Waste wood products as a pathway towards more economically-viable, conservation-oriented and First Nations inclusive **mine tailings restoration.**

Jasmine Williams, B.Eng, PhD Candidate

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Institute of Forestry and Conservation,
University of Toronto

Ecological restoration

The process of **assisting the recovery** of a degraded, damaged, or destroyed **ecosystem** to reflect **values regarded as inherent** in the ecosystem and to **provide goods and services** that people **value**.

Martin, DM (2017) *Restoration Ecology*, *25*(5), 668-673.

Ecological restoration

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Valued by **WHO** ?

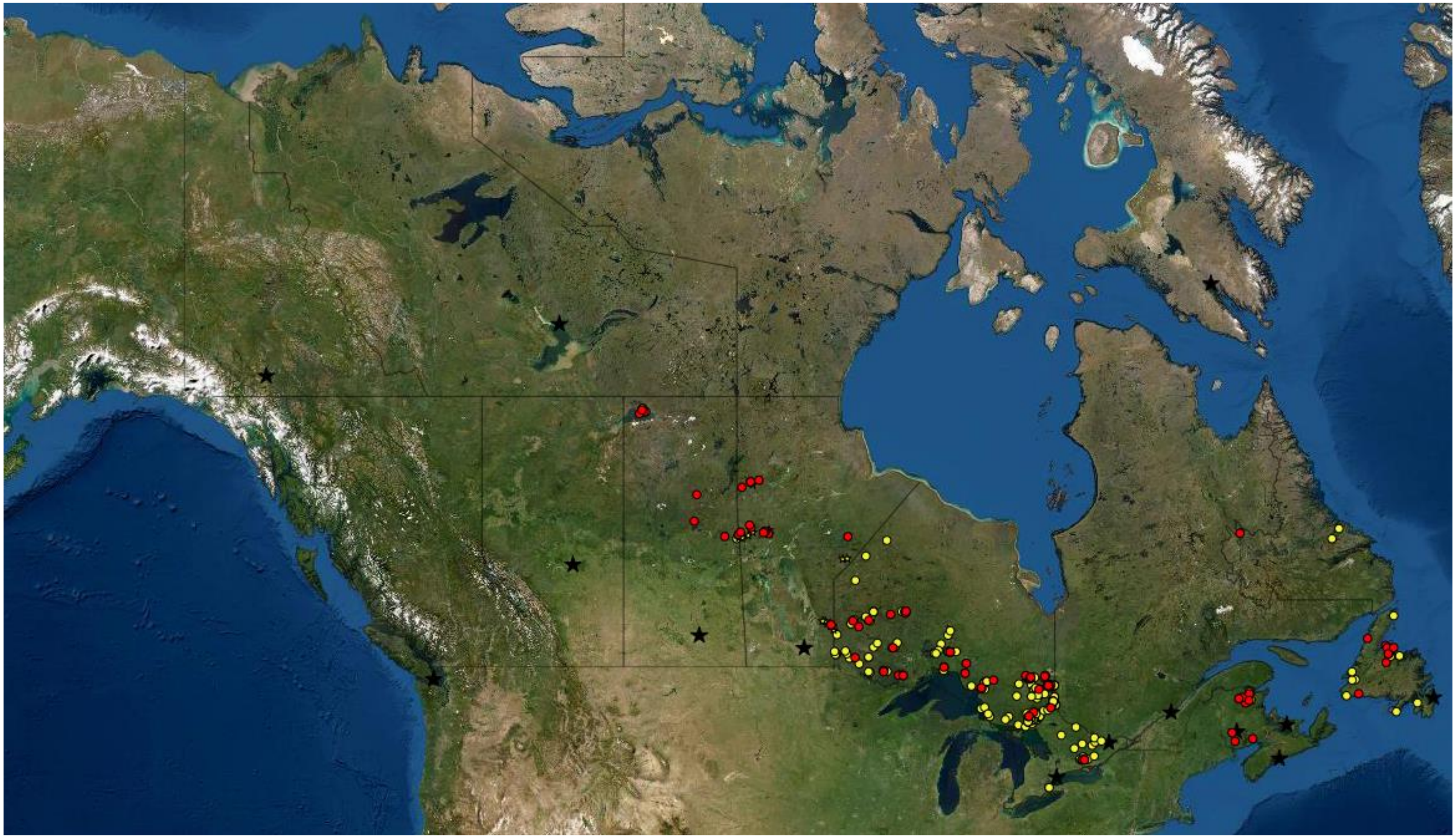
Inherent based on what?
Regional trends?
Traditional Knowledge?
Pre-operation state?

Martin, DM (2017) *Restoration Ecology*, *25*(5), 668-673.


The Nature Conservancy


930E
46

Orphaned and abandoned mine sites



naomi.org

- *site with potential to cause environmental, public health and public safety concerns*
- *site with limited potential to cause environmental concerns but with potential for public health and safety concerns*

Ecological restoration

The process of **assisting the recovery** of a degraded, damaged, or destroyed **ecosystem** to reflect **values regarded as inherent** in the ecosystem and to **provide goods and services** that people **value**.

Common goals:
(and expected biochar addition effects)

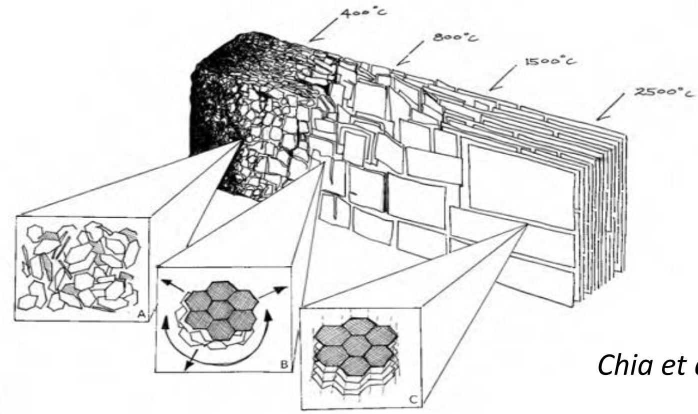
Increased primary productivity ✓
Reduced bioavailability of toxics ✓
Enhanced performance of valued species ✓

Biodiversity / Natural community structure ?
Reduced dependance on top soil & compost additions ?

✓ Documented in recent literature re: agriculture

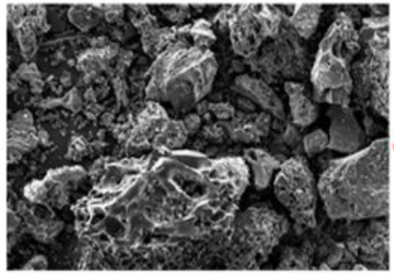
? Mostly empirical data with few field trials

Introduction to biochar

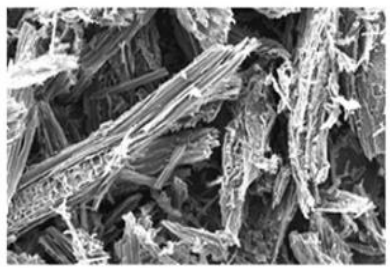


Chia et al., 2015

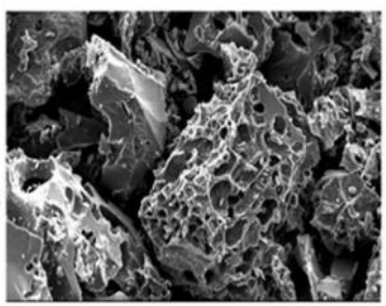
Mixed food waste — Pyrolysis → To food waste biochar



