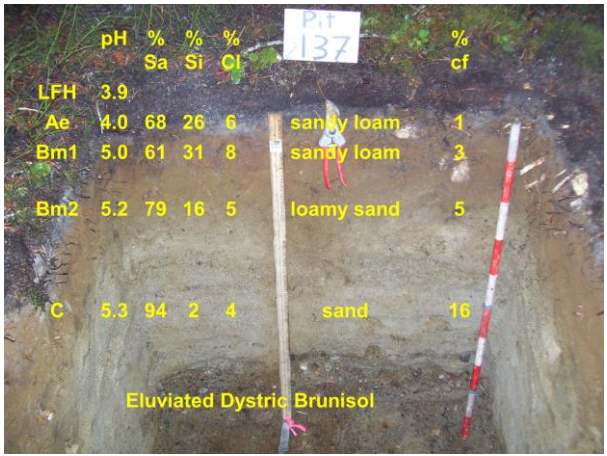
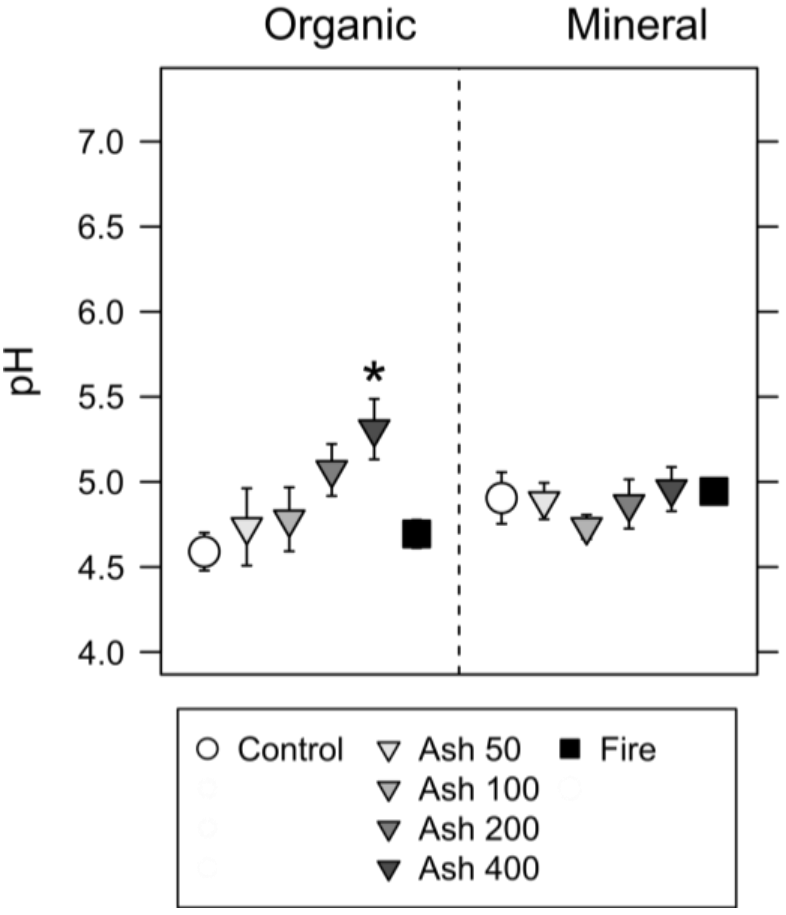
Island Lake Biomass Harvest Experiment



boreal forest - 40-year-old jack pine
deep glaciofluvial deposit
clearcut full-tree biomass harvest

ash applied 0, 0.7, 1.4, 2.8, 5.6 Mg ash/ha equivalent to 0, 50, 100, 200, 400 kg Ca/ha

