Bioenergy wood ash waste as a forest soil amendment: possibilities and pitfalls

NESMC March 26, 2015
Paul Hazlett, Canadian Forest Service

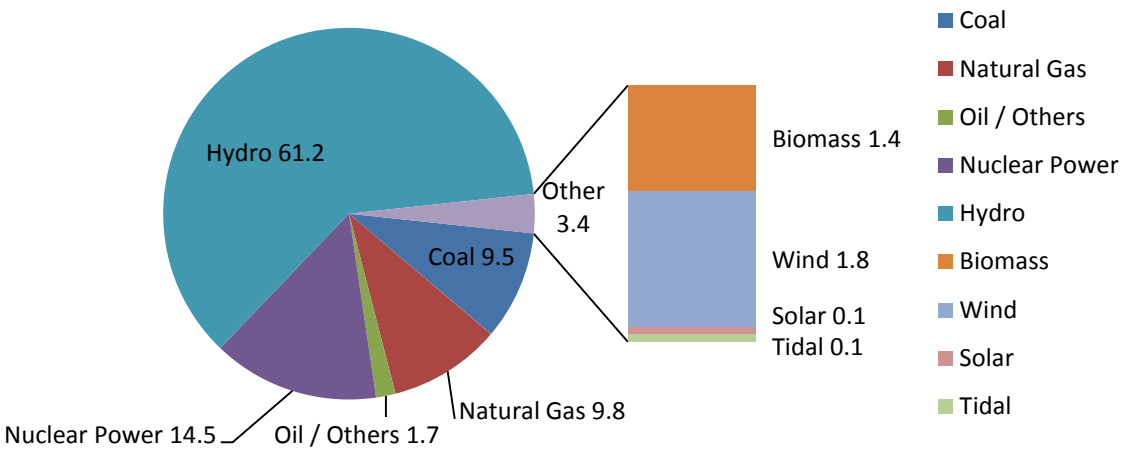
Natural Resources Canada | Ressources naturelles Canada

Canada

Outline

- why wood ash?
- what is ash?
- potential benefits and drawbacks
- what we know – Nordic experiments
- current Ontario trials
- future directions - PERD objectives

Canada's Total Electricity Generation in 2012
= 616 TWh
Generation source by % shown



Total electricity generation in Canada
Statistics Canada, 2012

"Barbecue again?"

Non-hydro renewable fastest growing source of generation in Canada

ecoEnergy for renewable power
ecoEnergy for biofuels

Green Energy Act
OPG Coal Phase Out
Forest Sector Prosperity Fund/Loan Guarantee

Biomass/ash in Canada/Ontario

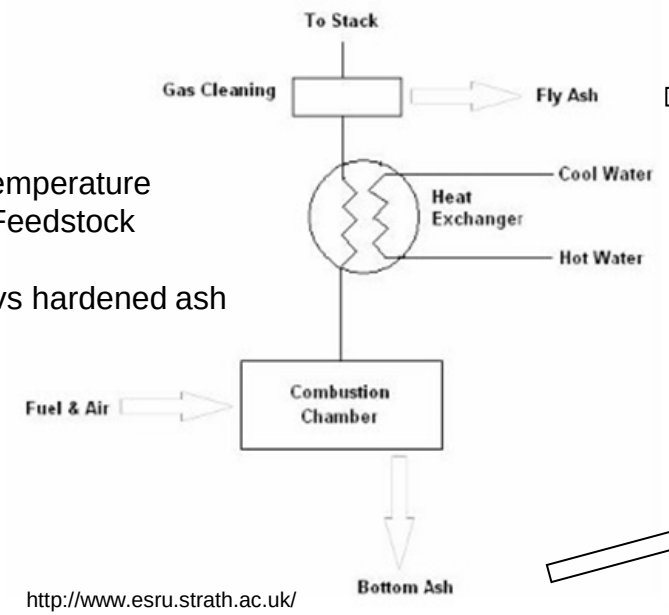
- 2000 - 5 projects (commercial/institutional/district heating)
- 2014 - 200 projects
- 2013 - pulp and paper mills, 39 biomass cogen plants (1600 MW)
  - independent producers (540 MW)
  - 77 biogas facilities
- Atikokan 205 MW, Thunder Bay 60 MW, Hornepayne 15 MW