Wood Waste — Pyrolysis → To saw dust biochar

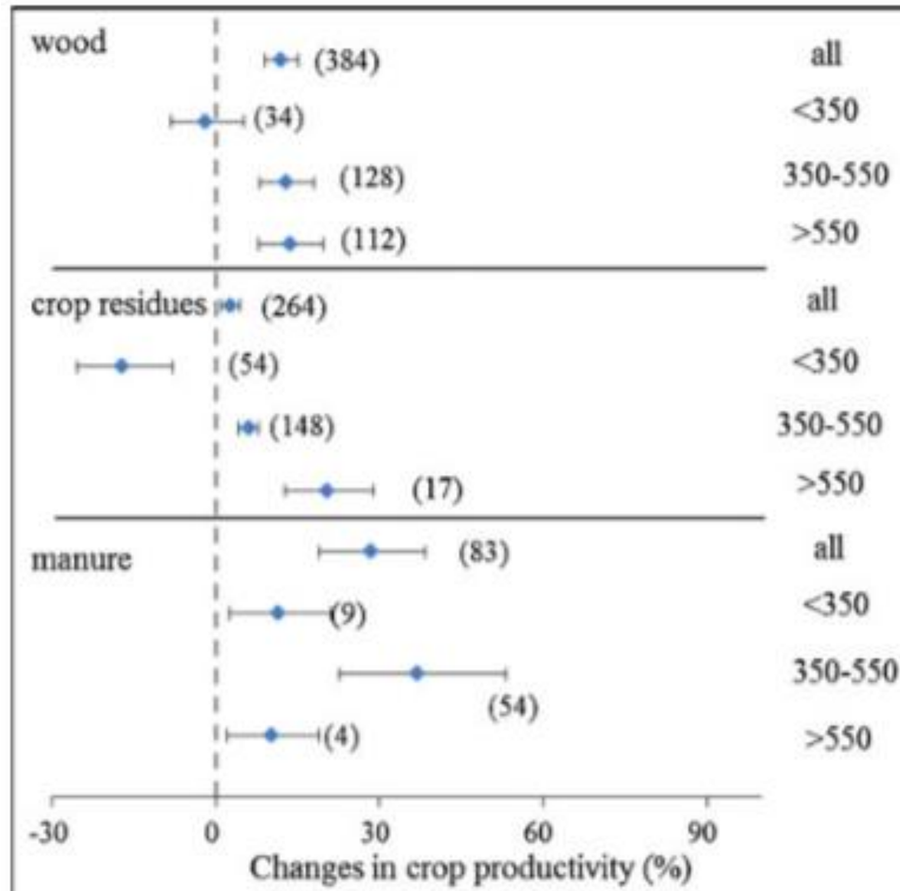


Rice waste — Pyrolysis → To rice waste biochar



Gupta et al., 2018

Liu et al., 2013



CAN HIGH-CARBON WOOD ASH ALTER RESTORATION OUTCOMES ON CONTAMINATED MINE TAILINGS ?

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Early clues

native seed germination & young seedling survival

Later clues

native volunteerism, invasive species response, species diversity

Longer term results

tailings chemistry, plant/tree metal uptake and changes in tree health

CAN HIGH-CARBON WOOD ASH ALTER RESTORATION OUTCOMES ON CONTAMINATED MINE TAILINGS ?

Early clues

native seed germination & young seedling survival

Does BC change seed germination rates?

Is this influence prompted by the type of biochar applied?

Is this influence variable based on the type of substrate (tailings)?

Are the effects of BC on seeds/seedlings species-specific?

Later clues

native volunteerism, invasive species response, species diversity

Does BC influence *native plant* establishment? And HOW?

Does BC influence establishment of *invasive species*? And HOW?

Does BC affect the *range of species* to recruit on tailings?

Longer term results

tailings chemistry, plant/tree metal uptake and changes in tree health

Does BC change mobile ion concentration in tailings?

How is this influence variable based on BC dose?

Does BC change tree root/shoot metal uptake?

Does BC affect survival and biomass (growth) of trees ?

Can wood ash play a role in the restoration of metal-contaminated mine tailings ?

Revegetation

Reforestation

Decontamination

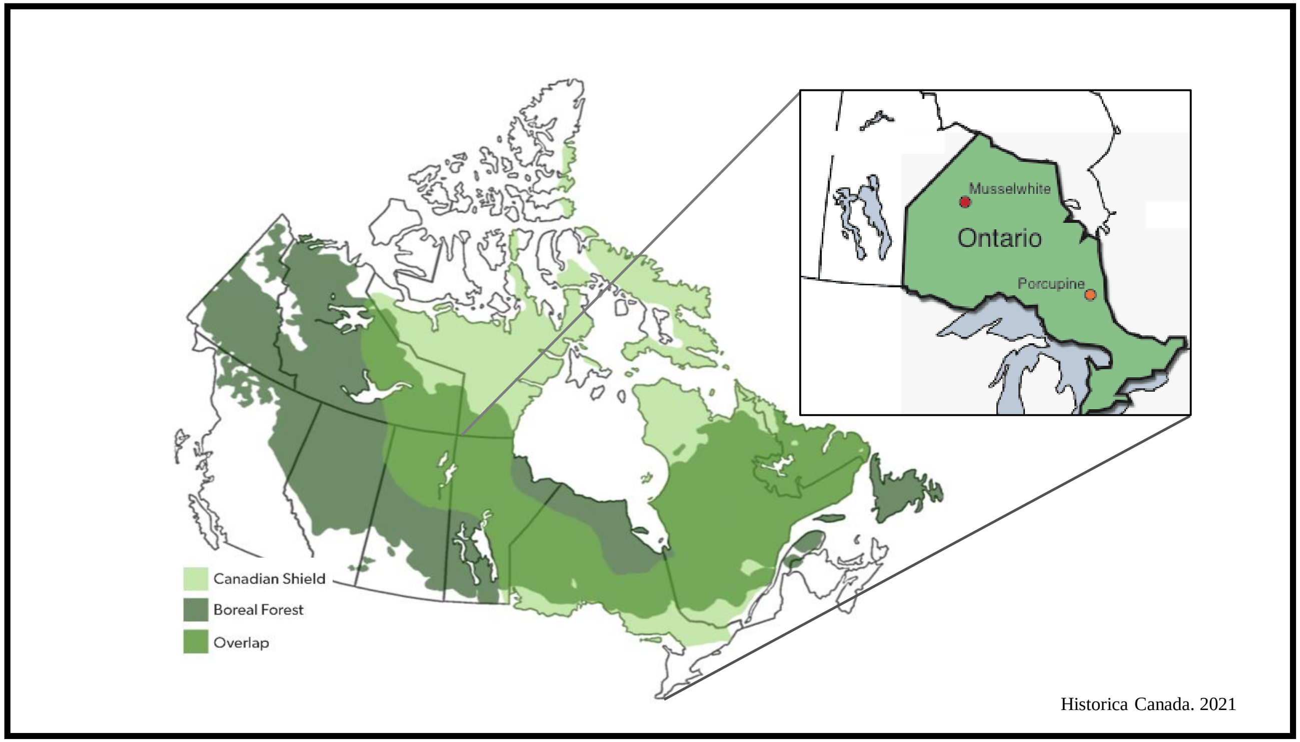
CAN HIGH-CARBON WOOD ASH ALTER RESTORATION OUTCOMES ON CONTAMINATED MINE TAILINGS ?