Soil pH



Organic layer

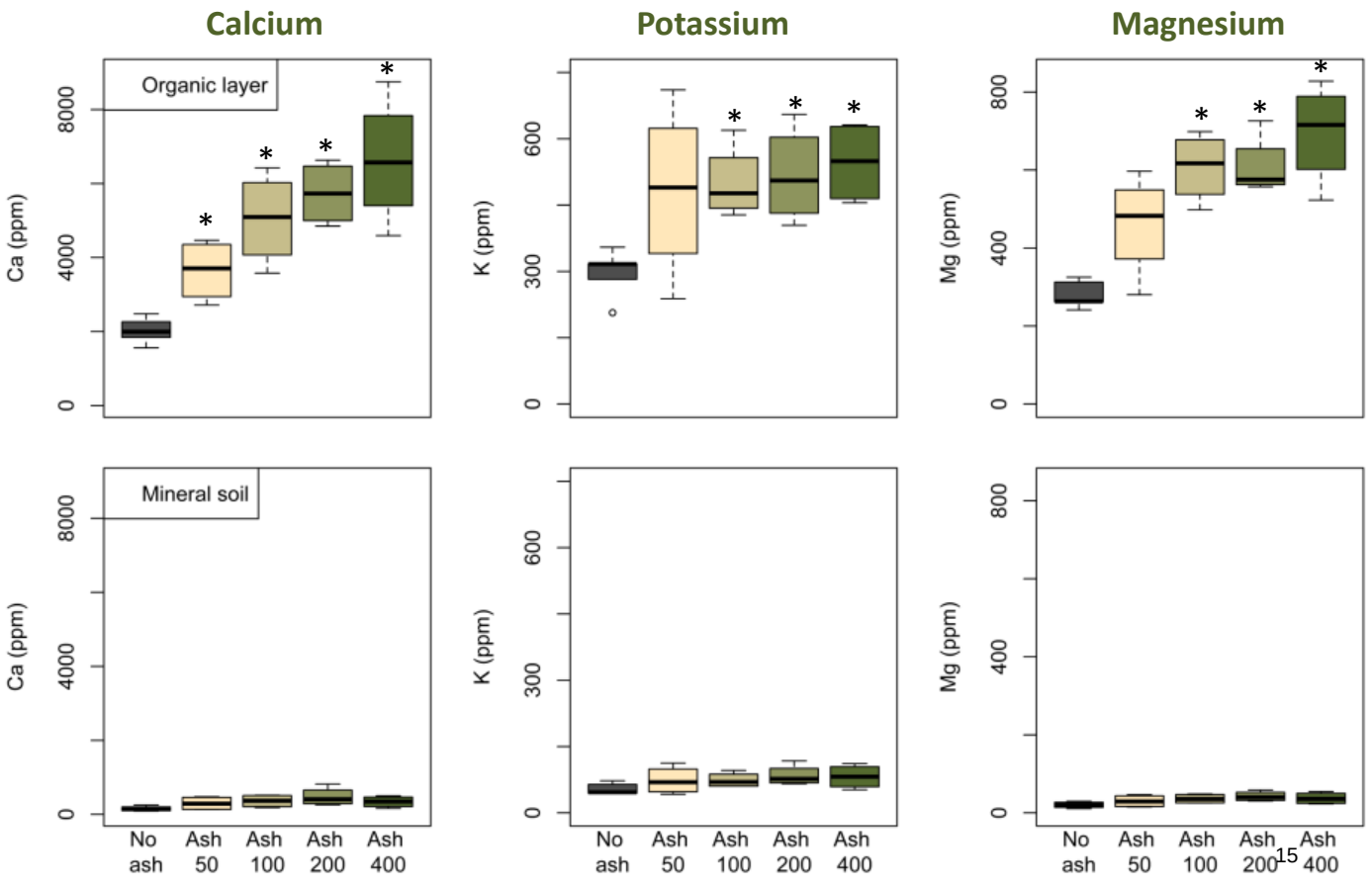
- ash 400 significantly increased soil pH by 0.72 units
- lower addition rates and forest fire had no effect