(Office of Energy Research and Development, 2014)

2002 – 775,000 tons of ash from pulp and paper mills
~ 80% landfilled (Elliot and Mahmood, 2006)

Challenges: Ash storage, disposal, usage, handling, transporting, spreading (James et al., 2012)

Biomass boiler ash – high pH (8-13)



Temperature
Feedstock

Loose vs hardened ash

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

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	30.4	7.2
Cd	mg/kg	23.5	1.9
Cu	mg/kg	146.3	87.6
Pb	mg/kg	182.6	40.9
Zn	mg/kg	4402.8	508.8

Swedish University of Agricultural Sciences wood ash database
http://woodash.slu.se

Potential environmental benefits of ash

- nutrient compensation - “recycling of nutrients should be a fundamental principle in sustainable forestry” (Saarsalmi et al., 2001)

Potential environmental benefits of ash

- nutrient compensation - “recycling of nutrients should be a fundamental principle in sustainable forestry” (Saarsalmi et al., 2001)
- reduce soil and surface water acidification – amendment of soils depleted of base cations (Ca, Mg) due to acid rain, “calcium depletion”

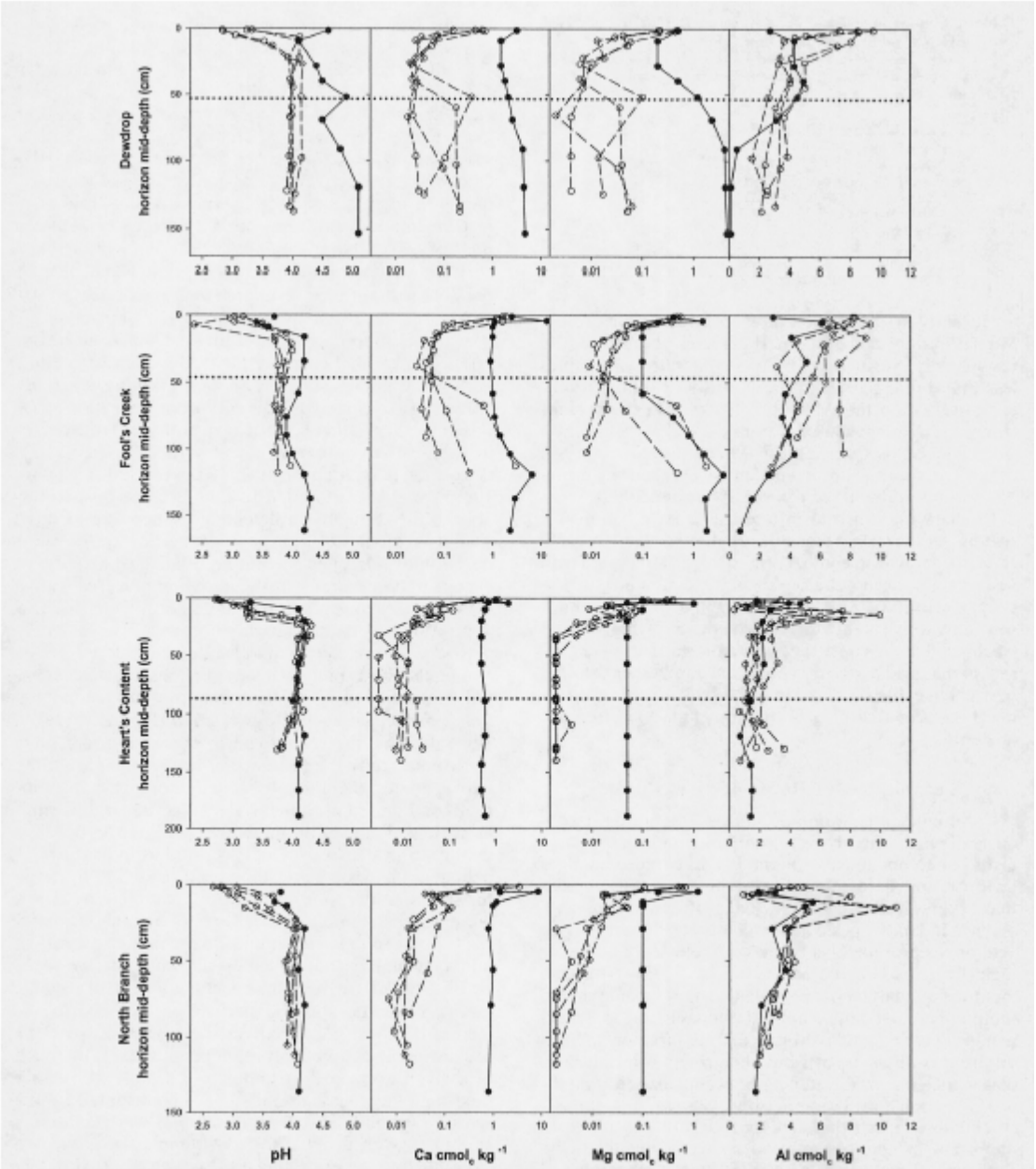


Fig. 4. Depth profiles of pH (standard units) and exchangeable Ca, Mg, and Al (cmol$_c$ kg^{-1}) at each of four study sites. The closed circles represent the data collected from the original pit dug in 1967. The open circles represent the data collected from four pits dug in 1997, located 10 m away from the original pit, in each of the four cardinal directions. The dotted horizontal line shows the average depth of the top of the fragipan, where present. A fragipan was found at three of the five pits at DD, all five pits at FC, and one of five pits at HC.

Bailey et al., 2005
Thirty years of change in forest soils of the Allegheny Plateau, Pennsylvania

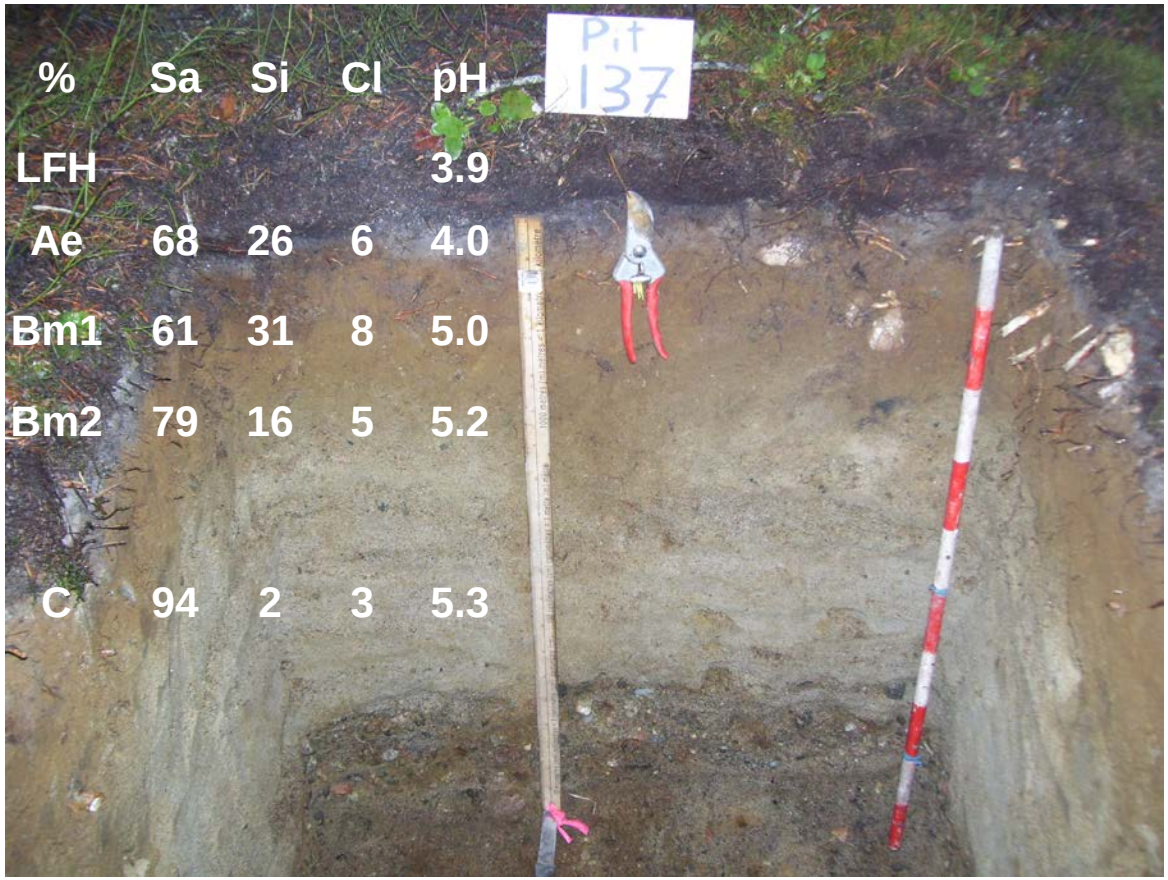
Northern hardwood forest
Declines in soil pH, exchangeable Ca, Mg