Early clues → ***Later clues*** → ***Longer term results***

- native seed germination & young seedling survival
- native volunteerism and invasive species response
- tailings chemistry, plant/tree metal uptake and changes in tree health

Understanding the complex interaction between biochar, metal mine tailings, and the ecosystem

IN-SITU EXPERIMENTS


Musselwhite
Ontario
Porcupine
Canadian Shield
Boreal Forest
Overlap
Historica Canada. 2021


500 m


1:1,200

Experiment sites

	Delnite Site	Musselwhite Site
LOM	1937-1964 (orphaned)	1997 – 2020est. (operational)
Substrate	Silt/Sand + Peat + Tailings/waste rock	Glacial till + Peat + Tailings *Emergency spillway, covered by sand
Processing	Flotation, cyanide leach circuit	CIP, and Air/So2 circuit for cyanide
Trials	1971: limestone and fertilizer 2003: mixed native grass seed sowed but veg. sparse	2001:thickened tailings, desulphurization, but not on direct test site
Current State	Current neutral pH, 2015 COC = arsenic, cyanide	Local pH 4-6, 2014 total PAG @ 75%

Delnite historical tailings

Delnite site

- 70 plots of 1.44 m^2;
  (1m X1m, 0.1m buffer on each side)

- Biochar applied to the top 6cm. of tailings on each plot

- Biochar doses of 0, 1.5, 3, 6, 9, 15, and 30 t/ha

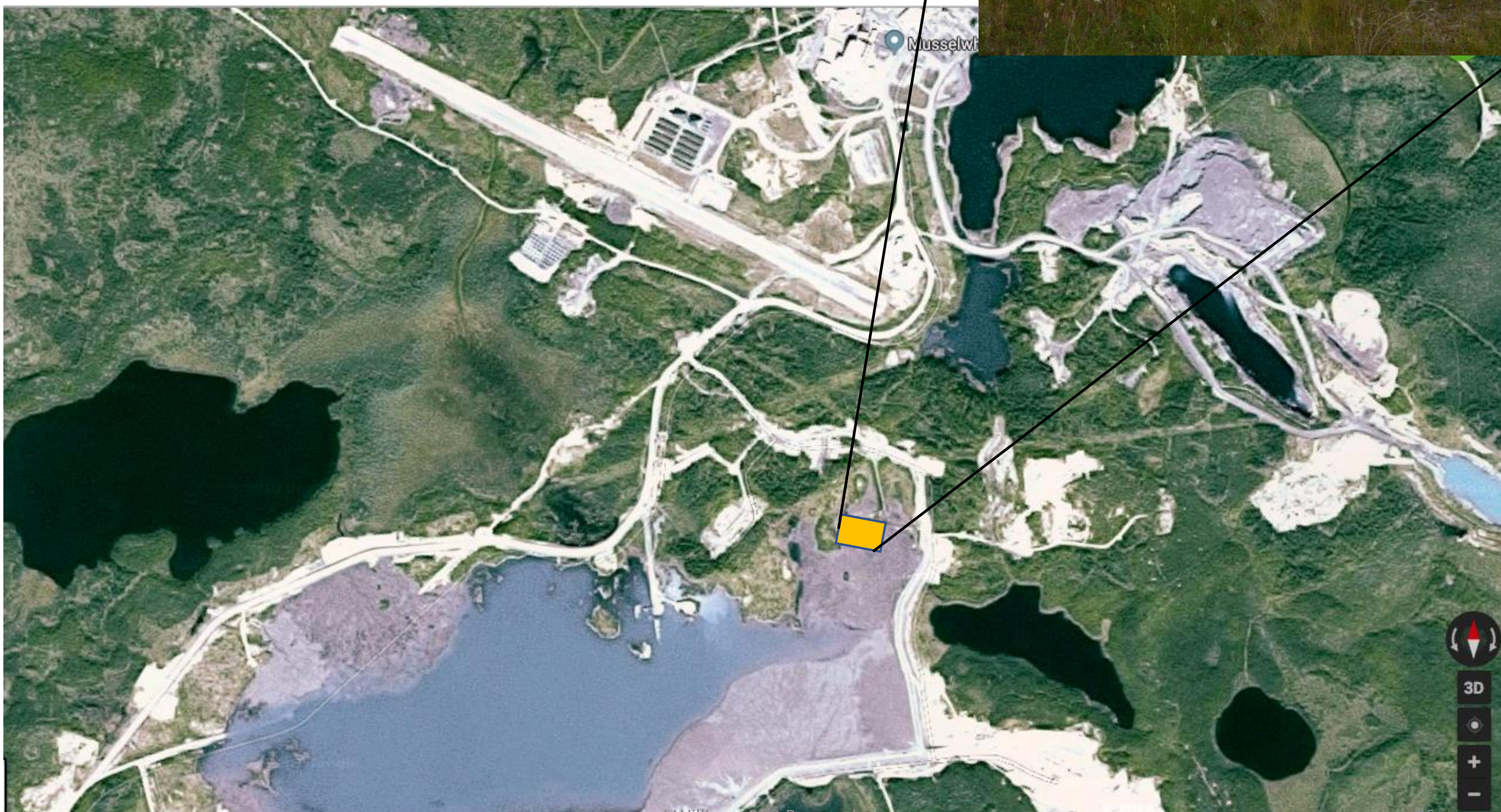
- 10 replications will need to be examined for block-effect, as topography and substrate variations.

Musselwhite site



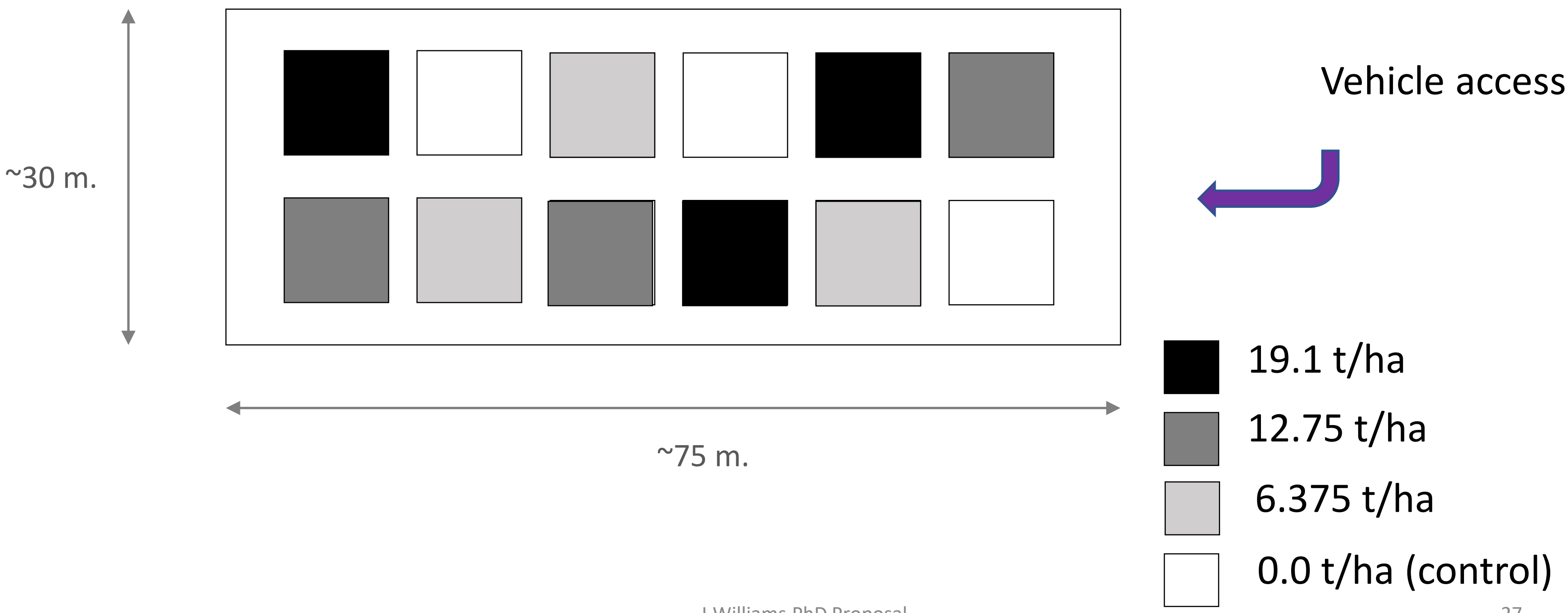

Musselwhite site

Musselwhite site



Musselwhite site

- 12 plots of 100 m^2; (10m X 10m)
- Biochar applied to the top 7cm. of tailings on each plot;
- Biochar doses of 0, 6.4t/ha, 12.75t/ha, 19.1 t/ha
- Homogenous surface which allowed for fewer blocks and larger plots.



