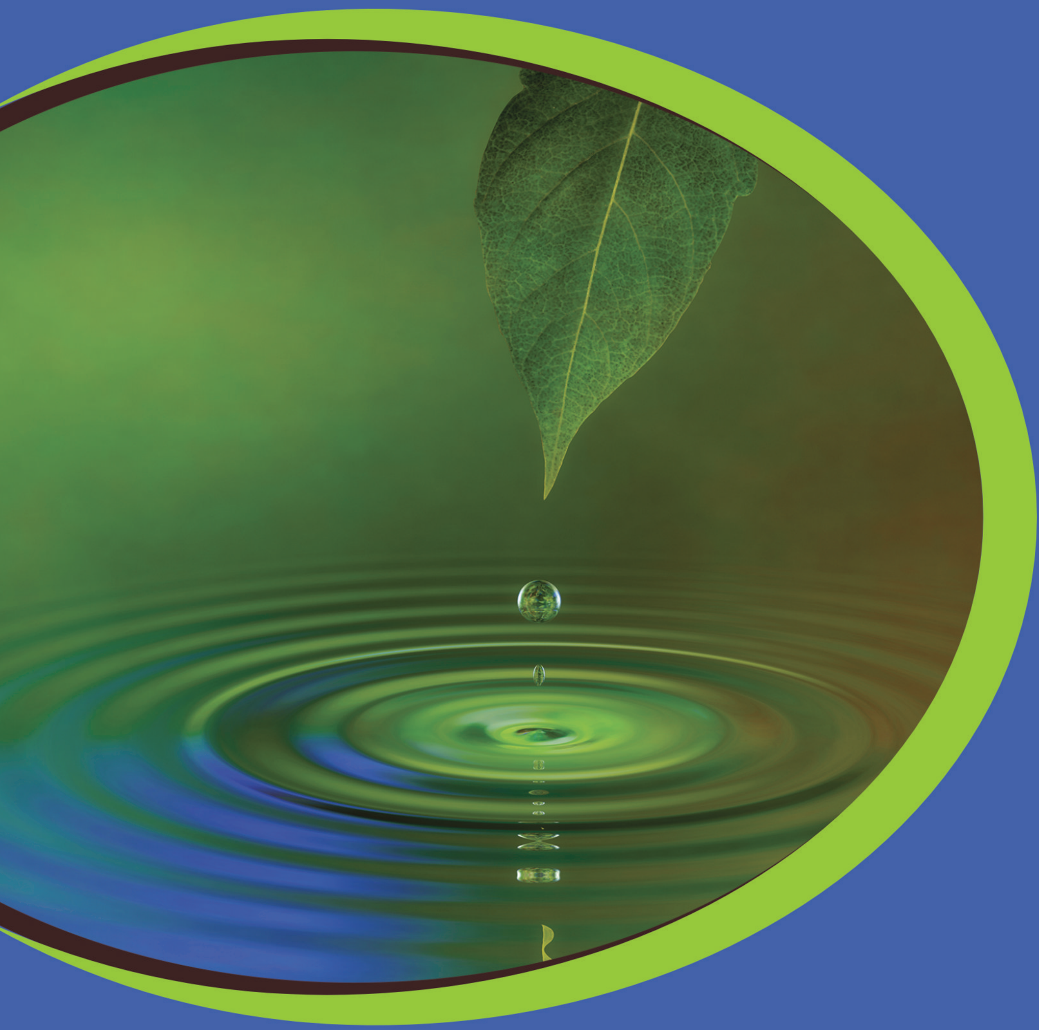
REPORT

CITIZEN SCIENCE: SUPPORTING ECOLOGICAL RESTORATION IN MUSKOKA'S FORESTS WITH WOOD ASH

A Report of Year One

FMW2023-02BR



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Friends of the Muskoka Watershed

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A report of year one

K. Paroschy and S. Sinclair, for Friends of the Muskoka Watershed, February 2023

Report # FMW2023-02BR

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Contents

Executive Summary

Friends of the Muskoka Watershed (FOTMW) has been working with community and academic partners since 2013 on developing a scientific understanding of the benefits and potential risks of residential wood ash to calcium depleted watersheds in and around Muskoka. Research results from Muskoka and around the world suggest that wood ash has the potential to reverse ecological damage from decades of acid rain. The scientific studies in Muskoka to date have mainly focused on the benefits of adding residential wood ash to sugar maple trees (*Acer saccharum*). Sugar maples have a relatively high demand for calcium and are an important part of the Canadian culture and economy via the maple syrup industry. Few studies have been done in Muskoka on the benefits of residential wood ash on native tree species outside of sugar maple stands.

To advance research and increase public awareness of the calcium decline issue while involving community members in the solution, the FOTMW Citizen Science program was launched. This was made possible through generous funding provided by the Ministry of Environment, Conservation and Parks (MECP).

Staff and board members began designing the Citizen Science program in January 2022 and launched in April 2022. The program design requires the involvement of private property owners who have safe access to at least two trees of the same species, similar size, and in similar growing conditions. The objective of the program is to compare metrics (measurements and observations) of a test tree (ash is applied) and a control tree (no ash application) over a period of at least one year.

Citizen scientists are provided with a training video, an instructional kit, personal protective equipment, sampling equipment, as well as filtered, homogenized residential wood ash. The wood ash was donated by Muskoka residents through the AshMuskoka program. Samples of the ash were tested for nutrients and heavy metals before distribution.

At the time of printing this report, the program is two-thirds done with two rounds of data collection complete, and at least one remaining. The metrics include tree height, diameter, percent canopy cover and observations of general tree appearance and health. Approximately 50 citizen scientists have also collected soil samples from the test tree before and after the ash was applied, as well as from the control tree. Foliage was collected during round two from both trees.

Citizen scientists reviewed the training material, collected the data and samples, and submitted them to FOTMW staff via a webform, email or in person. The soil and foliage samples were sent to Trent University's School of the Environment for analysis. All data was compiled and analyzed by FOTMW staff. Additionally, a quality control study was carried out by a Trent University student, with logistical support from FOTMW. This study ran parallel to the second round of data collection and followed the same procedure of the Citizen Science program, except forestry equipment was used to collect field data. In association with quantitative data collection,

qualitative data was also gathered from the participating citizen scientists through a phone survey.

Despite the option to select any native tree species, except American beech (*Fagus grandifolia*), sugar maple was the most chosen species in the Citizen Science program. Most trees were identified correctly. After the ash was applied, soil analysis showed that the pH of the soil became slightly more alkaline, which was supported by the quality control assessment. This increase in soil pH appeared to decrease the sodium concentration in the soil and slightly increase the calcium, potassium and magnesium concentrations. There were no significant changes in the concentrations of foliage metals or nutrients during the round two analysis.

Average tree height and diameter increased between the data collection rounds for both the test and control trees, and round two data was consistent with that of the quality control assessment. This consistency suggests that with sufficient training, inexperienced keen citizen scientists are able to effectively collect valuable information without the need for expensive equipment.

As the end users of the data, FOTMW recognizes how essential citizen scientists are to operating this program. The hope is that the relationship is mutually beneficial and citizen scientists develop new skills, find enjoyment, and have interest in contributing to a large-scale environmental solution and research initiative. Furthermore, through this research and other on-going environmental monitoring FOTMW hopes to reach the wider scientific community, local and provincial decision makers, as well as the public about the calcium decline problem and the solution of residential wood ash for ecological restoration.

1.0 Introduction

1.1 About Friends of the Muskoka Watershed

The Friends of the Muskoka Watershed (FOTMW) is a charitable not-for-profit organization with the vision of "*protection of Muskoka's freshwater ecosystems forever.*" The mandate has been to pair action-based approaches with innovative solutions grounded with the credibility of science. The FOTMW focuses on environmental issues that are widespread and not effectively being addressed by other organizations or governments.

With the mission to *"to protect freshwater watersheds using programs that: restore, preserve and defend them, improve management to adapt to major stressors, increase public understanding of their importance, and advance education through research and communicating results"* several programs have evolved over time in the organization. In 2022, FOTWM's main focus included three programs: 1) the environmental impacts of road salt, 2) the AshMuskoka program addressing the legacy of acid rain - calcium decline, in Muskoka watershed, and 3) the Citizen Science program – an extension of AshMuskoka to enhance our understanding of the benefits of residential wood ash and to better involve full-time and seasonal residents in the protection of the watershed.

This report is about the Citizen Science program.

1.2 Calcium depletion in Muskoka forest soils and watersheds

Environmental analyses have identified that a lasting negative outcome of acid rain has been the depletion of the mineral calcium from forest soils and lake water throughout Muskoka. Calcium (Ca) is essential for all life. Trees are about 1% Ca; fish, 2% to 8% Ca; and clams and crayfish over 20% Ca. The growth and health of sugar maple, for example, is now limited by Ca supply, and Ca levels in many Muskoka lakes have fallen by 25% to 40% over the last four decades. By analogy to osteoporosis in people, scientists call this problem "ecological osteoporosis." The problem is so severe that calcium-rich plants and animals are suffering and, in some cases, have disappeared (Azan, 2017).

FOTMW identified this issue and set out to find strategies to replenish calcium in our Muskoka watershed through the AshMuskoka program. An abundant and readily available source of Ca is needed to fix this environmental concern. Residential wood ash can help fill this need.

Residential wood ash is not only rich in calcium, but contains several other essential nutrients like potassium, magnesium, and phosphorus. Azan et al. (2019) summarized the nutrients in residential wood ash donated by members of the Muskoka community (**Table 1**).

Table 1: Average elemental composition of residential wood ash (%) from ten residential sources in Muskoka (adapted from Azan et al. 2019).

Element	Average (%) (n=10)
Major Nutrients	
Calcium	29.6
Potassium	7.9
Magnesium	1.7
Phosphorus	0.7
Sodium	0.1
Aluminium	0.2
Other Nutrients	
Boron	0.03
Iron	0.1
Manganese	0.9
Sulphur	0.4

The AshMuskoka program was initially called Hauling Ash to Solve Ecological Osteoporosis (HATSEO), and it sought a greater understanding of the dwindling calcium levels in Muskoka's lakes and soils. Through applied research, HATSEO explored, created, tested and refined an optimal way to collect, store and distribute residential wood ash. HATSEO successfully demonstrated that wood ash recovered from wood stoves in Muskoka is both chemically safe and biologically appropriate for use in replenishing calcium levels within the local watershed. Ultimately, this program became known as ASHMuskoka.