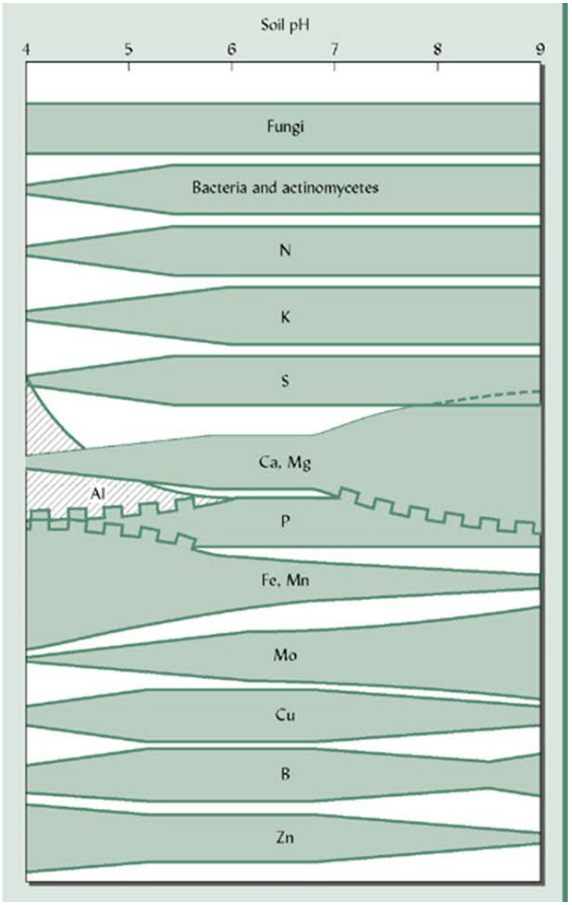
Potential environmental benefits of ash

- nutrient compensation - “recycling of nutrients should be a fundamental principle in sustainable forestry” (Saarsalmi et al., 2001)
- reduce soil and surface water acidification – amendment of soils depleted of base cations (Ca, Mg) due to acid rain, “calcium depletion”
- application to whole-tree and biomass harvested sites - enhance forest productivity - “liming substitute” = increase soil pH


DANGER

Soil pH and plant nutrient availability





Brady and Weil, 2002

Highest nutrient availability pH 6.0-7.5

Potential environmental problems of ash

- soil pH increase, changes in soil N production/availability, increased N levels in soil and surface water
- heavy metal contamination
- impacts on vegetation and soil biota - caustic