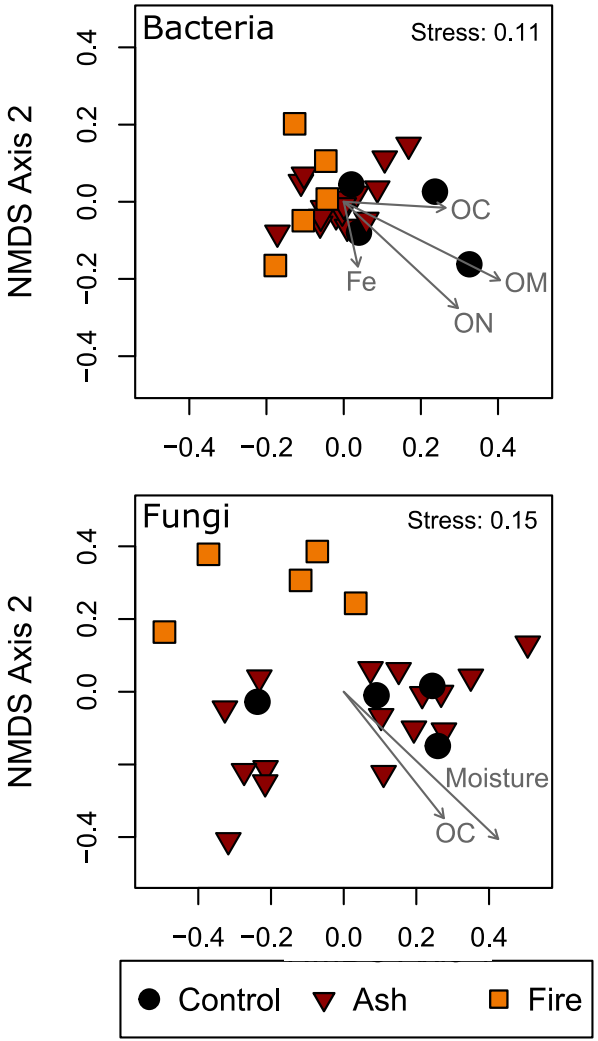
Mineral soil

- no significant effects

Genevieve Noyce, Nate Basiliko, Roberta Fulthorpe, Honghi Tran
U of Toronto

Exchangeable base cations





Microbial community characterization

- no effect of **Ash** on microbial biomass or microbial respiration

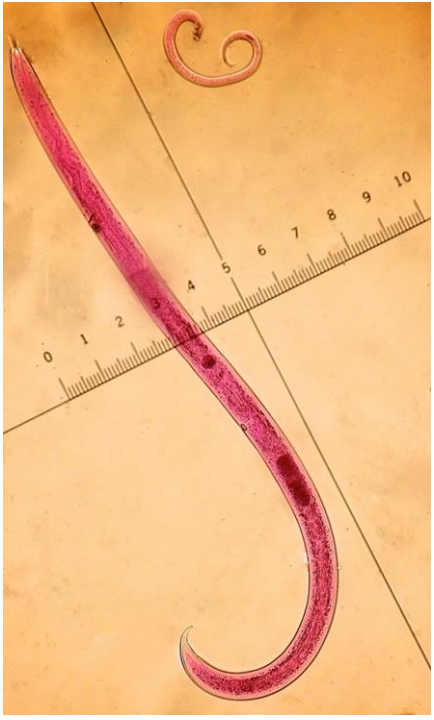
Microbial community composition

- different bacterial communities in **Control**, **Ash**, and **Fire** plots, but no effect of increasing ash addition rate
- no effect of **Ash** on fungal soil community composition, but significant **Fire** effect

Soil fauna - nematodes

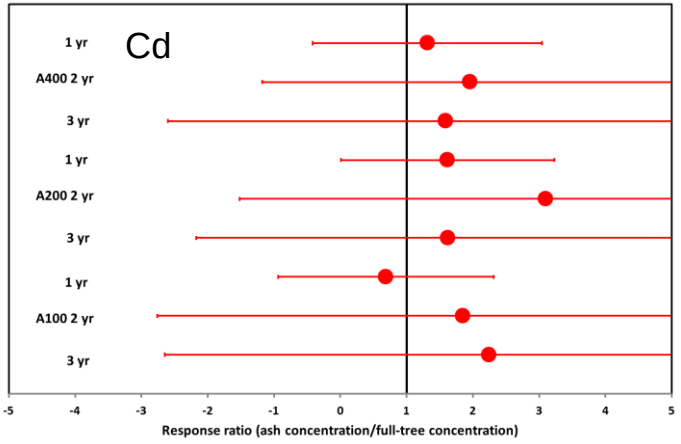
- nematode community composition is an important biological indicator of soil quality
- no effect of **Ash** on nematode community using morphological characteristics (richness, abundance, diversity), trait-based indices or molecular techniques

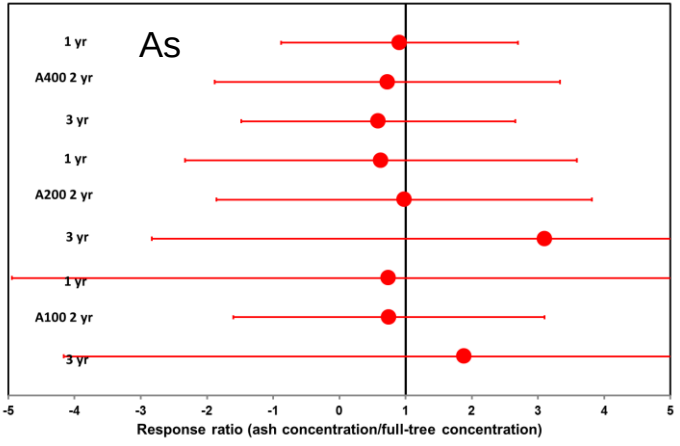
Paul George, Zoë Lindo
Western U



Heavy metal leaching

- no effect of **Ash** on heavy metal leaching from soil at 30 cm depth up to 3 years after application





Barriers and Knowledge Gaps

Need for increased knowledge of environmental benefits and risks

Knowledge of operational feasibility (economic, technical, regulatory)

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Outline

- background
- AshNet I - first stage
- barriers and knowledge gaps
- **current work**
- **future directions AshNet II**

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Can applications of bioenergy ash emulate the effects of wildfire on soil chemistry?