ASHMuskoka is a unique collaboration between scientists, municipal officials, and property owners, including citizen scientists, ash donors, and maple syrup producers. Since starting this program, FOTMW along with Trent University staff and students, community and government partners, as well as hundreds of volunteers have collected and spread over 9.2 Tonnes of wood ash in forest research plots (**Image 1**). The initial results of applying clean residential wood ash to forests appears to have "woken up" the trees. The nutrients in the residential wood ash restore soil and groundwater to their pre-acid rain levels. Furthermore, these results suggest that regulated ash application may assist with carbon capture in the trees and aquatic ecosystems, assisting in the fight against climate change, and potentially help with flood mitigation, though further research is needed (Kim, 2022)

Until now, FOTMW research has focused on three sugar bushes and one camp property, with the bulk of the research being on sugar maple (*Acer saccharum*) trees. The benefits of residential wood ash are not as well-known on different forests and tree species in Muskoka. To enhance this understanding and to meet the FOTMW objectives of engaging the public and scaling up the residential wood ash recycling program the Citizen Science program was created. The belief is that the Citizen Science program will not only be engaging, but potentially contribute to our scientific comprehension of the benefits of residential wood ash on Muskoka trees.

Image 1: Spreading ash with volunteers from Rosseau Lake College at Camp Big Canoe, Bracebridge, Ontario.

1.3 What is Citizen Science?

Citizen science is broadly defined as "the involvement of nonprofessional and amateur scientists - the average citizen - in scientific research efforts" (Dickinson et al. 2012). A citizen scientist can be paid interns, temporary workers or unpaid volunteers, and their efforts can augment data collection efforts undertaken by trained researchers, and thus expand the production of knowledge (Miller-Rushing 2012).

There are three types of citizen science efforts described in literature; each is based on the level of public participation during the research process (**Table 2**). FOTMW citizen scientists fall into the *contributory* type of participant, meaning that they collected data.

Table 2: Various ways citizen scientists contribute to science (Adapted from Miller-Rushing et al. 2012).

Participation Type	Outcome
Contributory	Public contributes to data collection efforts only
Collaborative	Involving the public in data collection and some parts of data analysis and results reporting
Co-created	Public involved in all or most parts of the research process, from generating research questions to analyzing and reporting results

2.0 Citizen Science at Friends of the Muskoka Watershed

The Citizen Science program (**Figure 1**) is an extension of the AshMuskoka program and has the primary objective to enhance understanding of the benefits of residential wood ash in various forest types and tree species throughout Muskoka and beyond.

Figure 1: Logo used for the Citizen Science program.

FOTMW chose to engage with citizen scientists as a logical next step of moving the organization's mission forward. Upon the onset of the program, the high-level goals of the citizen science program included discovery of knowledge in a democratic way to educate the public and scientists and FOTMW though engagement, then mobilize society to act using that knowledge.

The first goal of the Citizen Science program is to generate new knowledge through the help of citizen scientists about the benefits of wood ash to address calcium limitation to forest health and foster a nature-based solution to greenhouse gas emissions. This is to be done by testing ash benefits on most native tree species in various soil conditions and different environments.

The second goal is to democratize the research of using residential wood ash as a forest fertilizer by involving the public in the design of the program and collecting their feedback during and after. The participants were provided with data updates during and after the two data collection rounds, as well as the results specific to the trees on their property. Citizen scientists are also recognized as significant contributors to this report, and to any documents that result from the data collected.

The third goal is to educate all involved in the program including FOTMW, the relevant scientific community, the public and governing bodies. The aim is to continue spreading awareness about calcium decline and the known benefits of residential wood ash, the potential of it to be a nature-based solution to climate change, as well to inform and involve community members in scientific data collection.

Along with education, the citizen science program aims to build engagement and increase the *army of advocates* by building social networks, increasing FOTMW membership and generating more will for subsequent positive environmental action. The idea is to form a direct connection between community members and their local watershed thereby creating a lasting appreciation and upholding personal values relating to the natural environment while contributing to the science community. Through all of this, the Citizen Science program hopes to inform policy making.

The Citizen Science program asks participants to collect scientific data on trees on their property and share the data with FOTMW, and by extension, the greater scientific community. The primary objective of the program is for citizen scientists to spread ash at the base of one tree and not spread ash on a second tree of the same species and determine if the ash has an impact. For example, a participant may select two Eastern white pine (*Pinus strobus*) trees on their property, following the instructions they collect data on both trees. Ash is then applied to the soil at the base of one tree, and data collection is repeated months later. This study allows for data collection and remediation of calcium-depleted soils at the site level (i.e., the citizen scientist's property), as well as at the watershed level (i.e., accumulation of data from all participating properties).

3.0 Citizen Science Program Methods and Procedures

3.1 Location

Calcium decline is a widespread concern throughout much of the Canadian shield, including Muskoka, that experienced acid rain during the 1980s and 1990s. FOTMW operates throughout Muskoka, as well as in the Parry Sound and Haliburton area. The outreach campaign focuses on the Muskoka area, and slightly beyond (**Figure 2**).

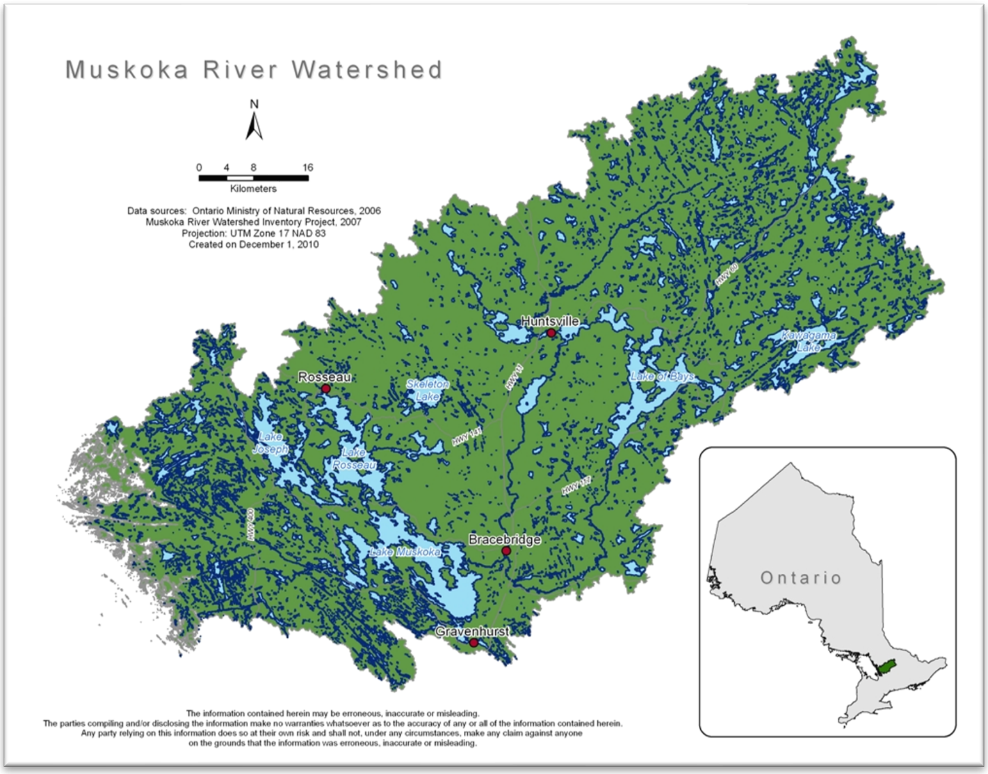

Figure 2: Map of the Muskoka River Watershed which is the focus area of the FOTMW citizen science study. The program extends into Simcoe, Parry Sound and Haliburton areas.

3.2 Ash Collection

As a part of the AshMuskoka program, residential wood ash is collected during the winter months at the Rosewarne transfer station in Bracebridge ON. Thousands of donations by fulltime and seasonal Muskoka residents of wood ash have been received (**Image 2)**. A full description of AshMuskoka and ash collection is available in *Residential Wood Ash Recycling and Forest Soil Amendment: An Operations Guide* by FOTMW.

Image 2: Volunteers and staff at an ash drive at the Rosewarne Transfer Station in Bracebridge.

3.3 The Ash

A portion of donated filtered ash from the AshMuskoka program was homogenized, and samples were analyzed by Trent University's School of the Environment laboratory for the Citizen Science program. Donated ash samples have been continually sampled during the AshMuskoka program and the metal concentrations are summarized in **Table 3**. Analysis is completed to ensure compliance with Ontario regulations.

One hundred and twenty-three recycled large ice-cream containers were filled with mixed and analyzed ash (**Image 3**) for the citizen scientists. These containers which hold approximately 6 kg of ash were labeled and stored separately from other ash used for the AshMuskoka program. Six kilograms of ash spread over 28 m^2, is approximately equivalent to 2 Tonnes/ha.

Table 3: Ontario government standards for unrestricted (CM1) and restricted (CM2) use of wood ash as a non-agricultural source material (Hannam et al. 2016), compared with average metal concentrations of 10 hardwood residential wood ash samples (2019), composite donated ash samples from 100s of Muskoka residents (2020), mixed ash donated from 100s of Muskoka residents (2022) and unamalgamated samples (n=107) and amalgamated samples (n=10) also in 2022. Blue bold numbers indicate metal concentrations that fell above CM1 but below CM2 targets. No concentrations fell above or close to CM2 concentrations.

