REPORT

DATA REPORT: EFFECT OF WOOD ASH ADDITIONS ON SOIL CARBON, SUGAR MAPLE TREE AND ROOT GROWTH, AND CARBON CAPTURE AT PRIVATE WOODLOT IN MUSKOKA ONE YEAR AFTER ASH ADDITION

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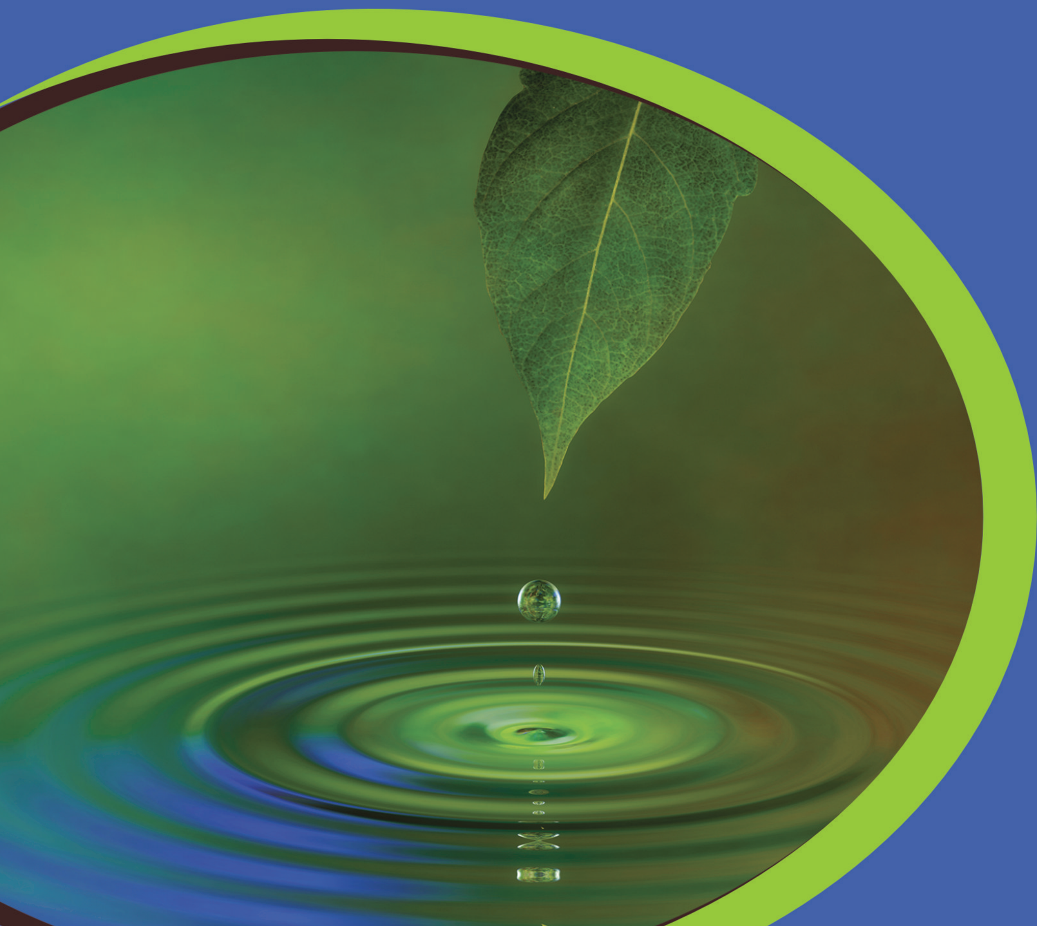

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Friends of the Muskoka Watershed

Data Report to the FOTMW from S. Watmough, Trent University

on MECP/FOTMW ASHMuskoka2 project C.3.3.c:

Study the effect of wood ash additions on soil carbon, sugar maple tree and root growth, and carbon capture

at private woodlot in Muskoka one (1) year after ash addition

Feb 14, 2023

Background

Research conducted over the last several years as part of the Trent University/Friends of the Muskoka Watershed ASHMuskoka project has made the following key advances in understanding:

- Soil quality for plant growth is improved by additions of residential wood ash, with dramatic reductions in acidity, and increases in base saturation and concentrations of key limiting nutrients especially Calcium (Ca)
- While ash additions do increase metal levels in the soil, there is little uptake of these metals by sugar maple, and essentially no increase in uptake for the most ecotoxic metals, including Cd, Pb and As.
- In contrast, concentrations of key plant nutrients, including calcium, potassium, magnesium, phosphorus and the micronutrient boron, increase substantially in mature and seedling sugar maple, improving foliar nutritional status.