Soil properties and vegetation surveying

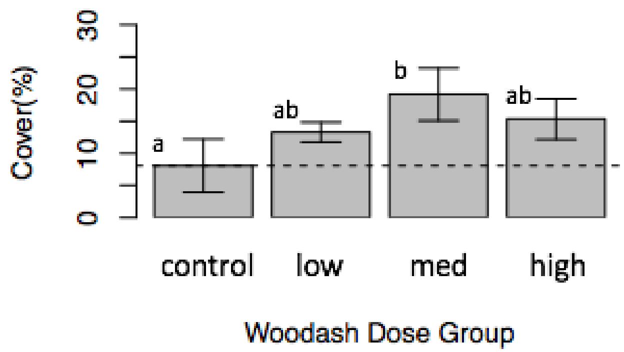
- 12 months and 22 months;
- **For each plot:** species identified with their associated frequency (stem count) and plot cover percentage (density);
- Samples were collected and dried for follow-up inspection and validation;
- Trace at Delnite ~ <0.5%, 8cm X 8cm
- Procedure repeated at Musselwhite, where each plot was subdivided into 4;
- Trace at Musselwhite ~ <0.25%, 0.5m X 0.5m

SELECT RESULTS

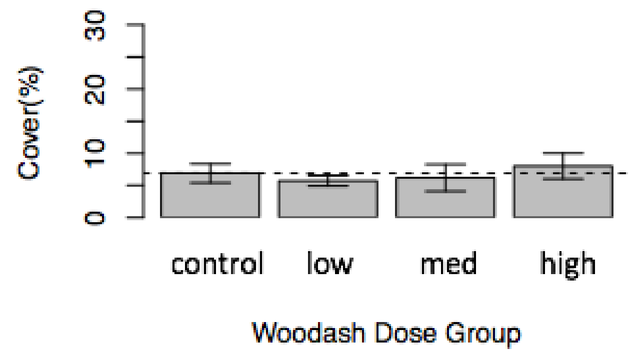
Volunteer revegetation

ONE GROWTH YEAR

Delnite



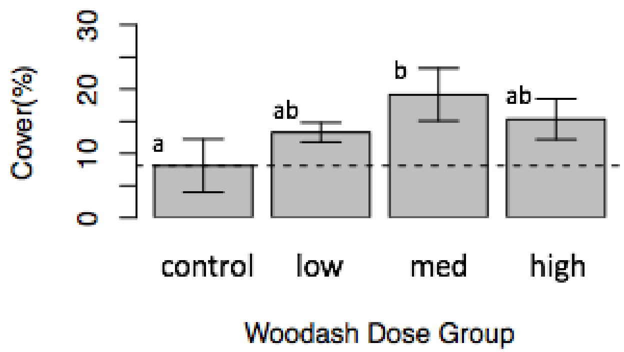
Musselwhite

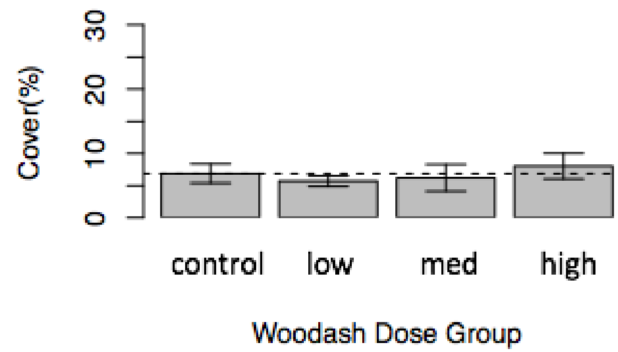


Volunteer revegetation

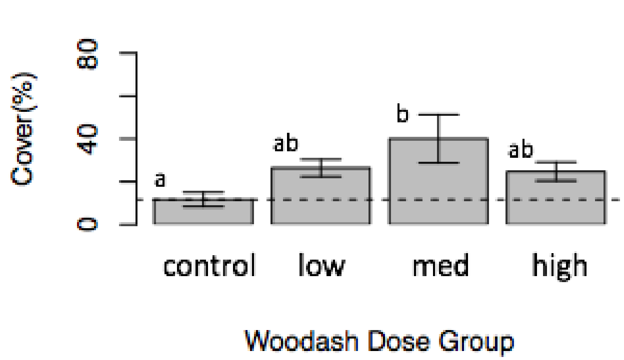
Delnite ***Musselwhite***

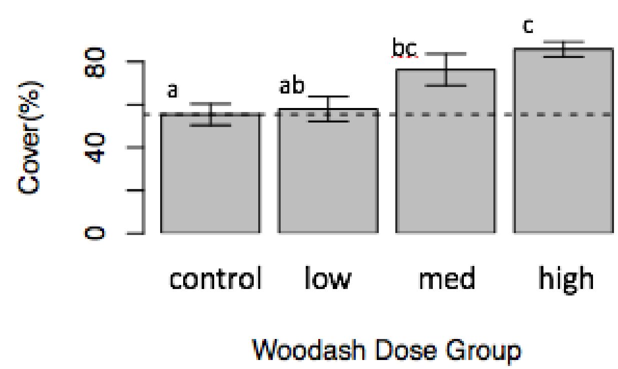
ONE GROWTH YEAR



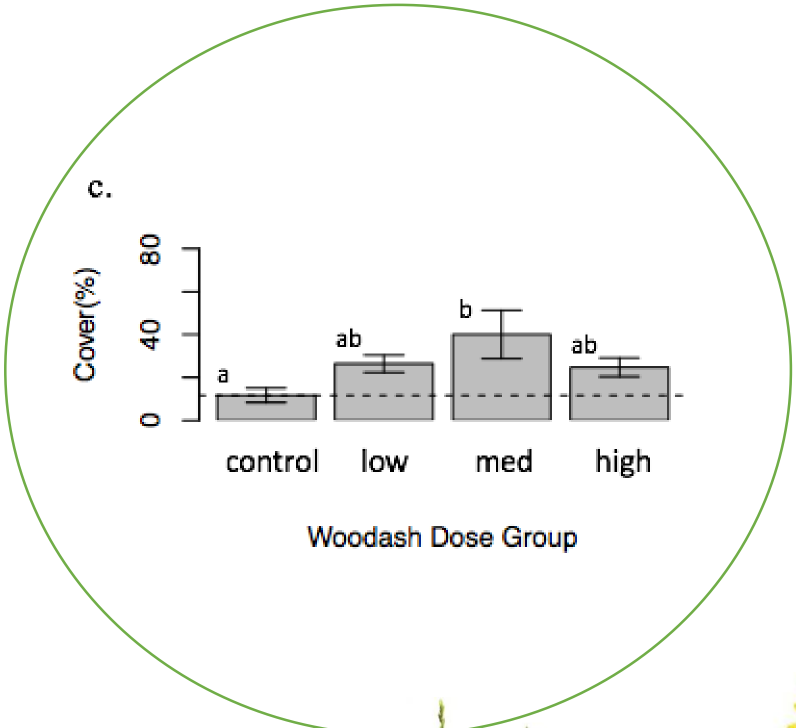


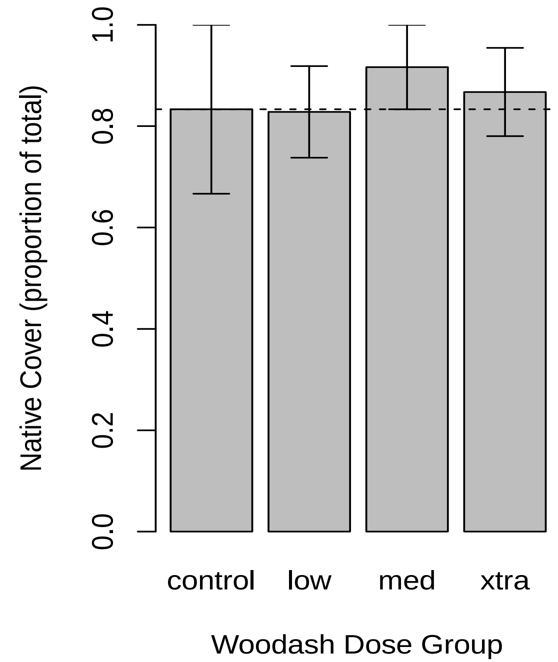
TWO GROWTH YEARS

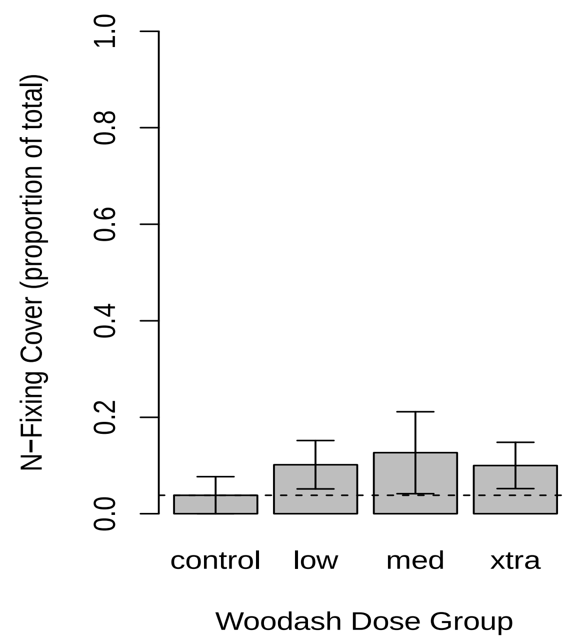




Community composition







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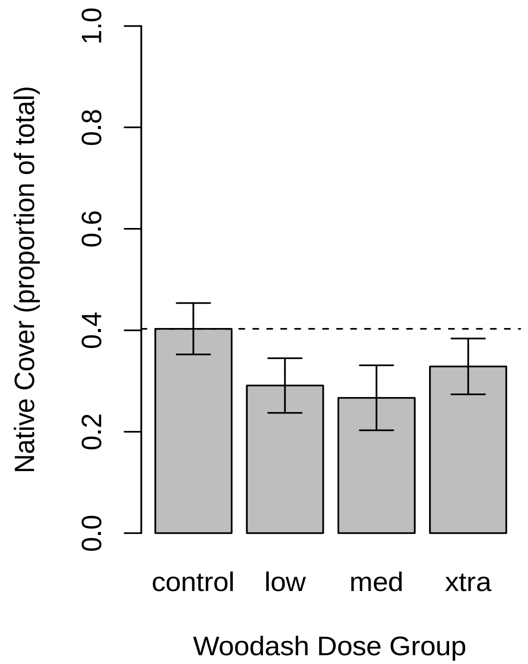