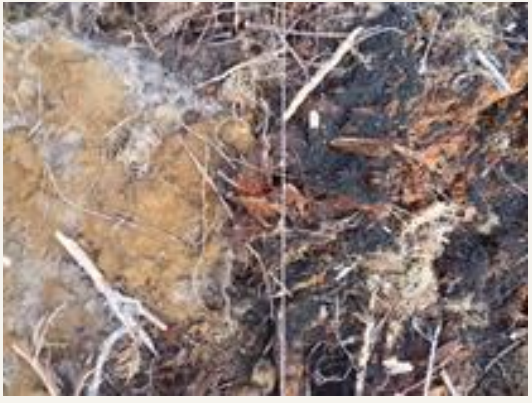
=

?

Meta-analysis of wildfire and bioenergy ash applications effect on soil chemical properties

Boreal, temperate and Mediterranean forests – 80 wildfire papers, 74 ash application papers

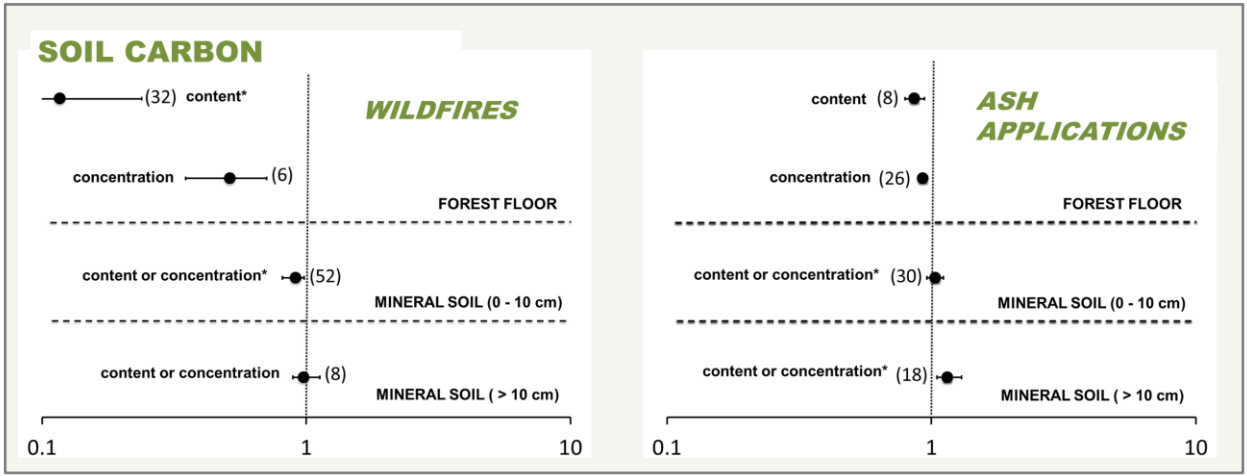
The chemistry of wildfire and Canadian bioenergy ash are similar

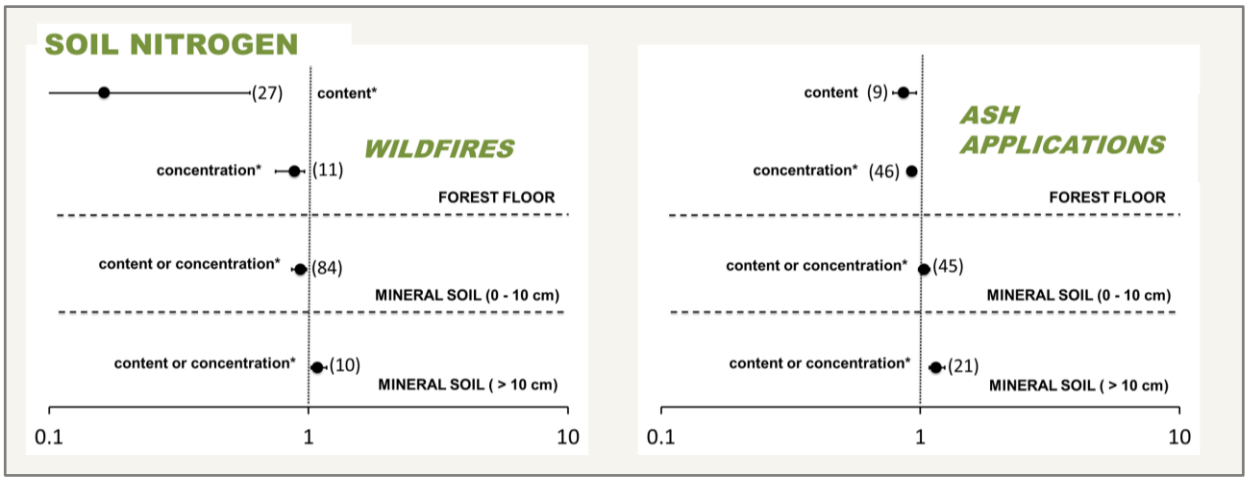


	Fly ash (g kg^{-1})	Bottom ash (g kg^{-1})	Wildfire ash (g kg^{-1})
Carbon	180.9	203.6	282.5
Nitrogen	1.7	0.9	8.6
Phosphorus	6.3	4.9	3.0
Calcium	153.5	103.7	159.5
Magnesium	14.6	11.8	15.8
Potassium	33.1	24.1	23.8