Element	ON CM1 (mg/kg)	ON CM2 (mg/kg)	Azan et al. 2019 Observed X (n=10) (mg/kg)	Composite Sample 2020 SGS (mg/kg)	Ash sample 1 2022 Trent (mg/kg)	Ash sample 2 2022 Trent (mg/kg)	Ash sample 3 2022 Trent (mg/kg)	Syeda., 2022 Unamalgamated Ash Observed X(n=107)(mg/kg)	Syeda, 2022 Amalgamated Ash Observed X (n=10) (mg/kg)
Arsenic (As)	13	170	0.61	**14**	5.57	6.38	1.7	8.6	3.9
Cadmium (Cd)	3	34	2.02	**3.2**	2.29	**3.44**	**3.18**	3	2.7
Chromium (Cr)	210	2800	2.92	25					
Cobalt (Co)	34	340	1.11	3.1					
Copper (Cu)	100	1700	**100.49**	**180**	**215.48**	**241.24**	**225.76**	**163.5**	**140.8**
Lead (Pb)	150	1100	3.05	32	17.97	8.44	18.27	45	24.3
Mercury (Hg)	0.8	11	0.01	<0.05					
Molybde-num (Mo)	5	94	2.65	3.9					
Nickel (Ni)	62	420	4.18	14	11.34	9.29	16.36	10.5	10.5
Selenium (Se)	2	34	0.21	<0.7					
Zinc (Zn)	500	4200	**500.6**	**770**	459.09	417.87	400.09	**502.1**	**523.5**

In addition to determining the concentrations of metals in the ash samples before distribution, nutrients were also measured and included calcium (Ca), potassium (K), magnesium (Mg) and phosphorous (P) (**Table 4**). Knowing the amount of nutrients in the ash can aid in anticipating how the soil and trees will respond. The pH and the organic matter of the ash were also assessed and as expected, the wood ash is very alkaline with an average pH of 13.81 for the three samples.

The Loss on Ignition (LOI) test on the ash samples demonstrated very low organic matter percentages, which makes sense as the organic matter would have been removed during the burning process.

Table 4: Nutrient concentrations of three randomly selected samples from filtered and homogenized residential wood ash donated by Muskoka residents

	Homogenized Ash Sample 1	**Homogenized Ash Sample 2**	**Homogenized Ash Sample 3**
pH	13.85	13.86	13.72
Organic Matter (%)	2.85	4.11	3.74
Ca (mg/kg)	262169.73	259642.81	272892.94
K (mg/kg)	93538.44	103860.41	93653.91
Mg (mg/kg)	20229.08	21611.19	20082.95
P (mg/kg)	7912.60	8283.71	7231.57

Image 3: Distribution of homogenized, filtered ash and citizen scientist kits at an AshMuskoka ash drive in April 2022.

3.4 The Campaign

To attract citizen scientists, an outreach campaign was launched in February 2022. The campaign included newspaper and radio interviews, articles in various newsletters, and emails to existing FOTMW constituents **(Appendix A)**, as well as presentations to community groups. Additionally, FOTMW partnership with the Gravenhurst Steamships and Discovery Centre has led to an AshMuskoka display which is used to disseminate information (example of display materials in **Appendix E**).

The outreach campaign attracted nearly 100 potential citizen scientists. Approximately 50 citizen scientists participated in the program, most of whom collected soil and foliage. Due to budget limits additional citizen scientists were still invited to participate in the program but did not collect soil and foliage data. The program includes three data collection rounds: round one - spring 2022, round two - late summer 2022, and round 3 - spring 2023 (**Table 5**). Citizen scientists were encouraged to collect additional rounds of data if they so wished. School groups, for example, collected additional information as the process was also used as a teaching opportunity.

Community members who expressed interest in participating in the citizen science program after the cutoff date (June 2022) were added to a waitlist for 2023.

Table 5: Data collection and submission schedule provided to citizen scientists.

Spring 2022	• Collect tree height, diameter, and note health of trees • Some Citizen Scientists: collect soil samples • Submit data
Summer 2022	• Collect tree height, diameter, tree health, and % canopy cover of trees • Some Citizen Scientists: collect soil and foliage samples • Submit data
Spring 2023	• Collect tree height, diameter, and note health of trees • Some Citizen Scientists: collect soil samples • Submit data

When an individual signs up to be a citizen scientist, they are given a program kit, which included instruction sheets, a tree identification guide, a residential wood ash Material Safety Data Sheet (MSDS), filtered homogenized ash, field sheets to record their observations, information on FOTMW, and tools to complete information collection. The tools include a mask, gloves, plastic bags, tailors' tape and flagging tape to mark the trees, as well as envelopes to send soil and foliage to FOTMW (**Image 4**). Citizen scientists are given the kits at events, presentations, workshops or picked them up at the FOTMW office. Citizen scientists need to contribute a metre stick, snips or a pole lopper, a camera or smart phone, and an open-reel tape measure (listed below). Access to a computer was also recommended, for photo and data submission.

<u>Equipment provided by FOTMW:</u>

- ◻ Digital and hard copy instructions and a link to an online training video
- ◻ Tree identification guide
- ◻ Material Safety Data Sheet
- ◻ 6 kg bucket of ash (homogenized, chemically analyzed ash)

- ◻ Masks (surgical grade)
- ◻ Nitrile gloves
- ◻ Measuring tape (sewing measurement tape)

Special collection (soil and foliage)

- ◻ Plastic trowel
- ◻ Ziploc bags
- ◻ Bubble mailer envelopes

Equipment CS are asked to provide:

- ◻ Metre stick (or any stick of equivalent length)
- ◻ Snips/Pole lopper for collecting foliage
- ◻ Digital camera or smart phone
- ◻ Open-reel tape measure
- ◻ Access to computer

Once a citizen scientist picked up a kit, they were assigned a unique identifying number (e.g., CS15) to provide anonymity when working with the data. This identity number was used to manage citizen science submission data.

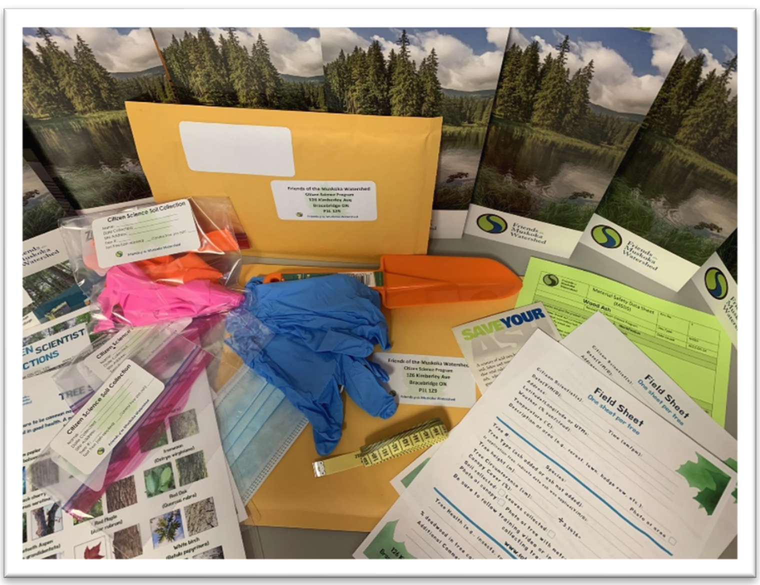

Image 4: Kit provided to citizen scientists including instructions and tools needed to collect, record, and submit information. Much of the materials provided in the kit are shown in **Appendix B**.

The Citizen Science program participants include private property owners, children's camps, schools and community groups who have safe and legal access to land with two trees of the same species and similar size. Most of the citizen scientists chose one pair of trees but a few chose up to ten pairs of trees.

In addition to the written instructions provided in the citizen science kit, a professional instructional video was made. The video featured FOTMW staff demonstrating how to take the measurements. The video, along with a short introduction video is posted on the FOTMW website. All citizen scientists are directed to the website and the video. To help citizen scientists locate specific sections of the instructional video, it is divided up into smaller parts with each section listed below the full video.

3.5 Studied Metrics

FOTMW board and staff, with input from Trent University Environmental Science department and forestry technicians decided upon the metrics of height, diameter, canopy cover and tree health because they can be measured with limited equipment and experience. These metrics are commonly documented in scientific research, as well as in government forestry literature. The literature also helped define other aspects of the program. For example, before data could be collected, citizen scientists had to select a minimum of two trees to monitor. Citizen scientists were asked to select trees that were larger than 10 cm in diameter, in good health and only trees native the area, except for American beech (*Fagus grandifolia*) were permitted in the study. Beech trees were excluded from the Citizen Science program, because all beech trees have or are suspected to develop beech bark disease (a disease that occurs after extensive bark invasion by *Xylococculus betulae* and the beech scale insect, *Cryptococcus fagisuga*), potentially impacting the results of the study. The objective of the study was to see if residential wood ash improves tree vitality or growth and not "rescue dying trees". Infected beech trees also pose a safety risk to people working under them as the crowns or upper branches can snap unexpectedly (Cale et al. 2017 and Heyd, 2004).

One tree was the 'control' tree and the other tree was the 'test' tree. The test tree received a dose of 2 Tonnes/Ha, and the control tree did not receive any ash (**Figure 3**). The trees were marked with flagging tape provided in the kit. The tree number and whether it had ash applied or not was written on the flagging tape with a permanent marker (**Image 6**). Waterproof stickers were also mailed to citizen scientists, which could be used for tree identification. The stickers were used for educational and outreach purposes, for example, if the trees were in a residential area, flagging tape made some residents think that the trees were going to be cut down, the stickers helped alleviate concerns.

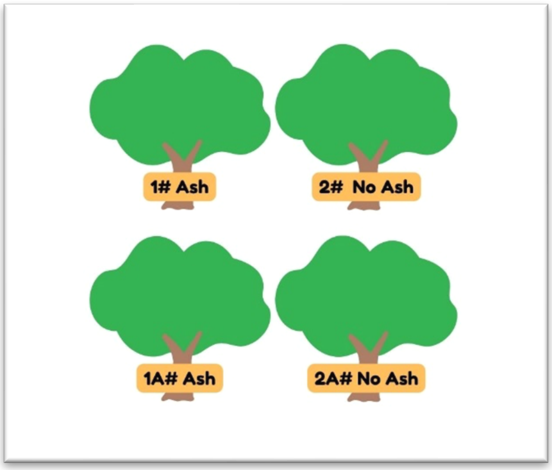

Figure 3: Graphic of trees on participating citizen scientist's property and labelling technique.