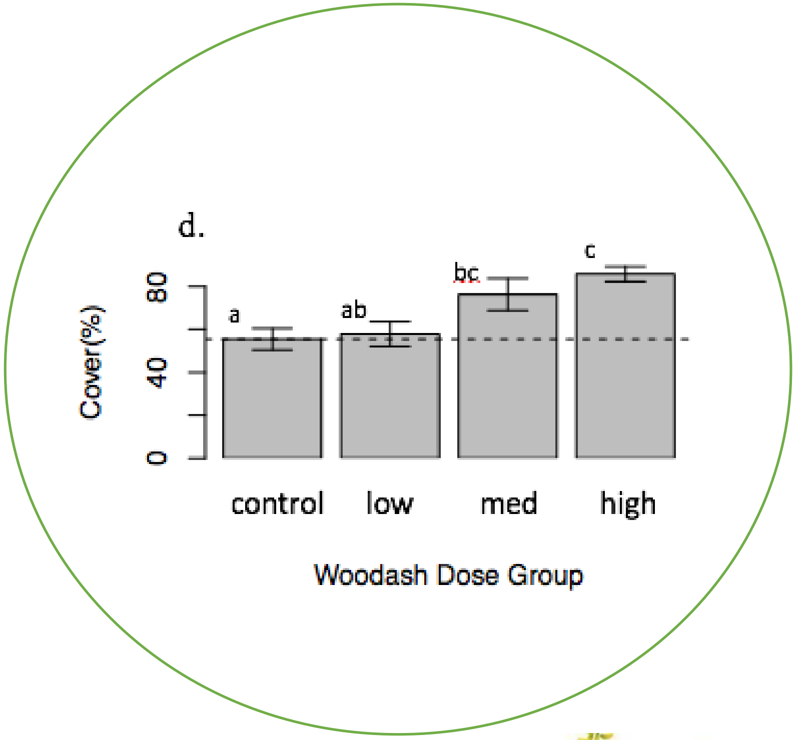

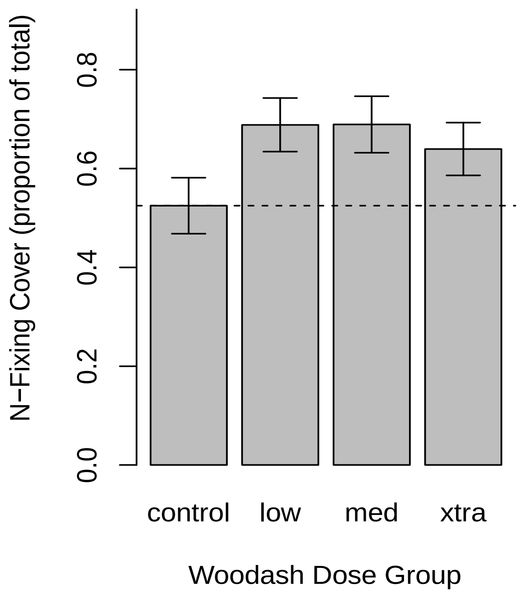

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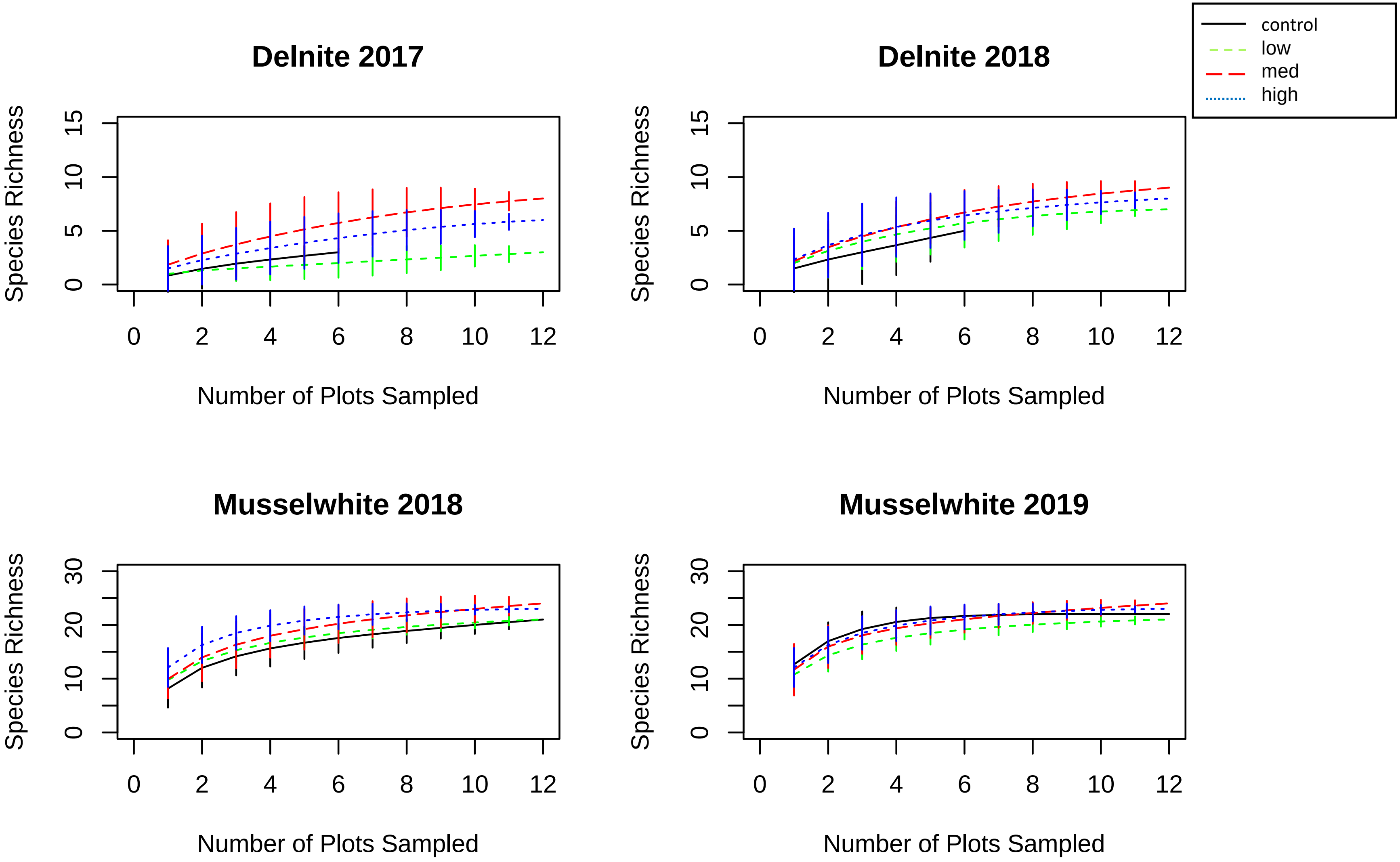

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