Muskoka forest soils have been impoverished by decades of acid rain. In summary, the ASHMuskoka research indicates that additions of calcium-rich wood ash improves soil quality and the nutritional health of trees in these forests (Syeda and Conquer 2023)

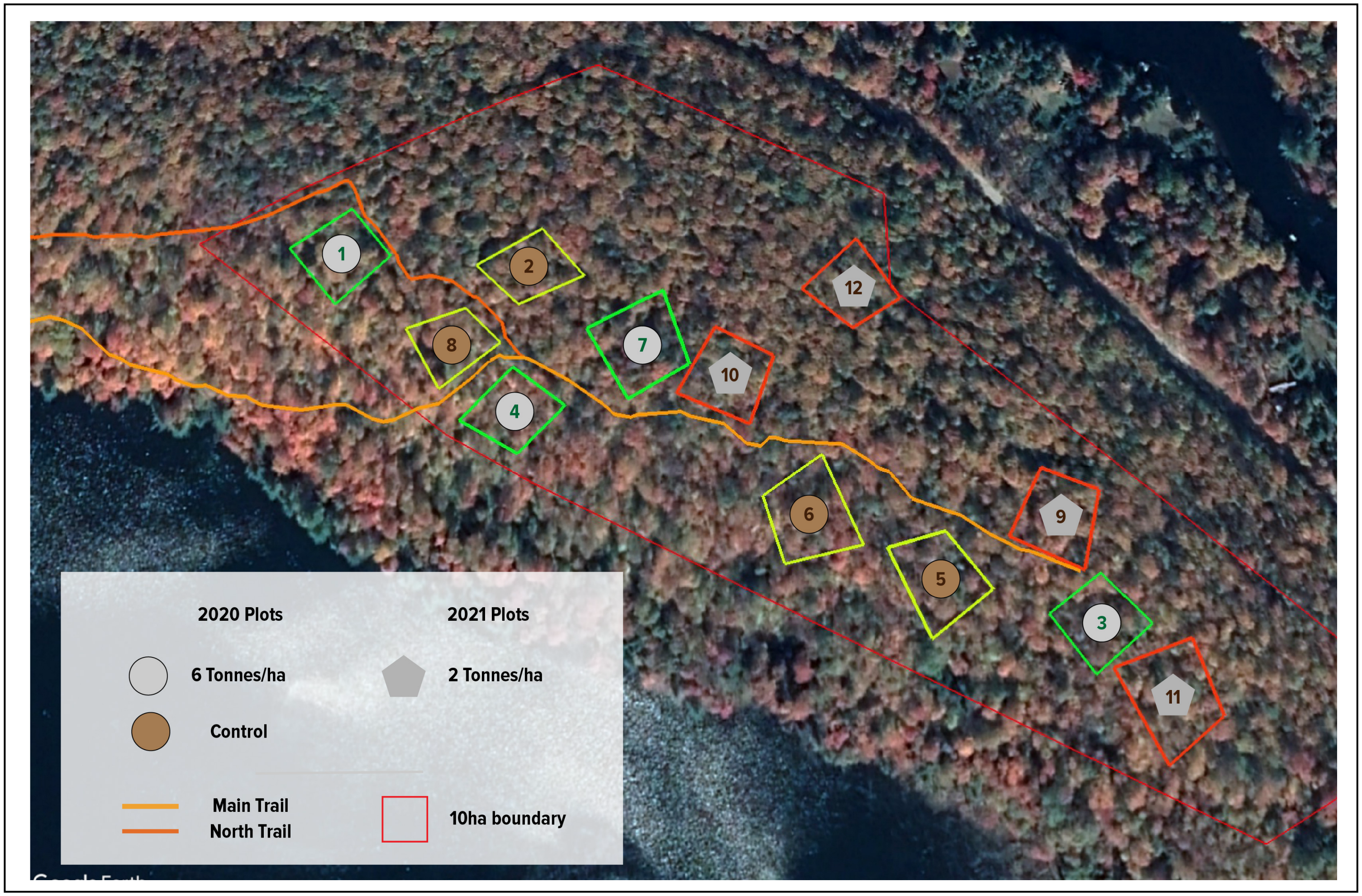
Research conducted in a sugar maple-dominated mixed hardwood stand at the Hubbard Brook Experiment Forest in New Hampshire suggest that this increased tree health should promote photosynthesis, thus increasing carbon capture rates (reviewed by Kim et al. 2022). In fact, Taylor et al. (2021) suggest that persistent increases in carbon capture in such forests may amount to one tonne of extra carbon captured annually following the restoration of pre-acid rain concentrations of calcium levels in soils. Project C.3.3c of the MECP Transfer Payment agreement to the FOTMW was initiated with two main purposes: i) to determine if a similar increase in Carbon capture would accompany additions of wood ash to a mixed hardwood forest in Muskoka, and ii) to determine the dose-response nature of this increase, to specifically determine the dose of added ash at which the increase in carbon capture would plateau. The objective of this data report is to briefly describe the methods employed to address these two objectives, and to summarize the data collected in the first year of the project.