3.5.1 Measuring Diameter

Diameter is a measure of tree growth. Diameter of the study trees was done by following standard forestry practices. Measurements were taken at breast height (DBH). Citizen scientists were provided with a 1.5 m fiberglass tailor tape which was wrapped tightly around the tree (**Image 5**). The citizen scientists were directed to take the measurement at 1.37 m from the ground unless the tree was on a significant slope, where the circumference was averaged from the highest and lowest points. Once circumference was determined and that number was multiplied by 3.1416 (pi) to determine the tree diameter.

Image 5: Citizen Scientist measuring tree diameter with tailor tape.

3.5.2 Measuring Tree Height

Measuring tree height is a second method used to assess tree growth. Tree heights were measured using a metre stick or a branch of equal length. The meter stick with brightly coloured flagging tap fastened to the top was placed vertically against the trunk of the tree (**Image 6**). The observer stepped back until the whole tree was in the frame and took a picture.

Image 6: Citizen scientists at work, recording tree height with a metre stick and taking a photo.

A second height measurement was taken using the 45° triangle and metre stick method. To start, the citizen scientist measured the length of their arm from shoulder to hand (**Image 7**). This measurement was the point at where the observer griped the meter stick. They then walked away from the tree to where they had the best line of sight and ideally across little or no slope to an estimated distance where the tree would cast a shadow. The metre stick was then held in an outstretched arm parallel to the tree forming a 90-degree angle with the arm. The citizen scientist then looked up towards the tree and imagined a line running from their eye to the top of the meter stick and onwards towards the top of the tree at 45°. The correct position was when the top of the tree aligns with the top of the metre stick.

The location directly in front of the observer's feet was marked by either putting a stick or a scuff mark in the ground, then the distance between the scuff and the tree was taken with an open real tape measure. Alternatively, the distance was paced out or measured using the tailor tape. This created an invisible right triangle where the height of the tree is equal to the length that was measured from the tree (**Appendix B**).

Image 7: FOTMW staff member measuring arm length as a part of the procedure to measure tree height.

3.5.3 Measuring Canopy Cover

Percent canopy cover is an observation of the canopy foliage density. The first step for the citizen scientist was to stand under the tree, with their back up against the trunk and look up into the canopy (**Image 8**) and compare the density of the leaves or needles to a density chart in the instructions (**Figure 4**).

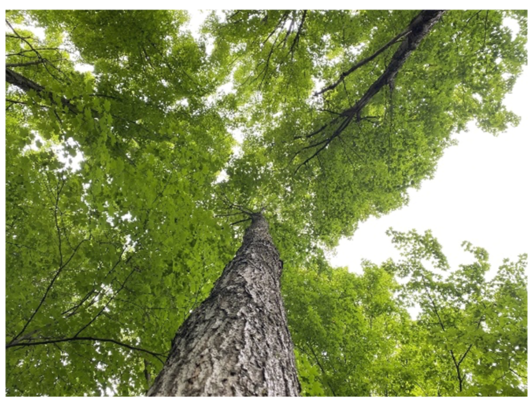

Image 8: Photo of sugar maple canopy, collected while estimating canopy cover.

The citizen scientist estimated, based on the four categories presented in the density chart, how dense the canopies of their study trees were. The location where the citizen scientist stood was marked with a rock or stick with flagging tape, as future measurements should be taken from the same location. Citizen scientists were asked to take a photo of the canopy from this location.

Unlike tree diameter and tree height, canopy density was only measured during round two (Summer 2022) of data collection because there wasn't sufficient foliage in the spring.

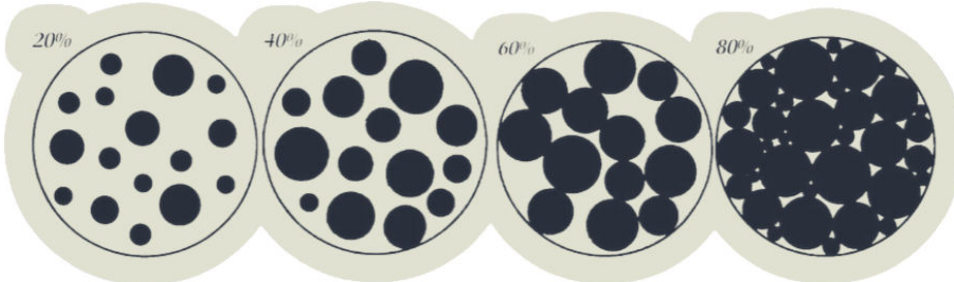

Figure 4: Graphic of percent canopy cover classifications.

3.5.4 Soil Collection

Soil samples were collected by most citizen scientists. Soil samples were collected from under both the test and control trees before the ash was spread, and again during the summer data collection (i.e., after the ash was spread). Three soil pits were selected within a three-meter radius around the base of the tree. A trowel was used to dig a 10 cm deep hole (surface soils) and soil from all three pits were added to a single clearly labeled plastic Ziploc bag (**Image 9**).

Samples were mailed, or dropped off at the FOTMW office and kept in a cool dry place in brown paper bags until they could be sent to the School of the Environment laboratory at Trent University for analysis.

Image 9: Example of composite soil sample in Ziploc bag. Citizen Scientists were asked to collect about half a bag to ensure sufficient amount for analysis.

3.5.5 Foliage Collection

The same citizen scientists who collected soil samples, were also asked to collect foliage samples. Foliage (leaves or needles) were collected once from both the test and control tree during round two. Approximately three samples of new growth were selectively snipped from the trees and put into a clearly labeled plastic Ziploc bag (**Image 10**). Samples were mailed or dropped off at the FOTMW office and kept in brown paper bags to dry them out. All foliage samples were sent to the School of the Environment laboratory at Trent University for analysis.

Image 10: FOTMW staff using long loppers to collect foliage samples.

3.5.6 Tree Health

Each study tree was visually inspected for any impairments that could affect the growth and vigor of the tree. Growths, swelling, cracks, angling, or leaf spots were noted (**Image 11**), along with an estimate of dead branches (**Appendix B**). Citizen scientists were asked to take and submit photos of any notable health related features.

Image 11: Needle spots indicating insect damage.

3.5.7 Spreading Ash

The final step during the spring data collection round was spreading ash around the test tree. A circular area of three metres out from the tree base was measured in all directions and marked using small sticks and flagging tape. Citizen scientists were provided with personal protective equipment including a medical grade style mask and nitrile gloves for spreading the ash. The ash was then scooped from the bucket using a small plastic scoop and lightly scattered over the entire three-meter radius area (**Image 12**). For safety reasons, ash was only spread on non-rainy and non-windy days.

 

Image 12: Image showing a citizen scientist measuring 3 m from the tree base and a second image illustrating where and how thick ash was spread.

3.5.8 Citizen Science Phone Survey

To aid in FOTMW's relationship building with those participating in the Citizen Science program, as well as to capture information about citizen science perspectives. Five questions were asked in a brief phone interview that was conducted in August 2022. The purpose was to also determine the interest of citizen scientists in taking part in future FOTMW programs. The questions asked by FOTMW staff were:

1. Why did you sign up for the Citizen Science program?

2. Prior to taking part in our Citizen Science program, have you taken part in any other citizen scientist programs like iNaturalist or eBird?

3. What's the education level of the participants? Elementary, secondary, post-secondary (e.g., University Bachelors and College), or higher (e.g., Master's or Doctoral)?

4. What age range are the people who participated? Under 18, 19-30, 31-50, 51 and over?

5. Was there anything that wasn't clear in the instructions or advice you have as the program moves forward?

During these phone discussions, citizen scientists were asked if they were willing to have a researcher visit their property to assess the study trees as a part of a quality control assessment.

3.5.9 Quality Control Assessment

To assess the quality and consistency of the data collected by citizen scientists, a parallel assessment was conducted on a large portion of the citizen science study trees during the second round of data collection. Quality control measures are undertaken to demonstrate the accuracy (how close to the real result) and precision (how reproducible the results are) of monitoring

(EPA, 2012). Quality control includes sampling, data analysis, data interpretation and data management, and is a critically important part of a scientific study.

This quality control assessment was led by Trent University honours student, Kira Nixon and assisted by the FOTMW summer student, Jimmy Yao (**Image 13**). All steps from the citizen science instructions were repeated except additional equipment used to record tree height (clinometer), canopy cover (densiometer), diameter (DBH tape), and soil (auger), as described in **Appendix C**. **Appendix C** also has the field sheet used to record data.

Image 13: Kira Nixon, Trent University Honours student, and Jimmy Yao, FOTMW summer student, collecting data for quality control assessment.

3.5.10 Data Management

Once data collection was complete, citizen scientists submitted field sheets and photos by mail, in-person at the FOTMW office, e-mailed or via the online webform on the FOTMW website.

In addition to the citizen scientist's data, the quality control data collected was compiled and analyzed separately. Hard copies of the field sheets were stored by round and citizen science number (CS#) in a filing cabinet. Digital photos and scanned field sheets were organized into files organized by CS # on the FOTMW cloud server.

3.6 Laboratory Methods for Soil and Foliage Analysis

Collected soil and foliage samples were sent to be analyzed at Dr. Shaun Watmough's School of the Environment Laboratory at Trent University and were analyzed using multiple tests including detection of calcium concentrations. Initially soil samples were prepped before analysis and placed in clean aluminum containers and dried in an oven for 24 hours at 105°C**.** The soil was broken down by being ground in a Wiley mill after drying. The mineral samples were sieved with a 2 mm mesh to remove large rocks and breakdown clumps of soil. Both types of samples had the following analysis performed: pH, loss on ignition, exchangeable cations and acid digest.

3.6.1 pH

The samples were weighed into 50 mL conical tubes with respective weights (2 g litter and material from the fermented humic layer (FH), and 5 g soil) (**Figure 5**). A 0.01M calcium chloride and b-pure solution (purified water) was then added to the conical tube at a 1:5 (2 g litter, 10mL $CaCl_2$) ratio to the soil and shaken on a laboratory shaker for two hours. This freed the ions from the soil and put them into the solution. The samples were then removed from the shaker and left to rest for one hour. Finally, pH was measured with a pH probe (Oakton pH meter 510 Series).