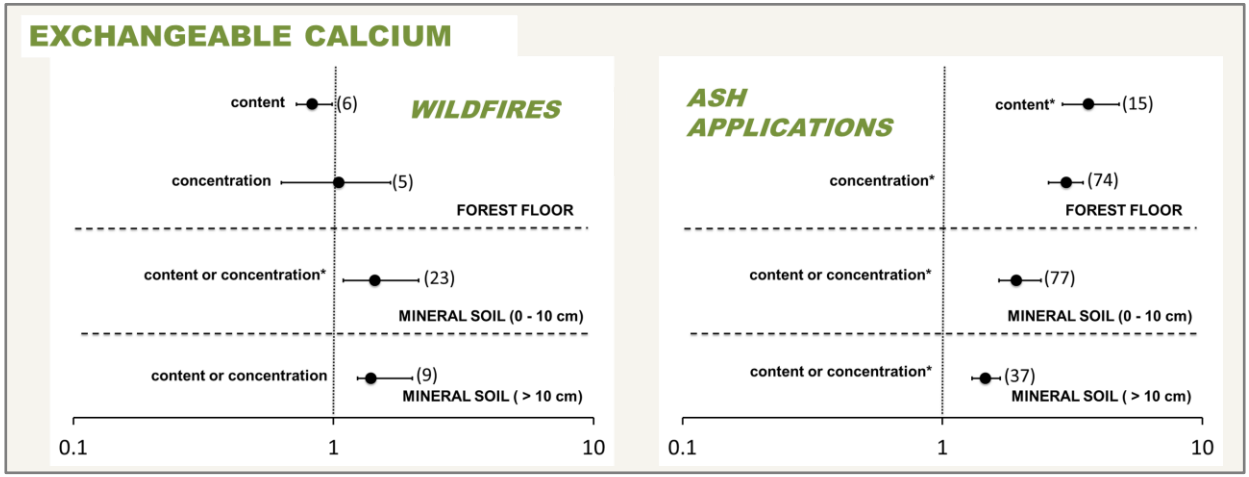
https://www.nrcan.gc.ca/forests/research-centres/glfc/ashnet/20288

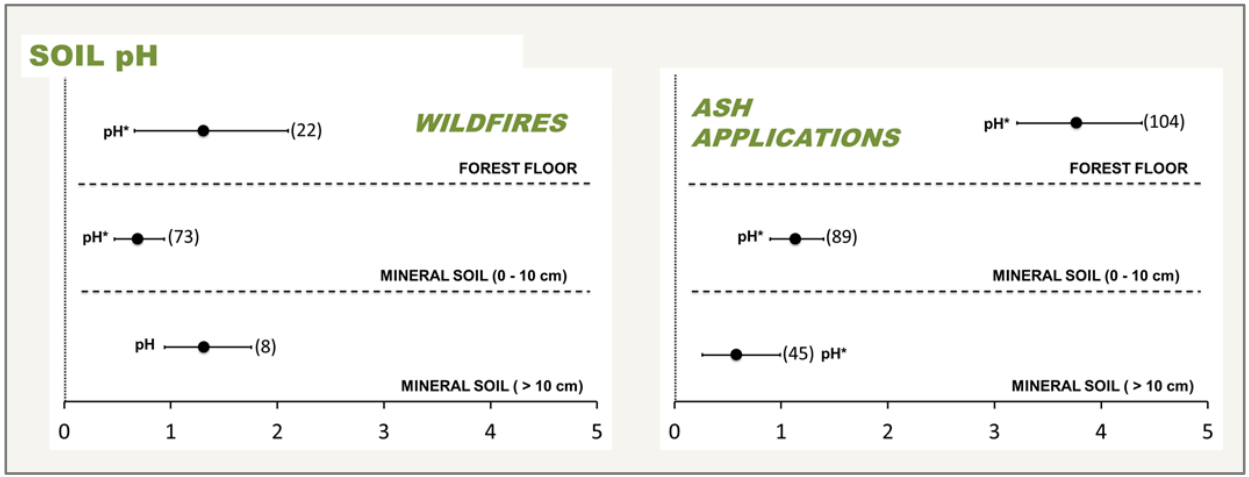
Losses of soil C and N are greater following wildfires