Methods

The experiment addressing these 2 objectives was conducted in the mixed hardwood forest at Camp Big Canoe, located east of Bracebridge Ontario. The forest block where the experiment was launched lies within the red line boundary in Figure 1, the area that has received MECP approval for experimental additions of wood ash. Figure 1 illustrates the location and shape of 12 roughly 1600 m^2 plots that are the ongoing long-term study plots for the examination of the impacts of 2 and 6 tonne/ha additions of wood ash in comparison with control plots. That work is not the subject of this data report.

The objectives of this study were addressed using 40 mid-age mature maple trees that while not located within these 12 plots, are all located within the red contour boundary. They are approved for ash treatments, but have not received ash prior to this new experiment.

Figure 1: Image of experimental forest block (within the red contour) at camp Big Canoe, Muskoka, on.



To address the objectives, we needed to:

- Compare the effects on above and below ground tree biomass accrual using a number of replicated doses of wood ash. We selected 40 mature trees, that were randomly allocated into 5 treatments (control with no ash addition, 2, 4, 6 and 12 tonnes/ha of ash) each with 8 replicates, i.e. 8 trees. The FOTMW staff collected, screened and homogenized the needed ash, and moved the required doses to the relevant trees. The doses were calculated to be spread on an area centred on each tree with a radius of 3m. Ash was spread in Nov of 2021.

- To compare above ground stem wood accumulation rates, from which above ground C accumulation could be calculated, we installed a band dendrometer on each tree (Figure 2)

Figure 2: example of an installed band dendrometer

- To prepare to quantify the effects of ash addition on below ground C dynamics we need to quantify both root growth and soil C respiration rates. Hence, we installed root collars in the ash addition zone around each of the 40 trees. These will be analyzed for root biomass changes in the summer of 2023. We also collected soils for an ex-situ study on the effects of ash vs. dolomite additions on soil respiration and CO2 production. These latter experiments were conducted in a greenhouse at Trent University, independently of this study.
- Finally we collected the following data, the results of which are summarized in this report:
    - 80 foliar samples, i.e pre- and one year after ash application, for nutrient and metal analyses.
    - 200 soil samples (pre and one year post ash addition) for analyses of pH, loss-on-ignition, nutrients and metals
    - Tree growth measurements on the 40 trees prior to ash additions and multiple times during the summer of 2022.

Quantifying effects of ash additions on tree growth and carbon dynamics requires long-term study. The Hubbard Brook experience teaches us that benefits will accrue over several years. Hence, we do not report answers to our objectives in this data report. They would be preliminary and will almost certainly change over time. Hence, what we provide here is simply a data report on the first summer's results compared with pre-addition baselines. These results will serve for future comparisons but should not be considered definitive at this point. The work in the sugar bushes (Syeda and Conquer 2023) makes it clear that results from year 1 can change dramatically in subsequent years.