Ash research in Scandinavia

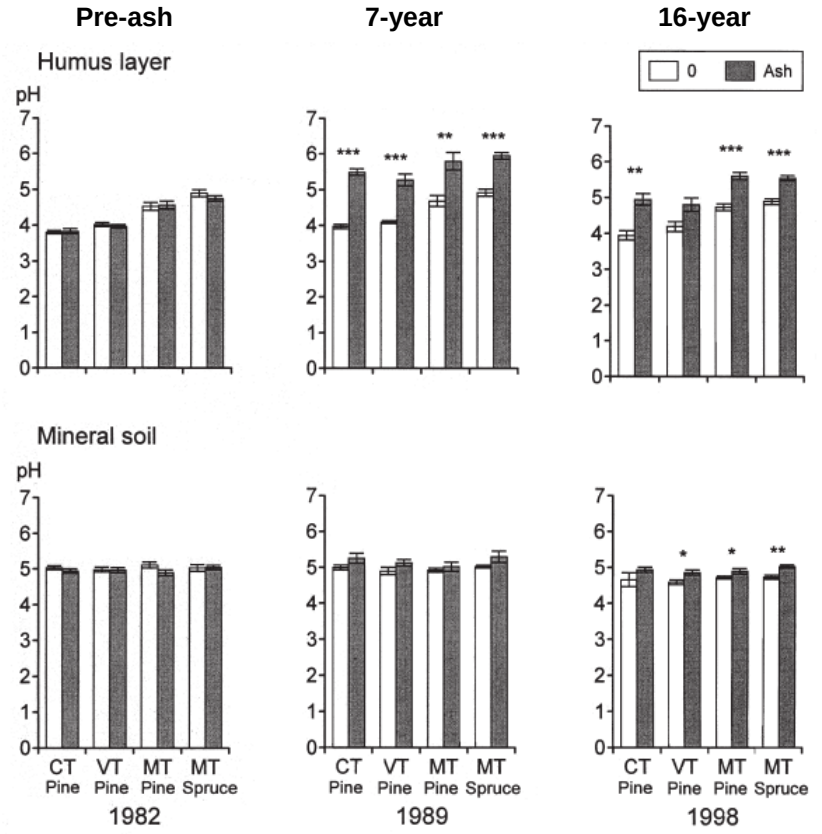


Fig. 1. Effect of wood ash fertilization on acidity ($pH_{(water)}$) in the humus layer and mineral soil on different sites. Sampling before (1982), 7 years (1989) and 16 years (1998) after wood ash application. Standard error of the mean is marked on the columns by bars.

Saarsalmi et al., 2001

Soil

- decrease acidity, higher pH, higher base saturation, increased microbial activity, increased decomposition and N mineralization
- initial impacts in the forest floor, later in mineral soil, long-lasting effect, larger dose = larger impact

Soil solution

- increased base cation and dissolved organic carbon leaching, no increase in heavy metal or nitrate leaching

Ash research in Scandinavia

Foliage

- increased Ca, K, P and B for organic and mineral soils, metals have low bioavailability (increased pH = decreased availability)

Tree growth

- organic soils - increased pH, increased decomposition, increased growth, K and P fertilizer
- mineral soils – N limited (high C:N), no significant effect – N rich sites (low C:N), increased growth

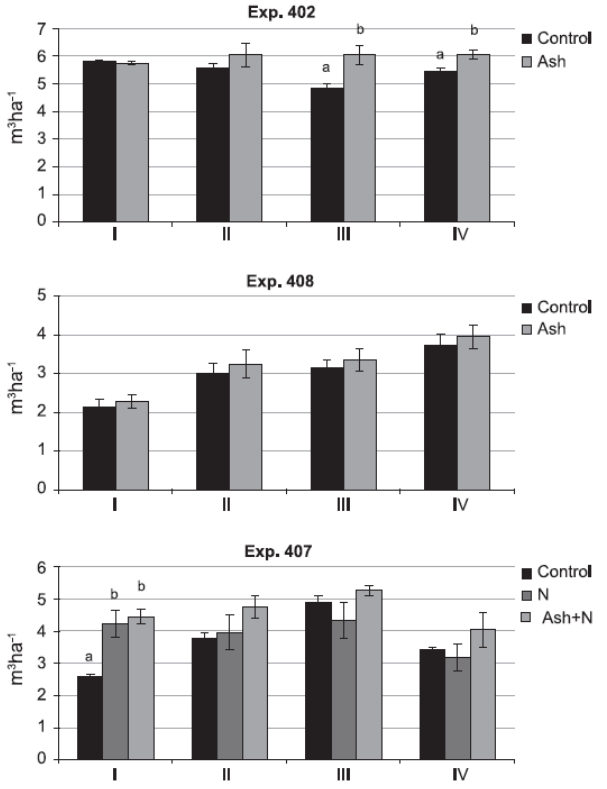


Fig. 3. Mean annual volume growth of tree stands on the upland sites during the first-, second-, third- and fourth 5-year period after treatments. Mean of three replicate plots. Mean values with different letters differ significantly from each other ($p < 0.05$). Standard error of the mean is marked 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