Bioenergy ash has stronger effect on soil pH & exchangeable Ca





Effects of wildfire and bioenergy ash on soil chemistry

- Post-harvest applications of bioenergy ash may preserve soil C and nutrient stocks better than wildfires
- Ash dosage rates and pre-treatment could be modified to more closely emulate wildfire as a natural disturbance

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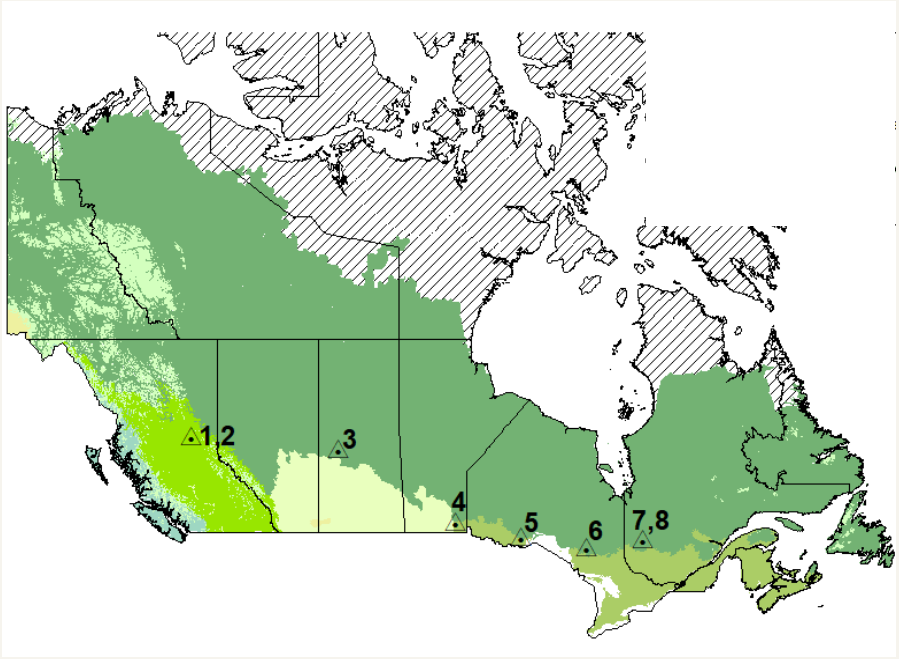
Can applications of bioenergy ash stimulate tree growth in Canada?



Dataset includes:

- Tree height, diameter, volume index
- Pj, Sb, Sw
- 1-6 growth years
- Newly planted & established stands
- Ash applied at 0.7 to 15 Mg ha^{-1} dry weight
- *Elemental: 9 to 433 kg K ha^{-1}