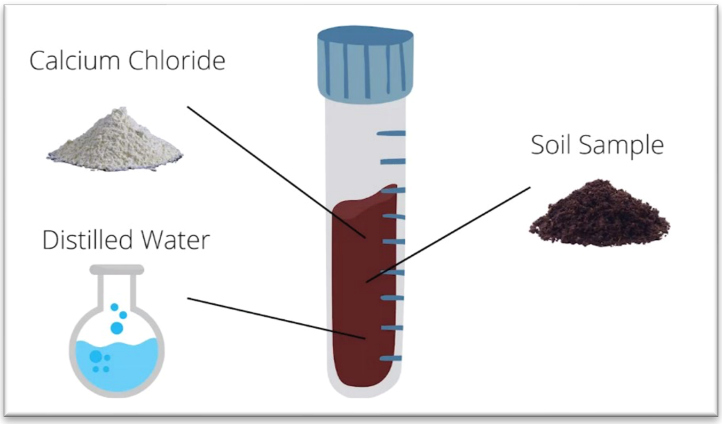

Figure 5: pH test suspension mixture: a combination of the soil, calcium chloride and purified water.

3.6.2 Loss on Ignition

A loss on ignition test (LOI) is completed to determine the percentage of organic matter. During the LOI test of the citizen scientist samples crucibles were cleaned and individually labelled before being placed into an oven and dried for one hour at 105°C to remove all excess moisture. The crucibles were then placed into a desiccator and their initial weight was recorded before taring (setting the weight to zero with the crucible still on the balance) the scale and adding the samples with their respective weights (2 g litter, 3 g FH, and 5 g soil). The crucibles containing the samples were then transferred in the desiccator and placed back into the oven at 105°C for 24 hours to remove all excess moisture from the soil. After 24 hours the crucibles were transferred back into a desiccator where they once again were weighed on a balance and then transported in the desiccator to a muffle furnace where they remained for 10 hours at 400°C, allowing for the ignition of organic matter. The differences in weight were then calculated to determine how much organic content was originally present in each sample.

3.6.3 Exchangeable Cations (Nutrients)

Soils were weighed into 50 mL conical tubes (1 g litter and FH, 5 g soil) and then 25mL 1M NH_4Cl was added to each tube. These were shaken for 2 hours and then allowed to rest for one hour. The samples were extracted through vacuum filtration with an additional 25 mL 1M NH_4Cl to remove any soil particles while allowing the cations to remain in solution. The samples may have been diluted for analysis with ICP-OES (inductively coupled plasma-optical emission spectrometry).

3.6.4 Acid Digest

This analysis looks for heavy metals in the soil and foliage, such as arsenic, lead or cadmium. Litter and fermented humic layer (LFH) and mineral samples were weighed to 0.2 g into 50 mL DigiTubes which then each received 2.5 mL concentrated nitric acid (HNO_3). The tubes were swirled so that all material came into contact with the acid. These tubes were then loosely closed with a lid and placed on a heating block at 100°C and left for 8 hours followed by a cold digestion for an additional 8 hours. Once complete the samples were filtered into a 25 mL volumetric flask and diluted to 25 mL with b-pure. These samples may have also then been further diluted for analysis with ICP-OES which was used to determine concentrations of heavy metals like arsenic, lead, or cadmium.

4.0 Results and Analysis

4.1 Citizen Science Program Campaign and Activities

For the Citizen Science program to be a success, several activities and events were carried out by FOTMW staff. These included community presentations and workshops (**Appendix F**). Staff also developed and distributed educational resources. During the first year of the program specific objectives were set, these included things like number of participants, number of soil and foliage samples to be collected and analyzed. Some of these activities, events and objectives are quantified in **Table 6.**

Table 6: pH test suspension mixture: a combination of the soil, calcium chloride and purified water.

Activity/ Event / Objective of the Citizen Science Program	Numbers Achieved to Date of this Report
Citizen science kits distributed	83
Six kg ash containers filtered, homogenized and analyzed	123
Number of supporting videos created and posted to website	3
Community presentations and workshops given	5
School presentations given	4
Camp presentations given	1
Number of media interviews given	5
Number of mainstream newspaper articles discussing the program	4
Number of citizen scientists participating as of spring 2022	50
Additional number of citizen scientists participating as of fall 2022 (e.g., school groups)	3
Number of new potential citizen scientists starting spring 2023	23
Number of physical metrics measured by each citizen scientist (i.e., height, diameter, canopy cover, etc.)	4
Number of soil samples analyzed for pH, % organic matter, metals and nutrients	~ 180
Number of soil samples to be analyzed spring 2023 (minimum)	90
Number of foliage samples analyzed for metals and nutrients	70
Number of foliage samples to be analyzed spring 2023 (minimum)	70

4.2 Location

Participating citizen scientists provided the location of the study trees when signing up for the program as well as when data was submitted. Most of the trees being assessed are located within the municipal lines of Huntsville (33%), Muskoka Lakes (27%) and Bracebridge (24%) (**Figure 6**). There are a small number of citizen scientists participating from outside of Muskoka/Parry Sound area in Haliburton County and Simcoe County. Other than the Bracebridge area, most properties are reported to be located in rural settings (**Figure 7**).

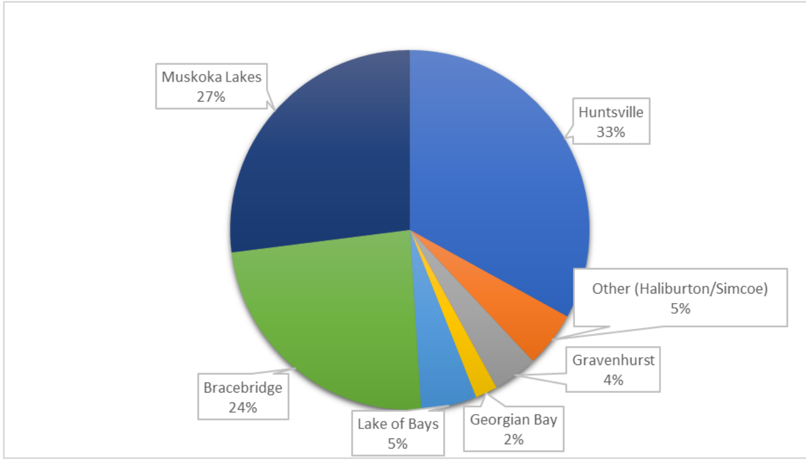

Figure 6: Pie chart showing which communities participating citizen science properties are located in.

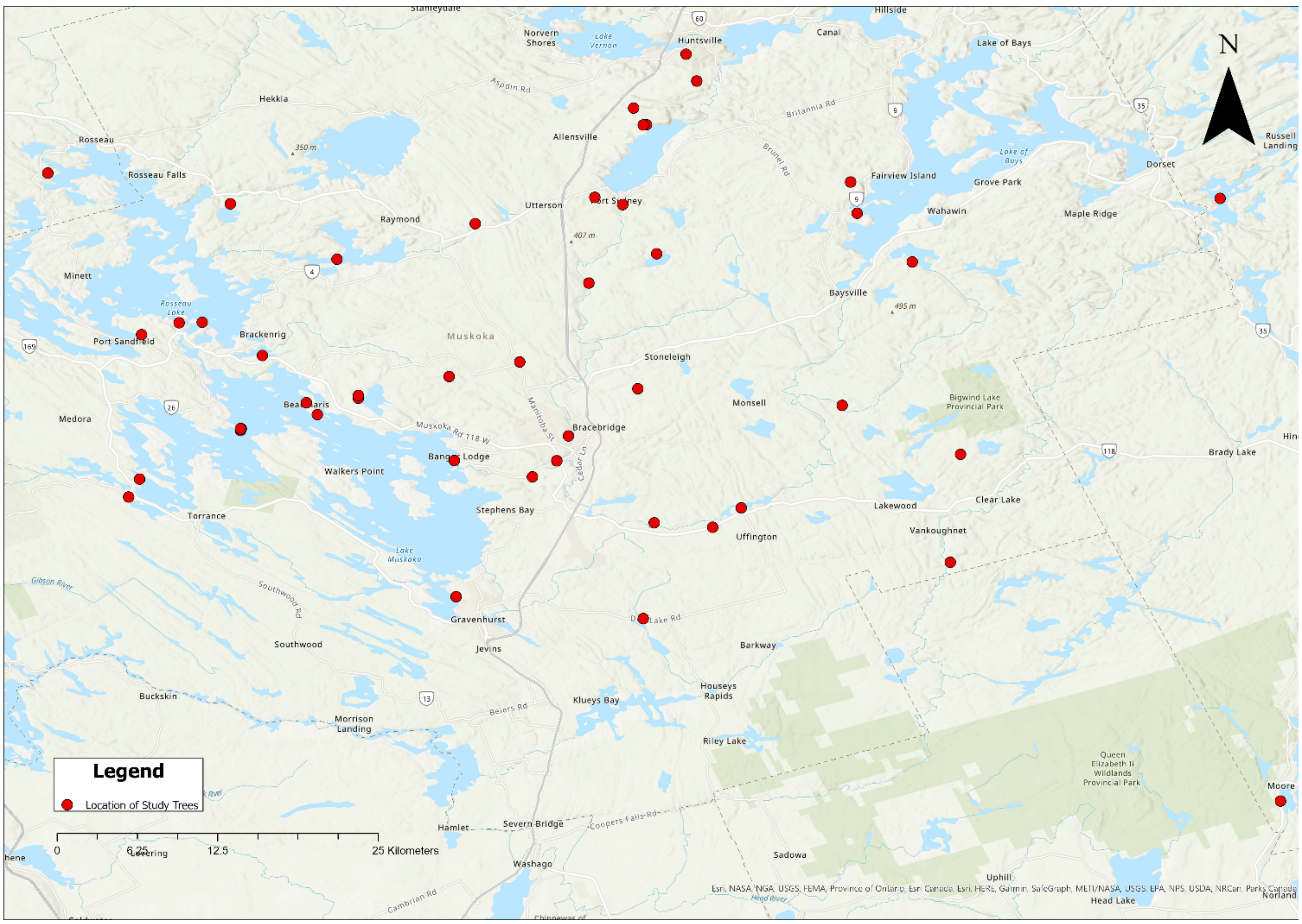

Figure 7: Map showing the approximate location of study trees (participating citizen science properties).