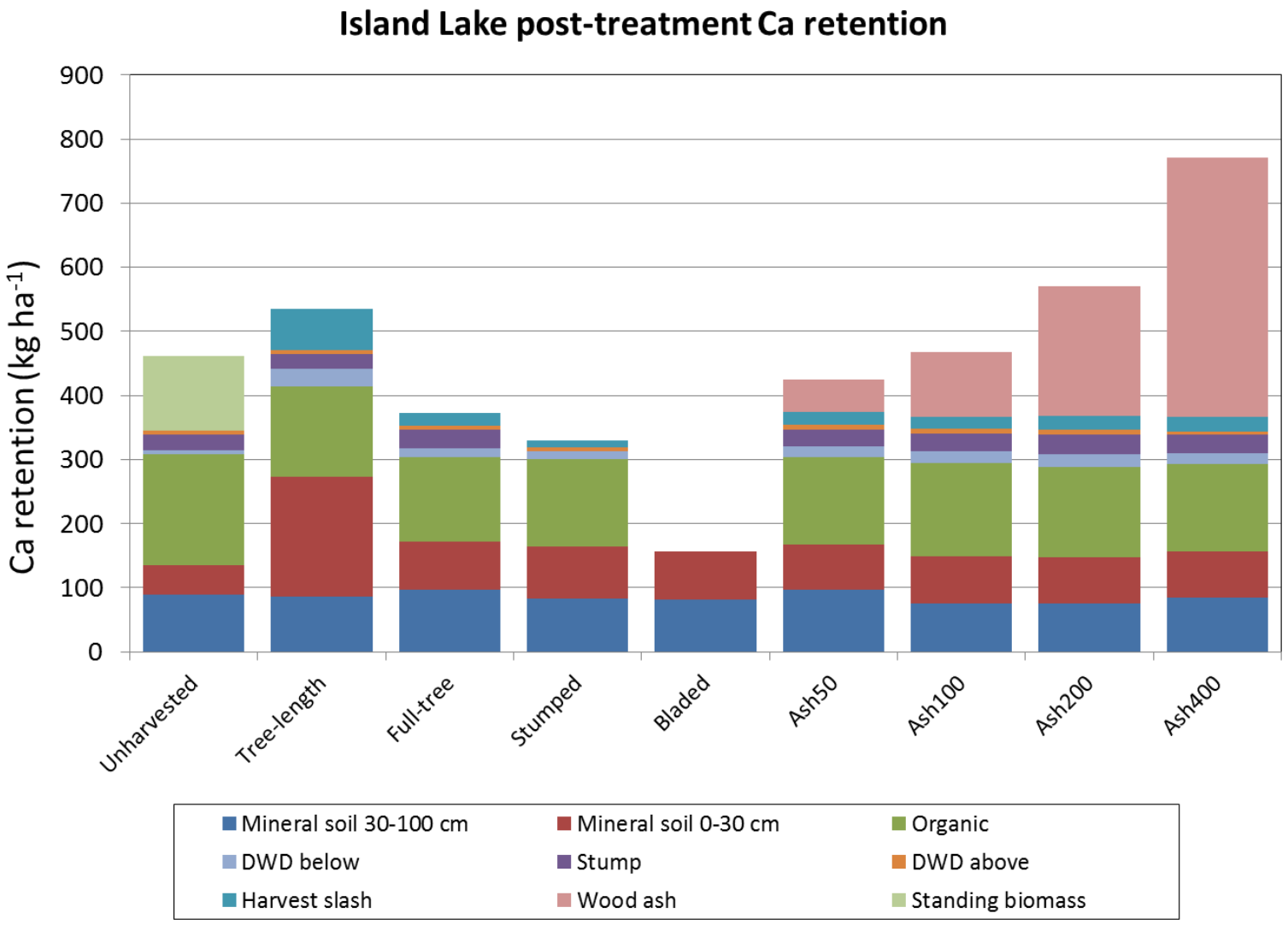
Recommendations

- “ash recycling following forest fuel extraction to counteract the soil acidifying effect as a result of increased extraction of base cations, and not to secure short-term site and stand productivity” (Consequences of an increased extraction of forest biofuel in Sweden, Swedish Energy Agency, 2014)
- application to soils depleted in Ca and Mg due to acidification (site restoration), application to soils low in K (fertilizer for K deficit forests) (Augusto et al., 2008)
- “studies showed a wide range of results which does not make it possible to give general guidelines for wood ash applications to forests….areas where wood ash application is likely to become a common practice, there is a need for an early evaluation of the expected effects” (Augusto et al., 2008)