All data have been provided and verified by Dr. S. Watmough and his team at Trent University

References cited:

Kim, N., S.A. Watmough and N.D. Yan. 2022. Wood ash amendments as a potential solution to widespread calcium decline in eastern Canadian forests. Env. Rev. dx.doi.org/10.1139/er-2022-0017.

Syeda, B.S. and S. Conquer. 2023. Non-industrial lwood chemistry and its biogeochemical effects on sugar maple (Acer saccharum, Marsh.) in three central Ontario sugar bushes 2 years after treatment. Report to the Friends of the Muskoka Watershed, Env. And Life Sciences program, Trent University. 24 pp.

Taylor, L.L., C.T. Driscoll, PM. Groffman, G.H. Rau, J.D. Blum and D. J. Beerling. 2021. Increased carbon capture by a silicate-treated forested watershed affected by acid deposition. Biogeosciences 18: 169-188.

Table 1: Comparison of metal and nutrient concentrations in sugar maple foliage prior to and one year after ash additions in control (no ash) and 2,4,6 and 12 tonne/ha doses (n = 8, SE in parentheses).

	Control		2t		4t		6t		12t	
	Baseline	Post Application	Baseline	Post Application	Baseline	Post Application	Baseline	Post Application	Baseline	Post Application
Al (mg/kg)	37 (8)	17 (1)	53 (15)	22 (2)	32 (6)	23 (6)	48 (20)	18 (0)	32 (9)	20 (1)
B (mg/kg)	46 (3)	34 (5)	47 (4)	57 (4)	56 (7)	53 (3)	38 (6)	70 (0)	39 (1)	47 (5)
Fe (mg/kg)	85 (11)	56 (14)	70 (19)	51 (2)	56 (7)	53 (7)	80 (22)	56 (0)	54 (9)	53 (6)
Mn (mg/kg)	958 (170)	1047 (90)	1174 (103)	1111 (101	1610 (287)	1798 (336)	831 (168)	996 (0)	1075 (224)	1079 (240)
Zn (mg/kg)	33 (2)	29 (3)	33 (1)	28 (2)	35 (3)	35 (2)	40 (2)	40 (0)	28 (4)	24 (3)
Ca (mg/kg)	11775 (1249)	10036 (1755)	11606 (670)	12101 (899)	11429 (1195)	12299 (850)	14040 (1483)	11286 (0)	13258 (809)	13581 (990)
K (mg/kg)	9260 (549)	9408 (719)	9428 (560)	10970 (1143)	8762 (813)	9633 (387)	9796 (436)	12000 (0)	9637 (927)	11822 (555)
Mg (mg/kg)	1567 (50)	1497 (55)	1513 (88)	1397 (116)	1505 (124)	1456 (80)	1675 (86)	1428 (0)	1528 (106)	1273 (109)
Na (mg/kg)	234 (20)	151 (20)	141 (34)	122 (32)	130 (20)	51 (17)	147 (20)	175 (0)	204 (36)	95 (35)
P (mg/kg)	1200 (60)	1162 (78)	1233 (47)	1241 (94)	1260 (97)	1165 (63)	1176 (73)	1229 (0)	1229 (63)	1039 (54)

Table 2: Comparison of pH, Organic Matter (OM) and metals levels in the **litter** layer of soils at 5 doses of ash additions before and one year after treatment.