4.3 Tree Species

Eighteen different tree species were selected by citizen scientists in the program. Sugar maple trees (n=36) were the most common, followed by Eastern hemlock (*Tsuga canadensis*) (n=16) (**Figure 8**). Citizen scientists were asked to select trees native to Muskoka that appeared to be in good health and were over 10 cm in diameter. It is suspected that sugar maple was the most selected species because those citizen scientists who follow other FOTMW research know that research has focused primarily on sugar maple due to their high calcium requirements (Kim, 2022).

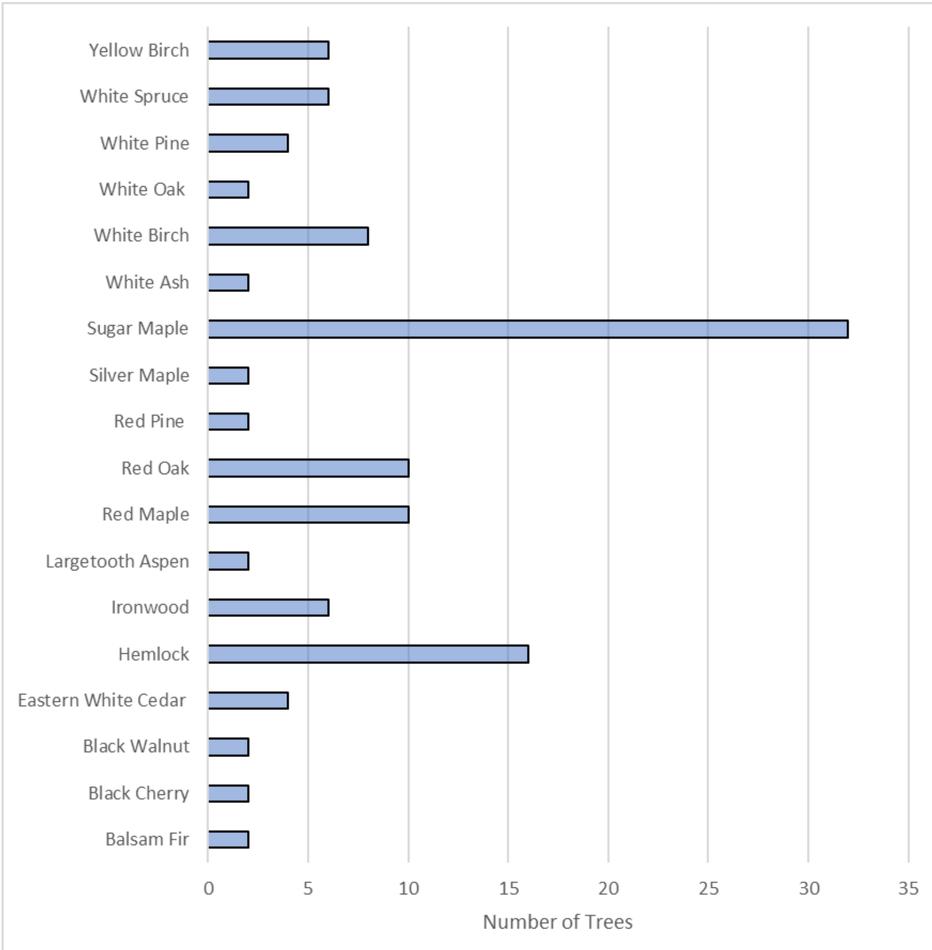

Figure 8: Graph showing number of each tree species selected by citizen scientists to be assessed for the program. Information from round one of the study.

4.4 Tree Identification in Quality Control Study

During the quality control assessment tree identification was confirmed. It was determined that of the trees reviewed, 86% were correctly identified, while 14% were incorrectly identified (**Figure 9**). Those that were incorrectly identified were often still in the correct genus, for example, red maples may have been miss identified as sugar maples.

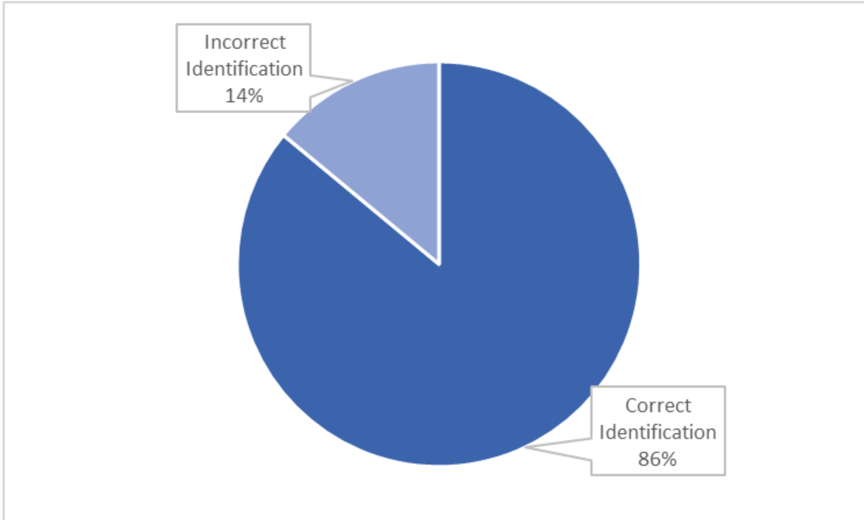

Figure 9: Pie chart showing the 86% accuracy of identifying study trees correctly.

4.5 Soil pH of Citizen Science Program

Approximately 43 citizen scientists collected and submitted soil samples before (round one) ash was applied and after ash was applied (round two) from under both the control and test trees. The samples were sent by FOTMW staff to Trent University for analysis of pH. There was an increase in pH after the ash was applied under the test trees, and a very slight decrease in pH of soil samples collected from under trees that did not receive an ash application.

The baseline (round one) average soil pH was 4.06, respectively. Once ash was applied, a time period of approximately three-four months passed before soil was collected again. At this time, the average pH was determined to be 4.38, respectively (**Figure 10**). The control trees varied little from the baseline soil with an average pH of 3.99 and changed very little between the first and second round of data collection with an average pH of 3.95.

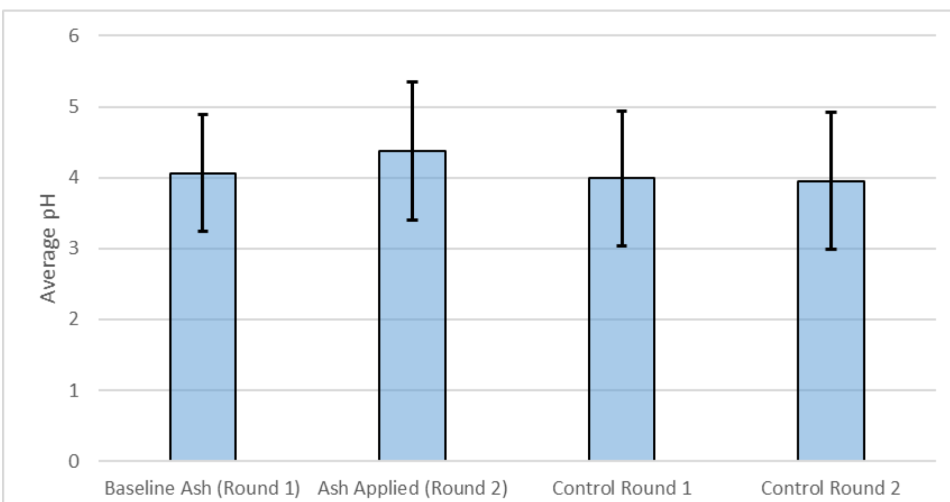

Figure 10: Average pH (-log) and standard deviation of study trees before and after ash distribution.

4.6 Soil pH of Quality Control Study

At approximately the same time (within two weeks) of the second round of data collection soil samples from below 68 trees were also collected and assessed by Trent University student, Kira Nixon to act as a quality control assessment. Rather than using a trowel, a soil auger was used to collect samples. P-value was determined to be 0.34 ($p>0.5$) and the R-value was 0.67, suggesting that there is not a significant difference between the pH results obtained during the quality control assessment and the soil collected by citizen scientists and there is a positive correlation of the data sets (**Figure 11**). In other words, there was little difference between the pH soil results gathered by the citizen scientists and those gathered during the quality control study despite the difference in protocol.

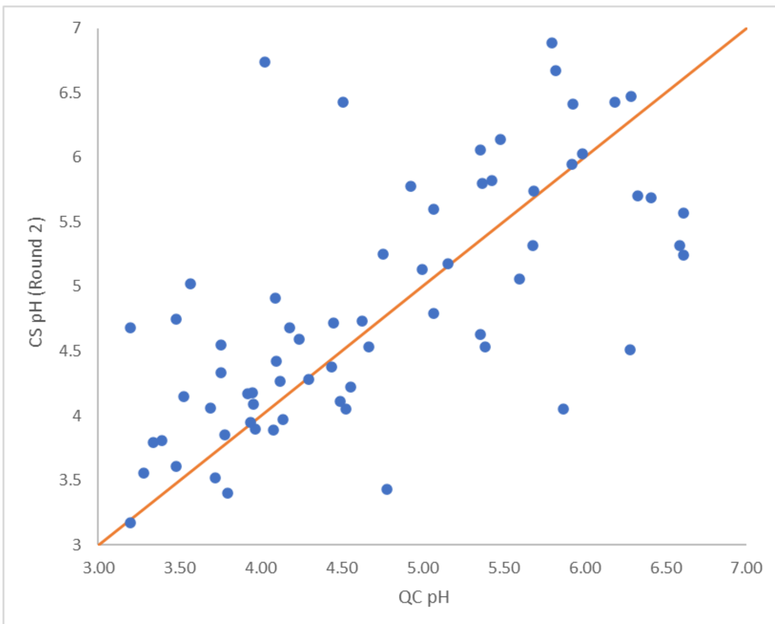

Figure 11: Correlation between soil pH of samples collected by citizen scientists and those collected during the quality control study.