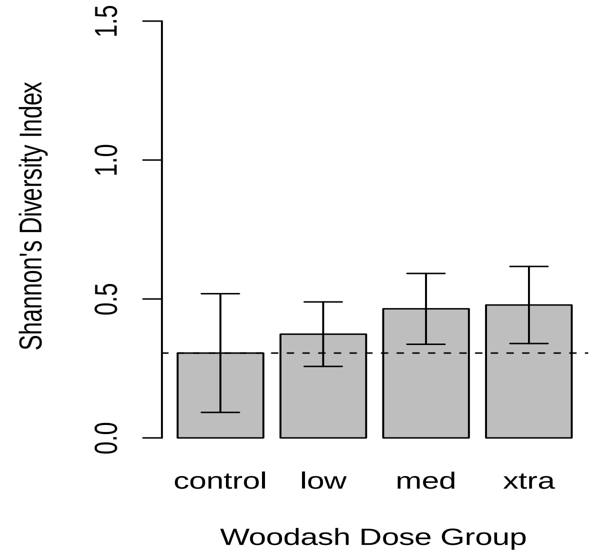
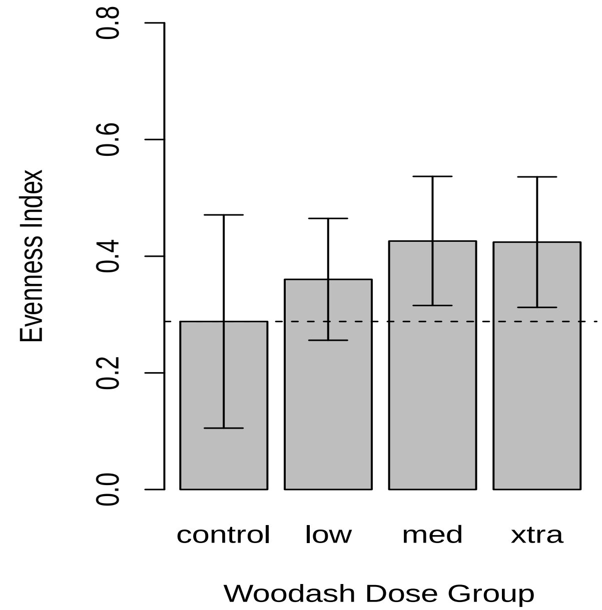
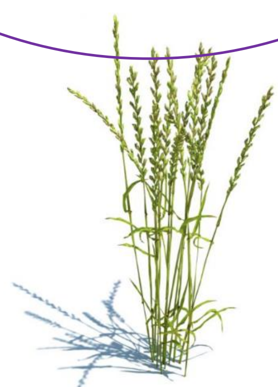
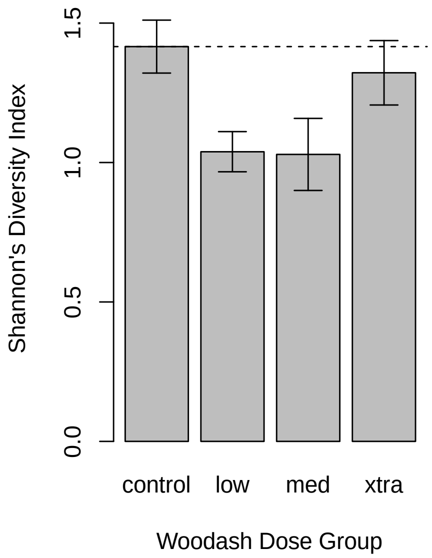
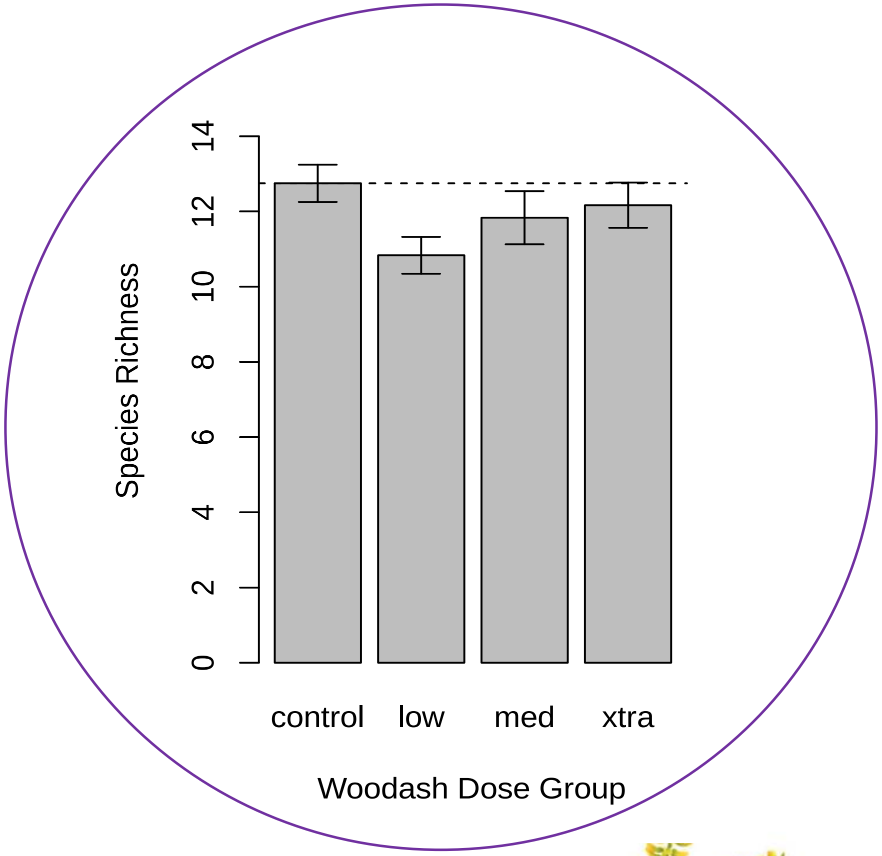