		pH	% OM	Al (mg/kg)	B (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
Litter											
Control	Baseline	4.8 (0.3)	89 (1)	307 (34)	18 (1.4)	0.7 (0.1)	13 (0.6)	503 (79)	1443 (136)	1.3 (0.1)	1.8 (0.4)
	Post Application	4.8 (0.4)	87 (4.1)	370 (88)	18 (0.9)	0.6 (0)	11 (1.1)	624 (223)	1250 (110)	0.7 (0.1)	2.3 (0.4)
2t	Baseline	4.8 (0.3)	89 (0.7)	315 (31)	20 (2.3)	0.7 (0)	13 (0.7)	468 (37)	1511 (115)	1.3 (0.1)	1.8 (0.1)
	Post Application	5.4 (0.6)	81 (8.08)	707 (181)	45 (6.1)	0.7 (0.1)	33 (8.5)	534 (86)	1868 (219)	1.6 (0.4)	1.8 (0.2)
4t	Baseline	4.9 (0.3)	90 (2.3)	282 (22)	15 (0.8)	0.8 (0.1)	12 (0.4)	461 (56)	1882 (197)	1.2 (0.1)	1.8 (0.3)
	Post Application	6 (0.3)	76 (4.8)	1140 (161)	46 (5.6)	1.0 (0.1)	53 (9.2)	1093 (204)	2482 (304)	2.4 (0.4)	3.8 (1.1)
6t	Baseline	4.8 (0.3)	87 (5)	277 (310)	15 (1.3)	0.8 (0.1)	13 (0.4)	1102 (660)	1829 (225)	1.5 (0.3)	2.8 (1.2)
	Post Application	6.1 (0.3)	76 (1)	738 (151)	49 (5.6)	0.9 (0.1)	65 (32)	755 (175)	2449 (282)	2.3 (0.5)	3.6 (0.4)
12t	Baseline	4.9 (0.3)	89 (0.9)	331 (20)	15 (0.9)	0.8 (0.1)	13 (0.4)	497 (45)	1691 (192)	1.3 (0.1)	1.9 (0.2)
	Post Application	6.2 (0.5)	68 (13.3)	1027 (201)	62 (7.8)	0.9 (0.1)	57 (11.1)	880 (172)	2732 (370)	2.9 (0.5)	6.5 (1.4)

Table 3: Comparison of pH, Organic Matter (OM) and metals levels in the **Fibrous Humic (FH) layer** of soils at 5 doses of ash additions before and one year after treatment.

		pH	% OM	Al (mg/kg)	B (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
FH												
Control	Baseline	4.4 (0.2)	53 (20.6)	3039 (641)	4.7 (1.7)	1.4 (0.5)	11 (2.9)	6501 (1334)	1381 (363)	5.9 (1.3)	34 (10.7)	66 (25.1)
	Post Application	4.4 (0.4)	58 (15.6)	2534 (579)	2.6 (0.7)	1.2 (0.2)	15 (0.8)	4920 (956)	2157 (388)	4.4 (0.6)	28 (5.2)	73 (6.2)
2t	Baseline	4.4 (0.3)	56 (13.8)	3150 (415)	2.7 (1.2)	1.1 (0.2)	11 (2)	6819 (863)	1182 (274)	6.1 (1.3)	26 (4.1)	64 (13.6)
	Post Application	5.2 (0.6)	58 (20.0)	2227 (461)	19.6 (5.2)	0.9 (0.1)	20 (2.8)	4441 (950)	1840 (185)	3.8 (0.3)	18 (3.3)	86 (10.3)
4t	Baseline	4.4 (0.2)	60 (12.8)	2904 (553)	5.7 (1.7)	0.9 (0.1)	11 (2)	5807 (1257)	1247 (286)	5.3 (0.8)	23 (5.3)	54 (13.8)
	Post Application	5.4 (0.8)	61 (13.5)	2382 (305)	29.9 (10.3)	1.4 (0.2)	47 (12.4)	3697 (751)	2698 (296)	5.2 (0.6)	21 (5.1)	133 (18.4)
6t	Baseline	4.2 (0.1)	58 (17)	3217 (745)	3.1 (1.2)	1.0 (0.2)	11 (1.7)	6598 (1759)	859 (277)	5.7 (0.7)	29 (5.3)	52 (10.8)
	Post Application	6 (0.5)	67 (8.7)	1652 (171)	37.6 (6.2)	1.0 (0.1)	55 (20.3)	2522 (296)	2587 (424)	3.7 (0.4)	16 (2.9)	130 (21.3)
12t	Baseline	4.3 (0.2)	54 (14.1)	2798 (503)	4.6 (1.4)	0.2 (0.1)	10 (1.8)	6088 (1064)	1295 (357)	5.6 (0.8)	30 (6.2)	47 (8.8)
	Post Application	6.6 (0.6)	44 (12.9)	2631 (334)	67.9 (15.9)	1.5 (0.3)	113 (50.4)	3676 (586)	3257 (463)	5.9 (0.6)	22 (4.7)	222 (54.7)

Table 4: Comparison of pH, Organic Matter (OM) and metals levels in **<u>Mineral layer</u>** of soils at 5 doses of ash additions before and one year after treatment.