4.7 Percent organic matter of Citizen Science Soil Samples

Organic matter is the portion of soil that is composed of living and dead things in various states of decomposition, such as plant roots and microbes. The amount of organic matter in the citizen soil samples collected to date ranged from 2.52% to 83.13%. There was no correlation between organic matter and the environment in which the trees were located (i.e., forest, forest edge, yard, etc.)

The average percentage of organic matter was approximately 17% and 15% during round one and increased slightly for both the treated and untreated soils, to approximately 18% (**Figure 12**). There were no significant differences in organic matter percentages between the rounds (spring and late summer) of data collection.

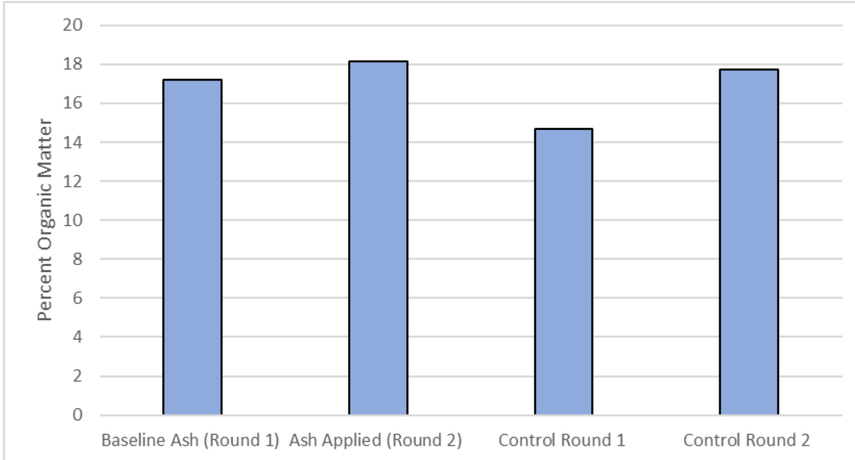

Figure 12: Percent organic matter averages for both the test and control trees for round one and round two of the Citizen Science program.

4.8 Percent organic matter of Quality Control Study

Organic matter of the soil samples was analyzed and the correlation between round two citizen science and quality control assessment was looked at. There was a p-value of 0.02 and an R-value of 0.58 (**Figure 13**). The percentage of organic matter in the citizen science samples was generally slightly higher than that of the quality control assessment.

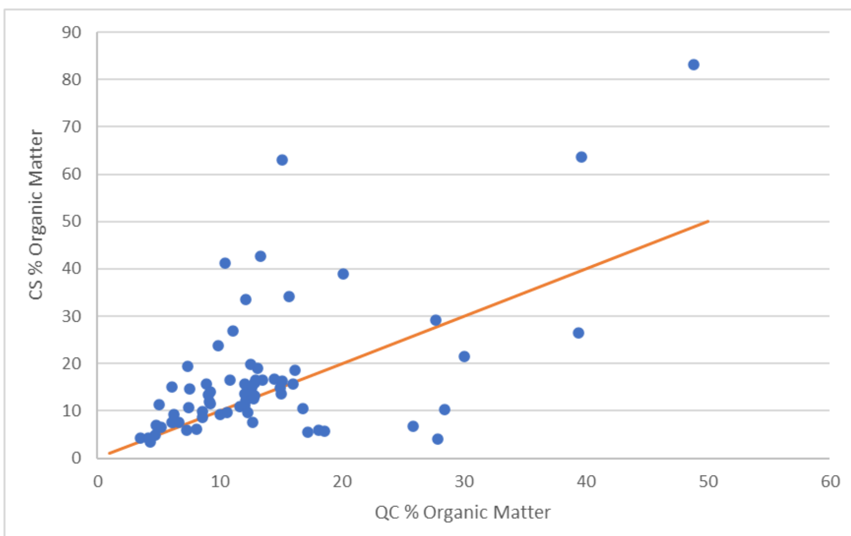

Figure 13: Correlation between soil organic matter (percent) of samples collected by citizen scientists and those collected during the quality control study.

4.9 Soil Nutrient Concentration

Soil samples were collected during both round one (spring 2022) and round two (late summer 2022) of the Citizen Science program. The nutrient levels of Ca, K, Mg, and Na were assessed by Trent University School of the Environment laboratory and the results are displayed in **Figure 14**.

The box plots below illustrate a slight difference between before and after ash was applied for the Ca and K concentrations. The Ca concentration had a mean value of 1.17 g/kg before ash was spread, and a mean value of 1.58 g/kg after the ash was spread. The mean values of the control tree samples increased by about 0.3 g/kg. The average of K in the soil samples increased from approximately 0.13 g/kg to 0.31 g/kg after the ash was applied. Na concentrations dropped noticeably after ash was applied on the test trees with an averages of 0.031 g/kg and 0.007 g/kg, respectively.

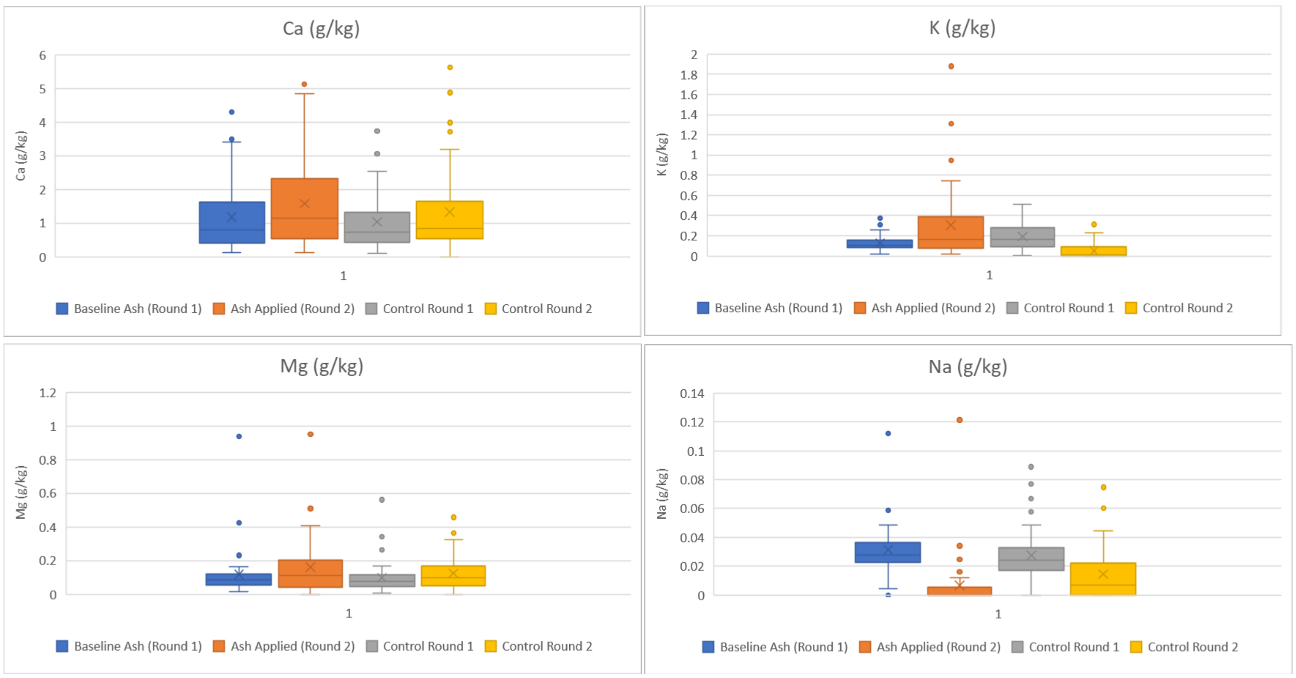

Figure 14: Soil nutrient concentrations from soil samples by citizen scientists in round one (Baseline: n= 49, Ash Applied n = 40, Control round one, n=48 and Control round two, N= 44) and round two of Citizen Science program.

4.10 Soil Metal Concentrations

Ten different metals were assessed in the soil samples collected by citizen scientists, they included aluminum (Al), arsenic (As), boron (B), cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) (**Figure 15**). Three of the metals assessed: As, B and Cd consistently fell below laboratory detection limits, therefore no statistical analysis could be completed. The others ranged greatly, for example manganese was found at a minimum level of approximately 24 mg/kg and a maximum level of 4533 mg/ kg. There were no differences between the soil samples collected from below the trees that received ash and those that did not or between the rounds.