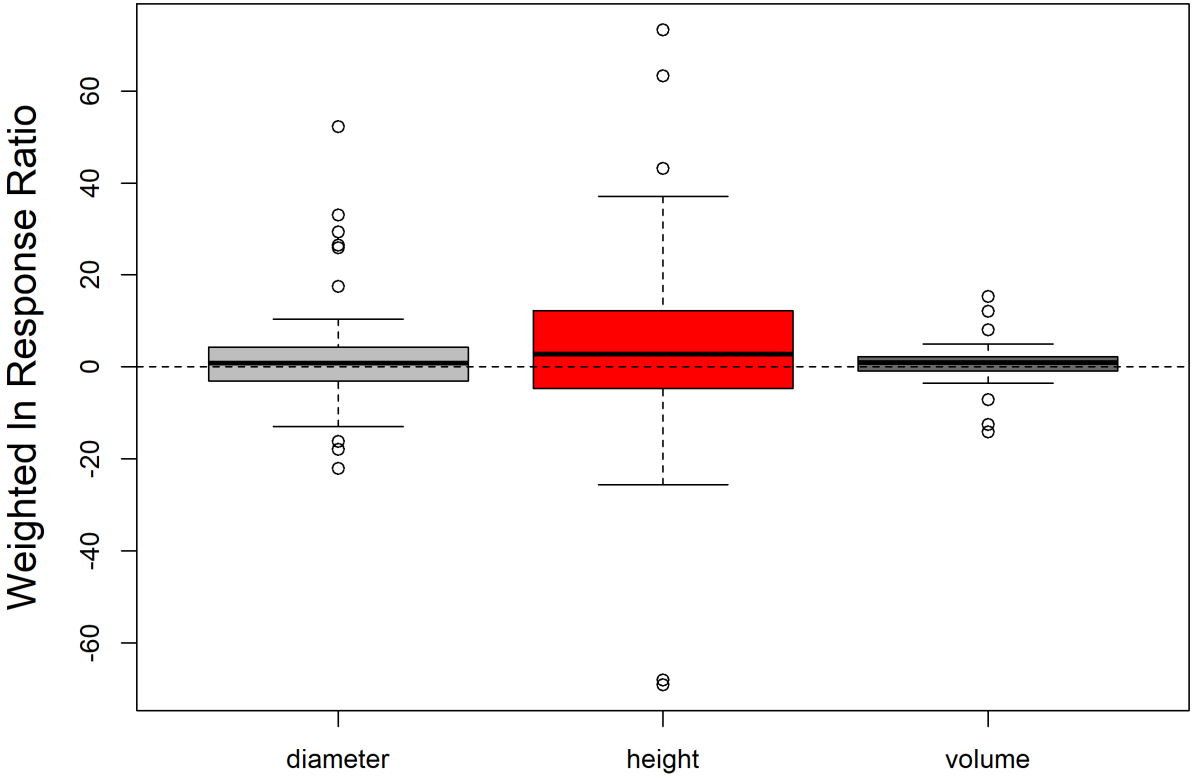
Weighted Response Ratios

$$\text{Response Ratio} = log(\frac{Mean.treatment}{Mean.control})$$

$$\text{Total Variance} = (Treatment\ Variance\ ) + (Control\ Variance)$$

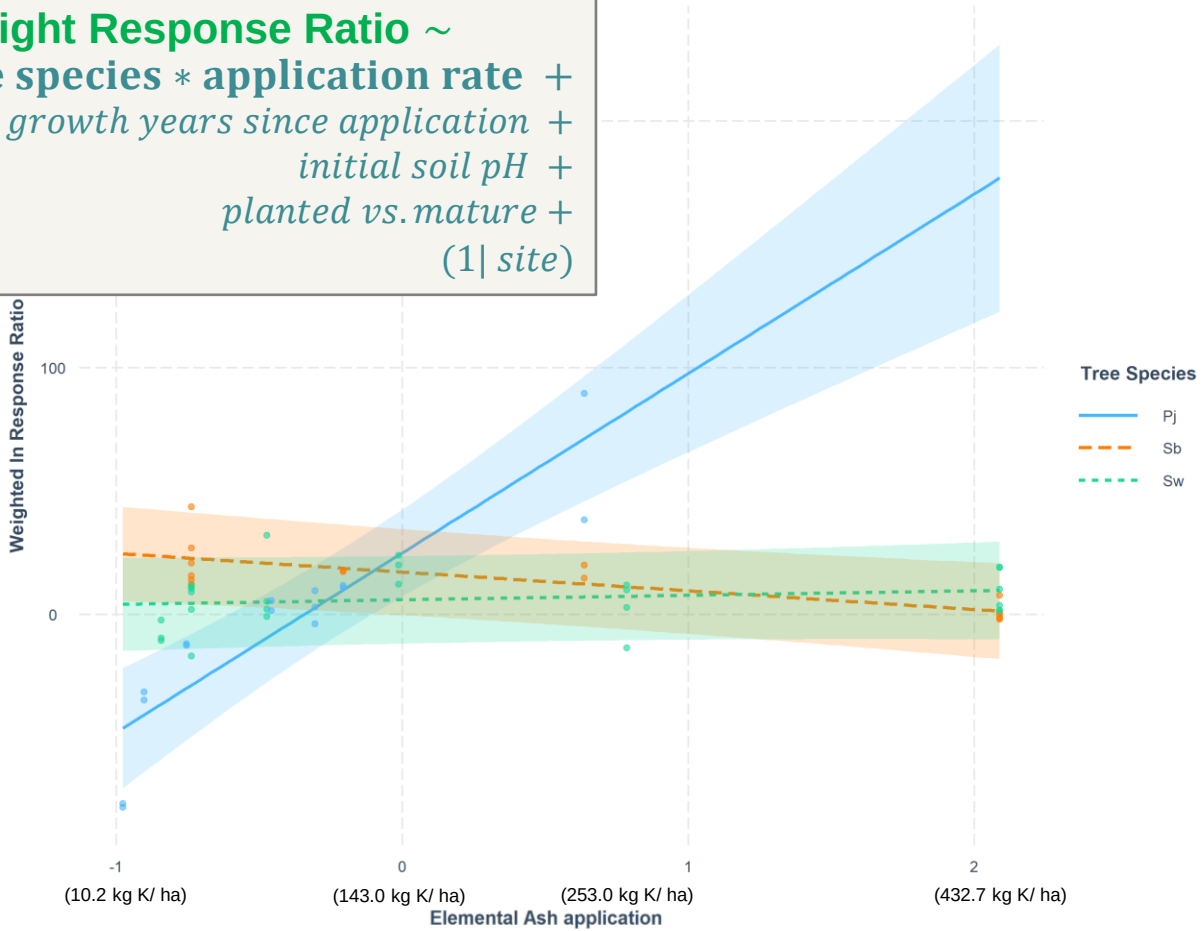
$$\textbf{Weighted Response Ratio} = \frac{Response\ Ratio}{Total\ Variance}$$

Variability in early tree growth response



Which variables help to explain this variation?