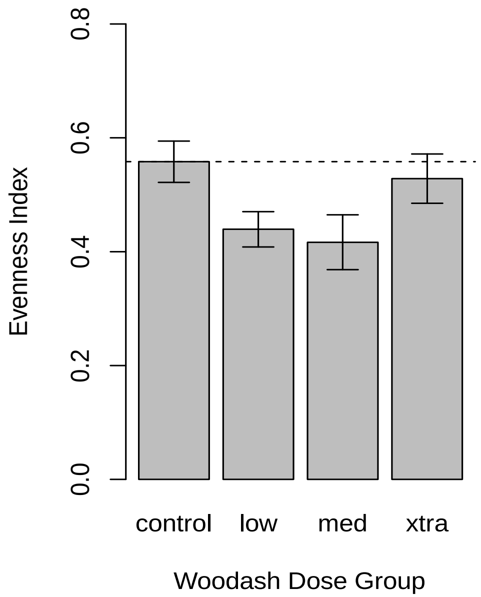






Species richness





Practical inferences: what did we learn ?

- Additions of high-carbon wood ash increased cover of “volunteer” vegetation growth on tailings sites at low to moderate dosages;
- Species richness was highest on tailings amended with moderate doses of high-carbon wood ash;
- High-carbon wood ash has high potential for large-scale use as a carbon-positive, cost-effective means to enhance both vegetation cover and species diversity on metal mine tailings;

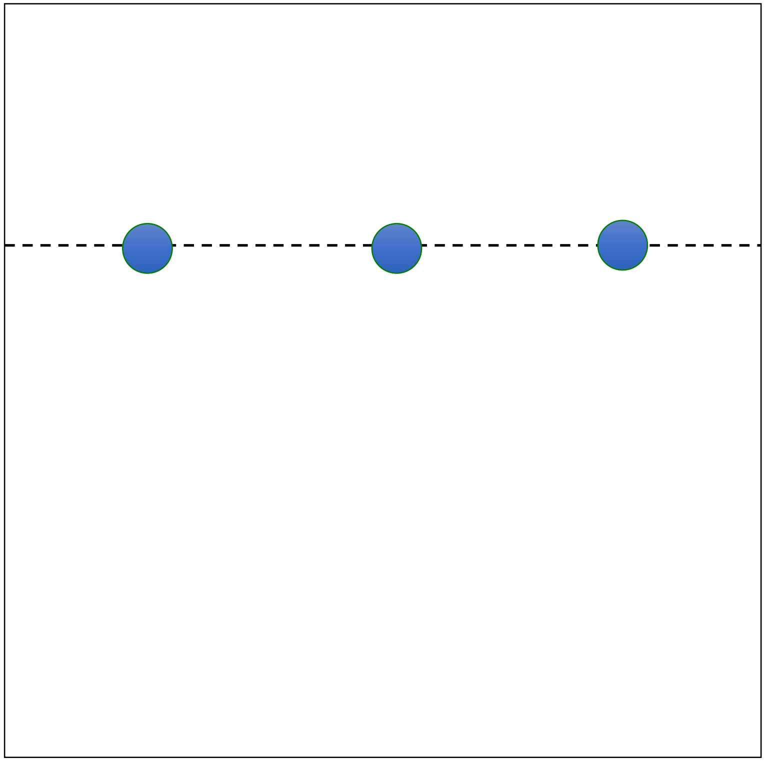
What comes next?

* site-specific vegetation dose response patterns;

* mixing biochar with “traditional” soil amendments.

Revegetation vs. Reforestation

Delnite site:
planting design within plots



● Jack pine (100 %)

- Equal spacing along horizontal axis
- 3 trees / plot x 7 plots X 10 blocks

210 trees

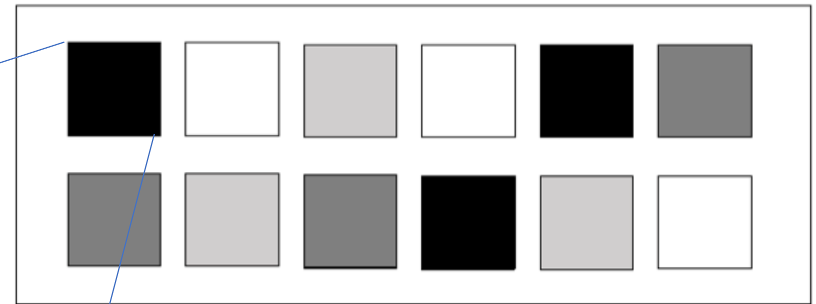
Delnite site: planting design within plots

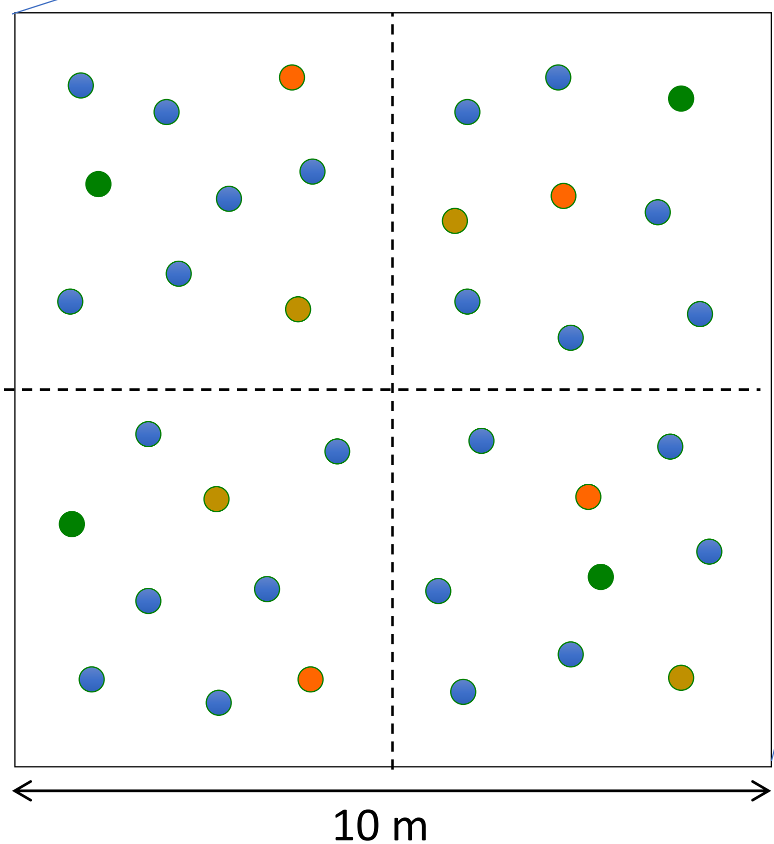
● Jack pine (100 %)