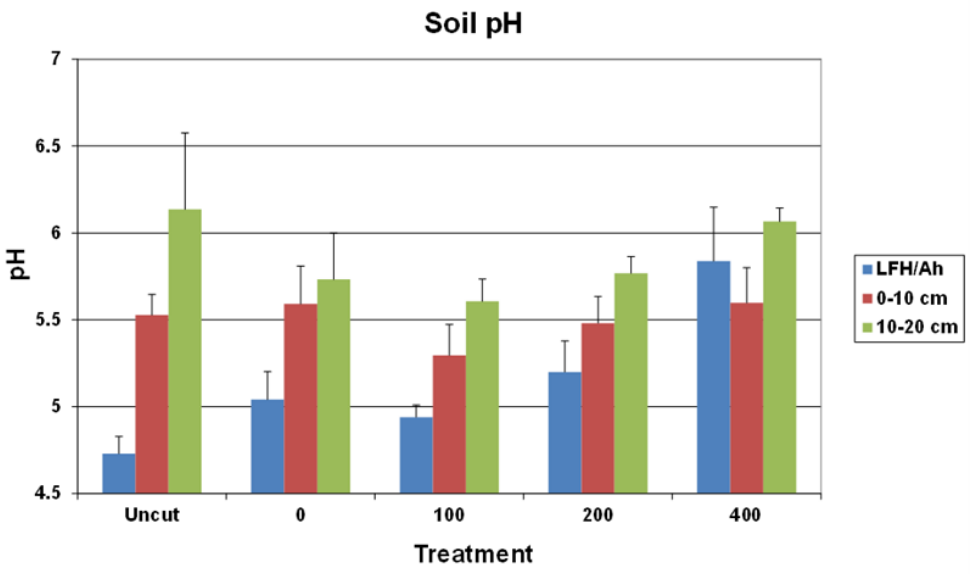
Ontario ash trials

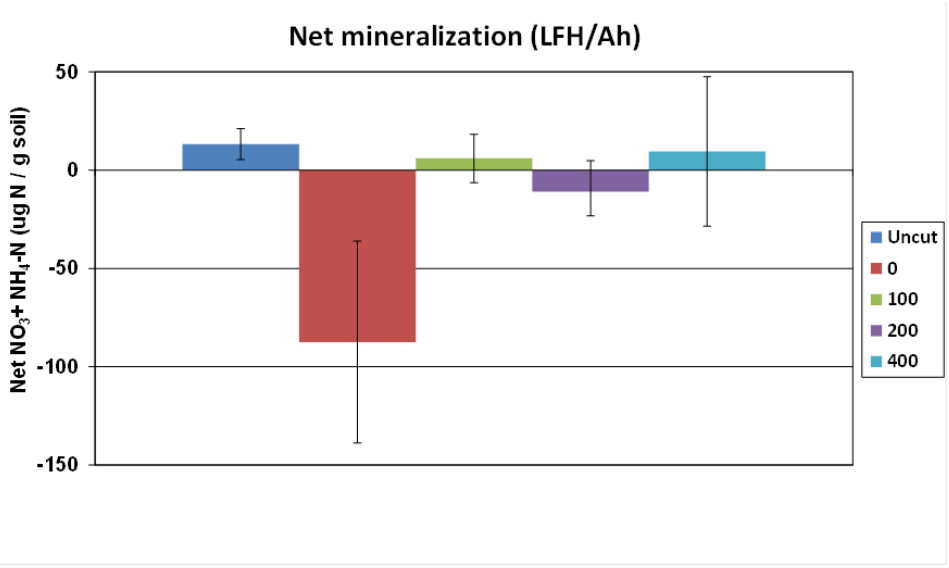
- Island Lake Biomass Harvest Experiment – boreal forest, near Chapleau - clearcut full-tree biomass harvest - bottom ash application October 2011, 4 application rates
- Haliburton Forest and Wildlife Reserve - Great Lakes St. Lawrence forest, near Haliburton - partial harvests, biomass utilization - fly and bottom ash application October 2013, 2 application rates
- tree, ground vegetation ,soil, soil water, biodiversity assessments