Tree Height Response Ratio ~
tree species ∗ application rate +
growth years since application +
initial soil pH +
planted vs. mature +
(1| site)



Effects of wood ash on tree growth: Early AshNet results

- Both positive and negative growth responses observed
- Different response to increasing quantity of ash depending on tree species
- Baseline to compare to - year 10, 15, 20 re-analysis? Include hardwood species, more site data (e.g. nutrient status)
- Similar analysis on foliar nutrition data

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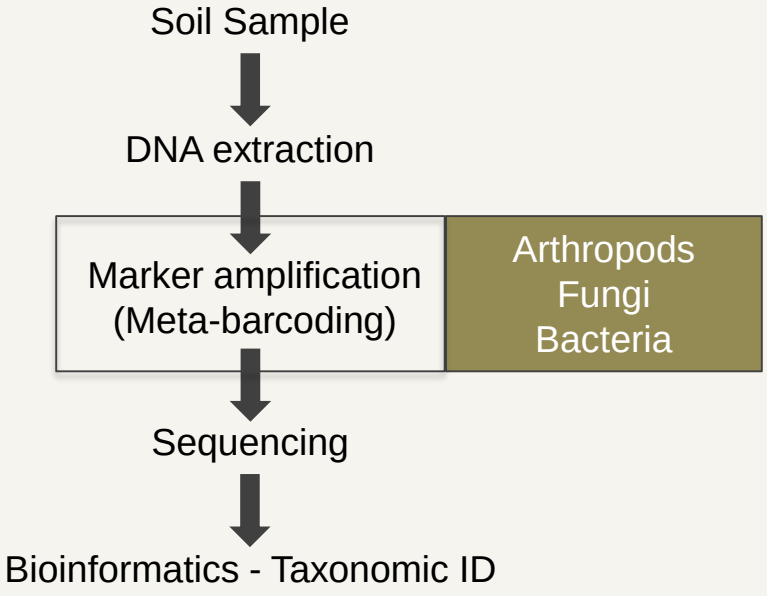
Other AshNet Initiatives in Progress

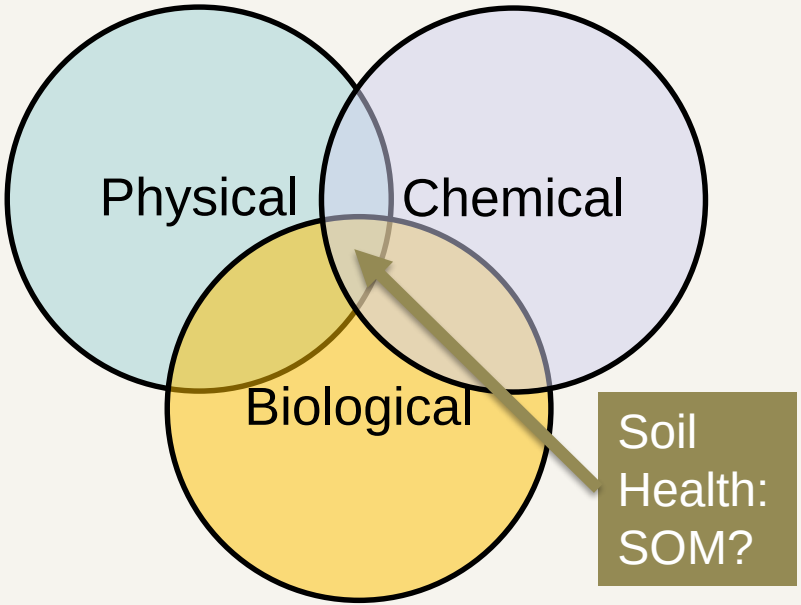
Soil biodiversity study



Question:
Is ash application influencing soil communities and carbon and nutrient cycling?

Other AshNet Initiatives in Progress

Soil health project



Question:
Can properties of soil organic matter (SOM) capture physical, chemical and biological indicators to classify soil health?

Other AshNet Initiatives in Progress

Ash applications as a silvicultural tool

Beech bark disease

Question: Can wood ash applications act as a silvicultural tool in combination with vegetation control to promote maple/birch competiveness over beech?

Other AshNet Initiatives in Progress

Soil water studies

Question:
Do ash applications influence soil water quality through metal leaching, or eutrophication?

Future directions: AshNet II

- Operational scale (techno-economic, technical, environmental), watershed scale effects
- Longer-term environmental risks and benefits (soil fertility, forest growth)
- Network development - focused on even greater policy/regulation integration

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Questions/Discussion

Contact us for more information:

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caroline.emilson@canada.ca

Annual AshNet meeting March 5, 2019

1-4 pm EST WebEx

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