- Equal spacing along horizontal axis
- 3 trees / plot x 7 plots X 10 blocks

210 trees

Musselwhite: planting design





High-C wood ash dosages

- 0 t/ha (control)
- 6.4 t/ha
- 12.8 t/ha
- 19.1 t/ha

- Jack pine (67%)
- Trembling aspen (11%)
- Paper birch (11%)
- Bebb’s willow (11%)

- Irregular pattern, min. 1m. spacing
- 36 trees / plot x 12 plots = 432 trees

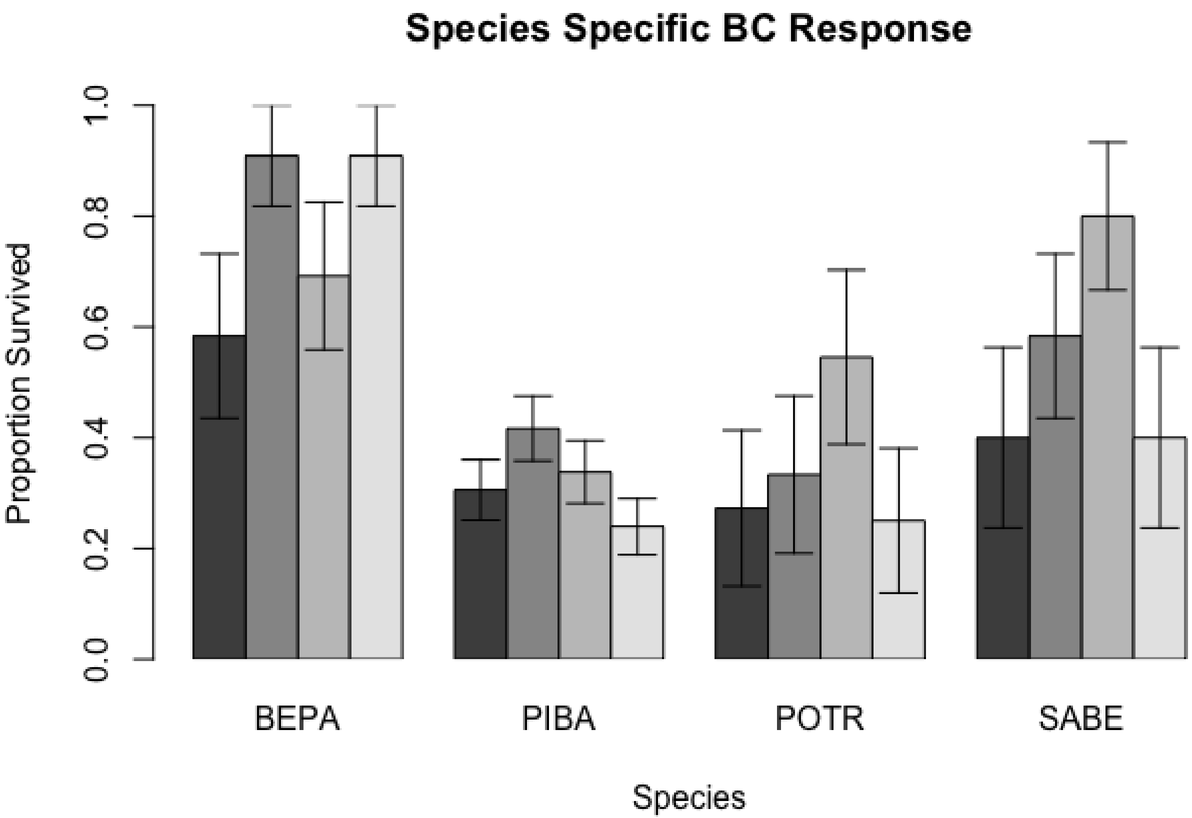
288 Jack pine, 48 other species

Species specific survival

Musselwhite site

$p_{species} = 10^{-8}$

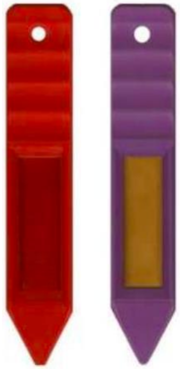
$p_{species \sim dose} = 0.05$

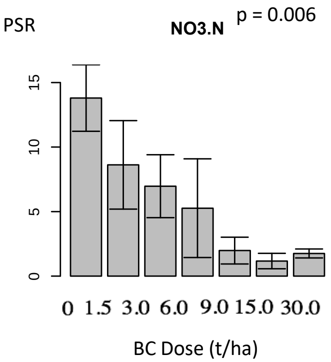


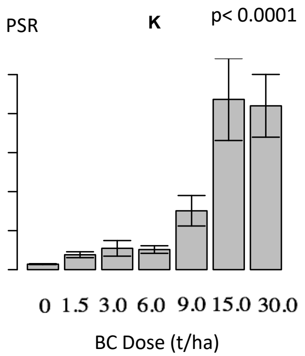
BEPA: *Betula Papyrifera*
PIBA: *Pinus banksiana*
POTR: *Populus tremuloides*
SABE: *Salix bebbiana*

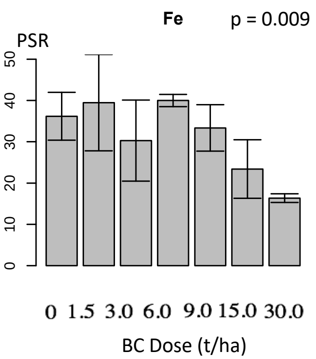
Tailings chemistry

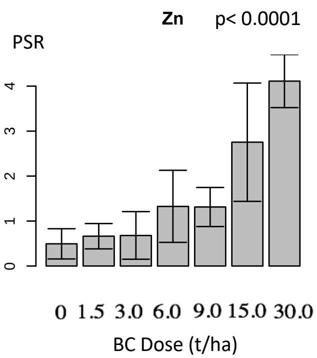
Delnite site

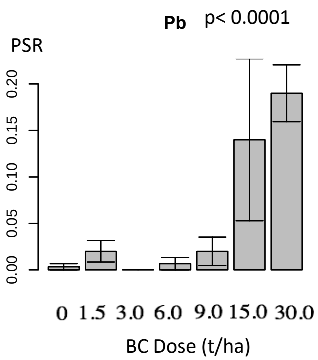


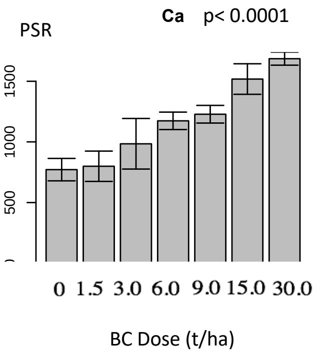


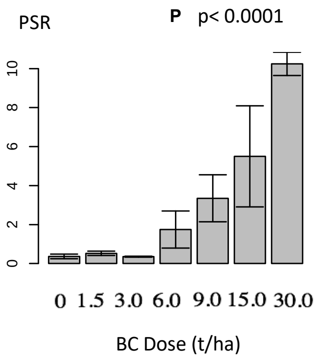


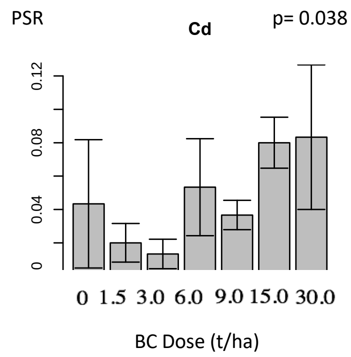












*Note: Probe Supply Rates (PSR) in micrograms/10cm²/burial length time

Industrial Partners:

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Newmont Porcupine:
Tyler Provencal and Amanda Piche

Research Contributors:

Professor Sean Thomas, Ph.D, University of Toronto