		pH	% OM	Al (mg/kg)	B (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg
Mineral											
Control	Baseline	3.9 (0.4)	9 (2.3)	7926 (1328)	0.5 (0.4)	8.6 (1.4)	12984 (1472)	576 (161)	4.1 (0.8)	7.3 (1.8)	40 (5.7)
	Post Application	3.9 (0.2)	8 (1.2)	7549 (1391)	1.2 (0.6)	7.0 (1.3)	12293 (798)	613 (311)	3.9 (0.9)	6.1 (1.6)	31 (4.7)
2t	Baseline	4 (0.2)	10 (1.9)	6479 (1287)	1.7 (1.2)	5.9 (1)	13343 (2800)	297 (77)	4.3 (0.8)	4.7 (1.1)	37 (8)
	Post Application	4.1 (0.2)	10 (3.3)	8068 (940)	0.0	7.3 (0.9)	12848 (599)	451 (146)	3.8 (0.5)	11.7 (2.6)	34 (5.1)
4t	Baseline	3.8 (0.2)	9 (2.3)	7631 (997)	0.0	8.0 (1.4)	14374 (1142)	792 (293)	4.2 (0.8)	5.1 (1.2)	33 (3.8)
	Post Application	3.9 (0.3)	8 (1.9)	8076 (1234)	0.5 (0.3)	4.7 (1.9)	5544 (1375)	816 (230)	3 (0.9)	12.6 (6)	21 (3.5)
6t	Baseline	4 (0.2)	9 (2.1)	8005 (974)	1.1 (1.1)	7 (0.7)	13487 (1212)	208 (60)	3.2 (0.5)	5.5 (2.2)	28 (4.2)
	Post Application	4.1 (0.4)	8 (3.3)	5819 (414)	1.3 (0.7)	6.1 (0.6)	13155 (747)	402 (92)	3.1 (0.3)	12.4 (1.8)	32 (3.3)
12t	Baseline	3.8 (0.2)	9 (1.4)	6233 (1028)	0.1 (0.1)	6.2 (1)	14423 (1563)	783 (355)	4.5 (1.2)	12.8 (2.9)	37 (6.3)
	Post Application	4.5 (0.9)	8 (1.8)	5971 (759)	0.1 (0.1)	6.3 (1)	12476 (1147)	914 (400)	4.2 (0.7)	10.5 (1.6)	35 (6.3)

Table 5: Comparison of base cation levels (Ca, K, Mg, Na) in litter, FH and mineral layers of soils around the 40 trees at 5 doses of ash, one year after ash additions.

	Ca (mg/g)	K (mg/g)	Mg (mg/g)	Na (mg/g)
Litter				
Control	11 (4.7)	1.3 (0.4)	1.1 (0.7)	0 (0)
2t	16 (4)	1.7 (0.3)	1.9 (0.7)	0.1 (0)
4t	17 (7.3)	1.6 (0.7)	2 (1.1)	0.1 (0)
6t	17 (2.2)	1.6 (0.3)	2.2 (0.6)	0.1 (0)
12t	17 (6.1)	1.5 (0.4)	2.1 (1.4)	0.1 (0.1)
FH				
Control	9 (1)	0.8 (0.1)	0.7 (0)	0.1 (0)
2t	13 (1.2)	1.0 (0.1)	1.7 (0.3)	0.1 (0)
4t	14 (1)	1.2 (0.1)	2.1 (0.4)	0.1 (0)
6t	15 (1)	1.3 (0.1)	2.7 (0.2)	0.1 (0)
12t	14 (1)	1.1 (0.2)	2.6 (0.3)	0.1 (0)
Mineral				
Control	0.2 (0)	0.4 (0.1)	0 (0)	0.1 (0)
2t	0.4 (0.1)	0.2 (0.1)	0 (0)	0 (0)
4t	0.3 (0.1)	0.2 (0.2)	0 (0)	0 (0)
6t	0.6 (0.2)	0.2 (0.1)	0.1 (0)	0 (0)
12t	0.5 (0.1)	0.4 (0.1)	0.2 (0.1)	0 (0)