Island Lake – early results

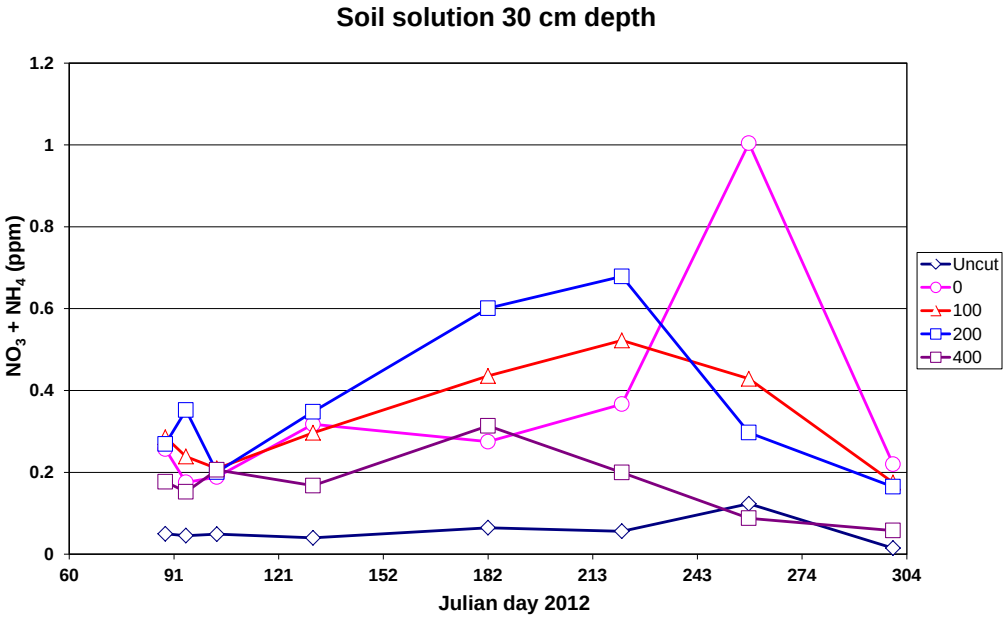


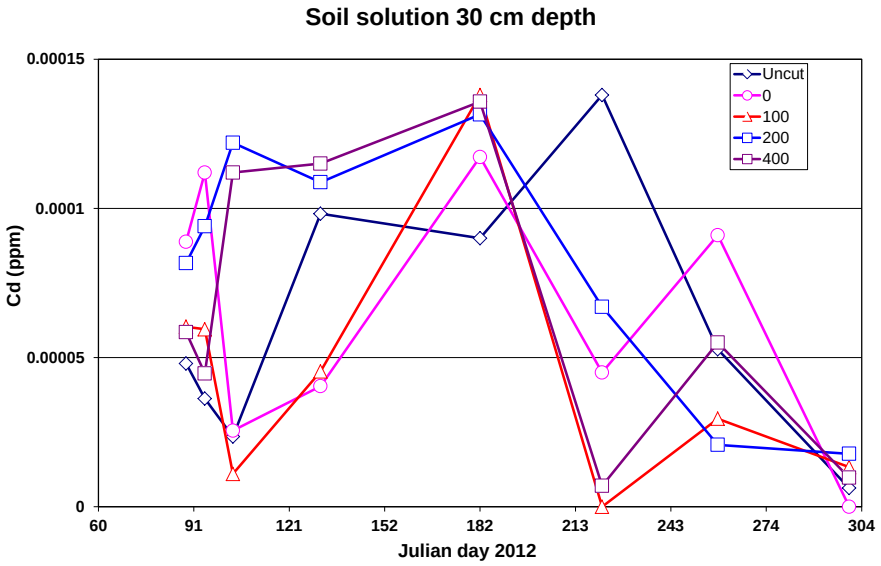
Island Lake – early results





Island Lake – early results





Future directions - PERD

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 guideline/regulation synthesis
2. Economic analysis
3. Network of researchers and knowledge
4. Monitor ongoing and new experiments

Partners: Ontario Power Generation, Wood Pellet Association of Canada, Tembec, CanFor Pulp, J.D. Irving, Resolute Forest Products, OMNRF, FP Innovations, Laurentian, Lakehead, UNBC

Questions/Discussion