Figure 3: Tree growth (i.e. basal area increment in cm) of 40 mature sugar maple trees using band dendrometers prior to (October) and in the year after ash additions at Camp Big Canoe

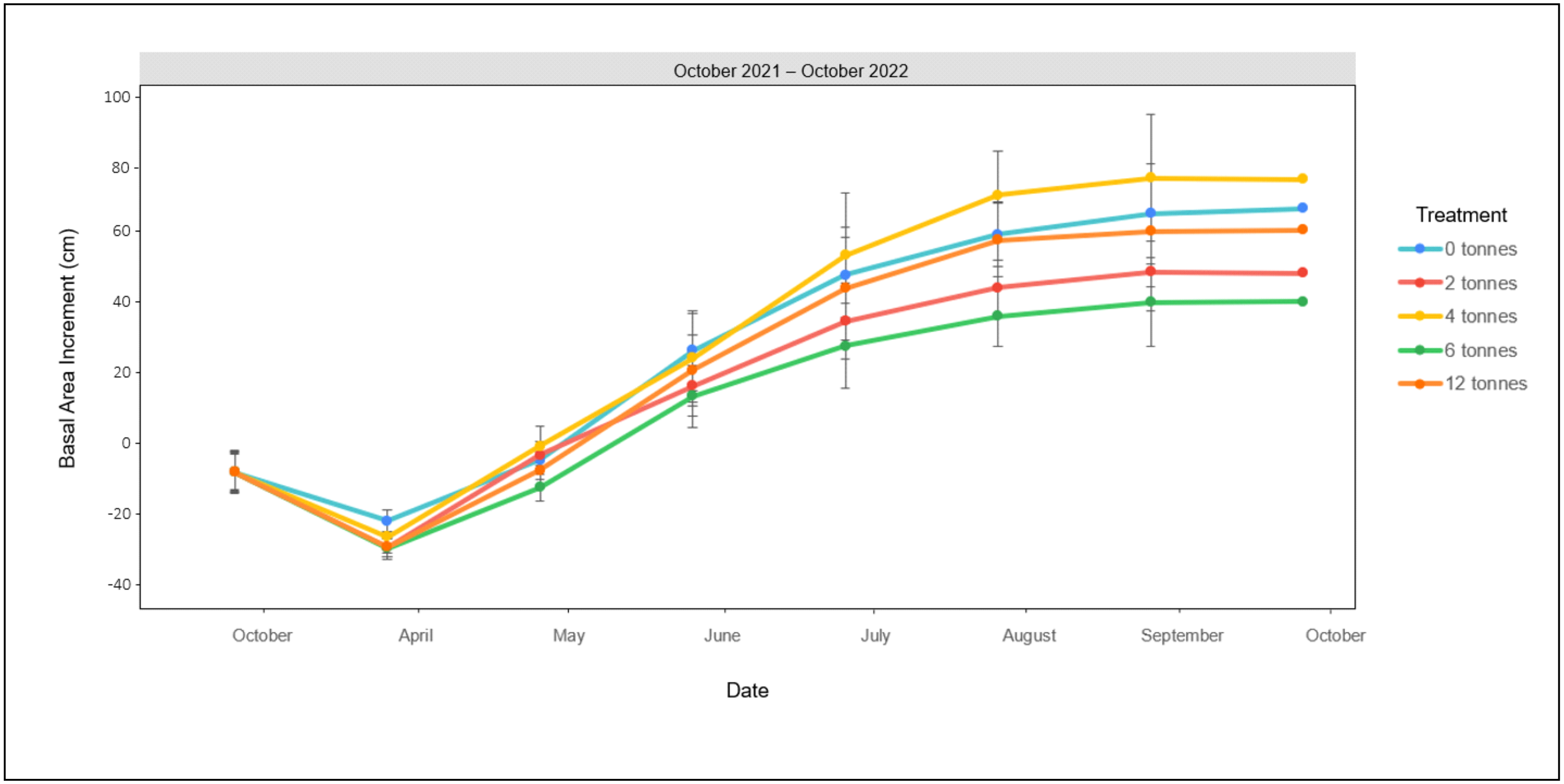


Figure 4: Preliminary results from the soil respiration trial, comparing soil CO2 production rates from soils with ash and dolomite treatments.