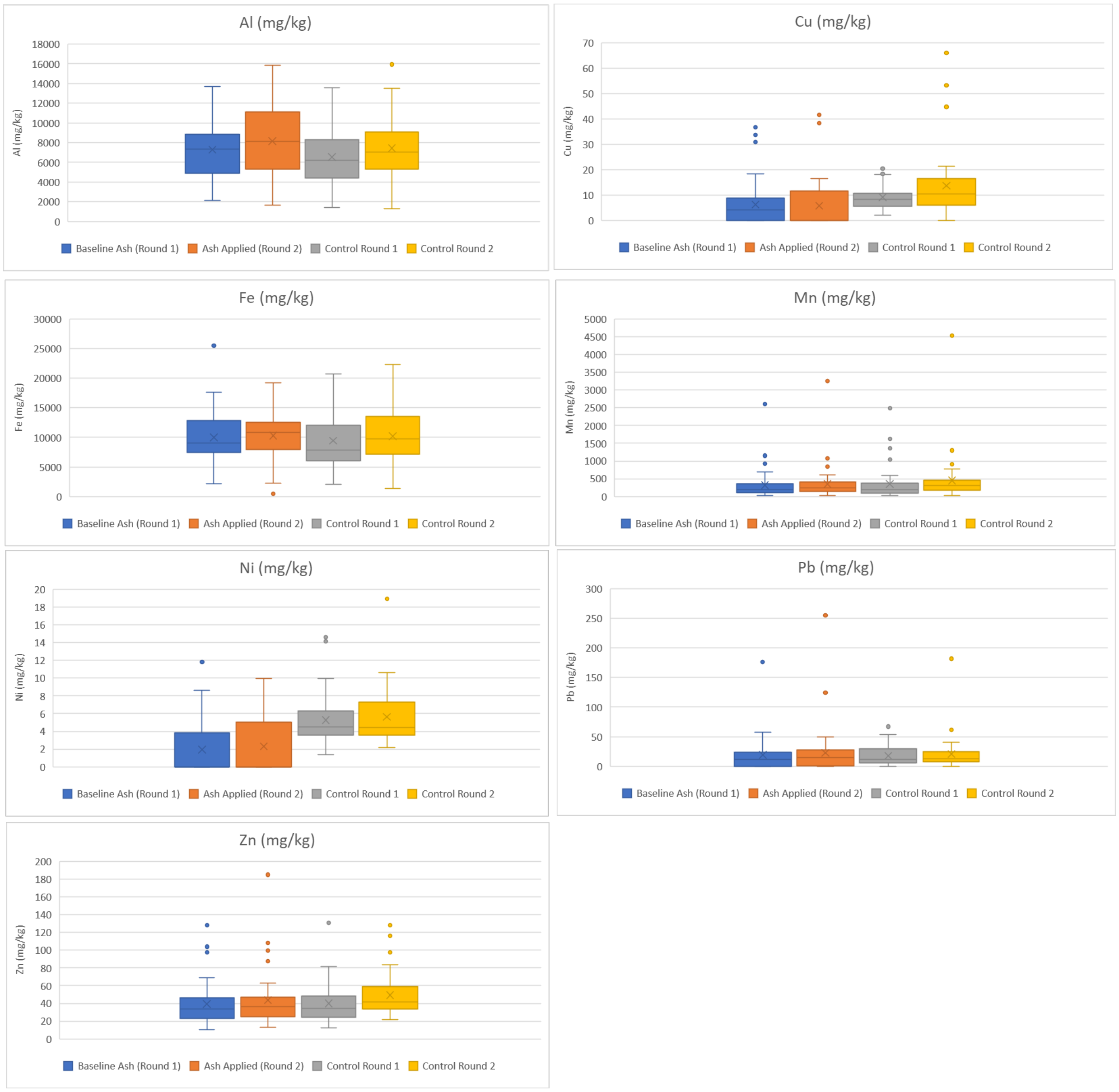

Figure 15: Metal concentration (Al, Cu, Fe, Mn, Ni, Pb and Zn) results for control and test trees collected during round one and round two of the Citizen Science program.

4.11 Foliage Nutrient Concentrations for Citizen Science Program

Foliage (leaves or needles) were collected during round two (late summer 2022) of the Citizen Science program. The nutrient levels of Ca, K, Mg, Na and P were assessed by Trent University's School of the Environment laboratory and the results are displayed in **Figure 16**. The box plots below illustrate that there was a slight difference between the Ca and Mg in the foliage of the test and control trees. The Ca concentration ranged from 1804 mg/kg to 27494 mg/kg with a mean value of 8029 mg/kg before ash was spread, and Mg concentration ranged from 673 mg/kg and 6573 mg/kg with an average value of 1479 mg/kg. The averages increased to 8975 mg/kg and 1633 mg/kg, respectively. No differences were noted of the K, Na, and P concentrations between the test and control trees.

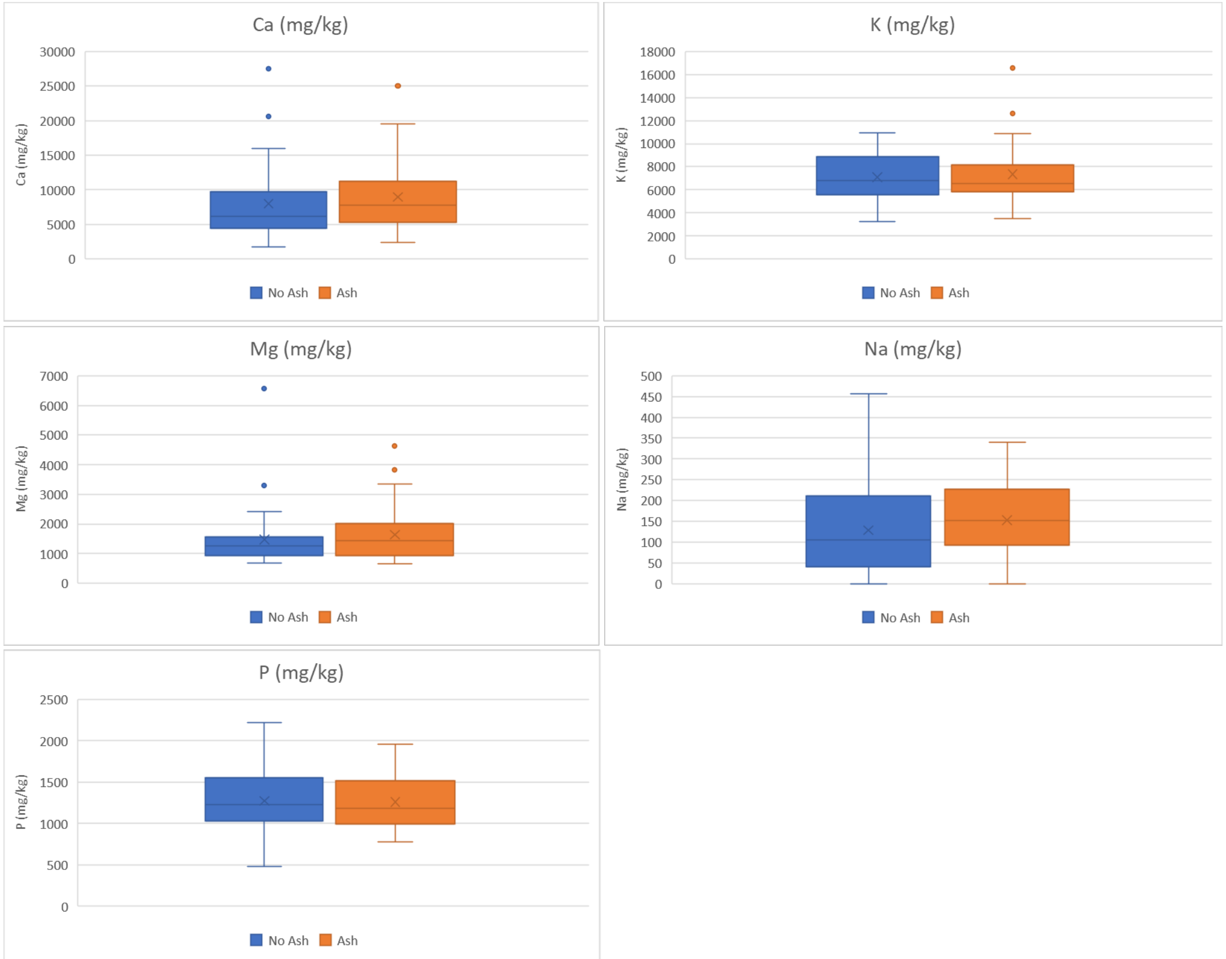

Figure 16: Nutrient level (Ca, K, Mg, Na and P) differences in foliage between trees that received ash, and those that did not.

4.12 Foliage Metal Concentrations for Citizen Science Program

Metals exist in the natural environment, and it is important to monitor how metal concentrations change when wood ash is spread in the forest. Ten metals were assessed: Al, As, B, Cd, Cu, Fe, Mn, Ni, Pb and Zn. Here it was noted that arsenic and aluminum concentrations varied from site-to-site in the control trees, yet were very low, with a small range and much lower means of 118 mg/kg and 2.87 mg/kg, respectively in the foliage collected from the trees that received ash. The test trees for As and Al had means of 86 mg/kg and 0.59 mg/kg (n= 33 and n= 37). Other metal concentrations appeared to have not differed between the trees that received ash, and those that did not (**Figure 17**). It is also important to note that for many of the samples, metal concentrations were below laboratory equipment detectable limits.

Figure 17: Metal concentrations of foliate samples collected during round two of the Citizen Science program. Metals with sufficient data were Al, As, B, Cd, Cu, Fe, Mn, Ni, Pb and Zn.

4.13 Tree Height for Citizen Science Program

Tree height was collected by citizen scientists during both rounds of data collection. The shortest tree recorded was 2.4 m, while the tallest was 40.4 m. During round one, before ash was spread, the baseline trees had an average height of approximately 16.04 m (n= 51) and the control trees had an average height 15.94 m, respectively (**Figure 18**). During the second round of data collection, there was an increase in both the test and control tree height measurements, at 16.32 m and 16.31 m, respectively. There was a greater change between round one and round two of height data collection for the control trees with a change in growth of approximately 0.38 m and a change in growth of 0.13 m for the trees that received ash.

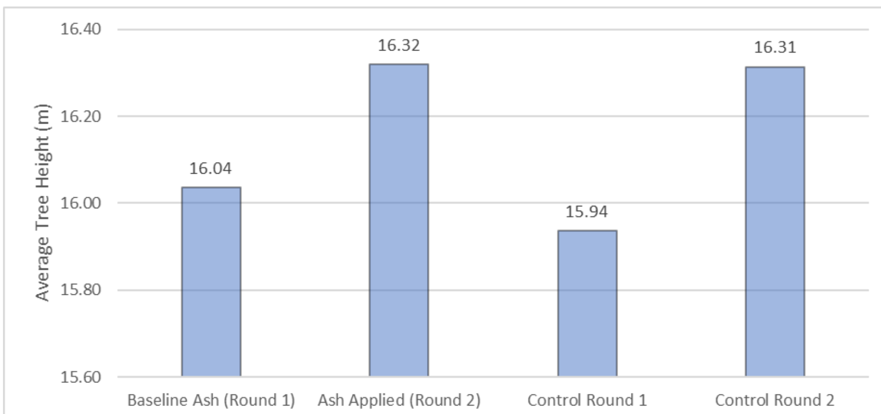

Figure 18: Average tree heights collected from round one and round two of the Citizen Science program.

4.14 Tree Height for Quality Control Study

The quality control study assessed tree height during round two using a clinometer. The results suggest that the tree heights measured by citizen scientists and in the quality control assessment were similar and strongly correlated with an R-value of 0.83 (**Figure 19**).

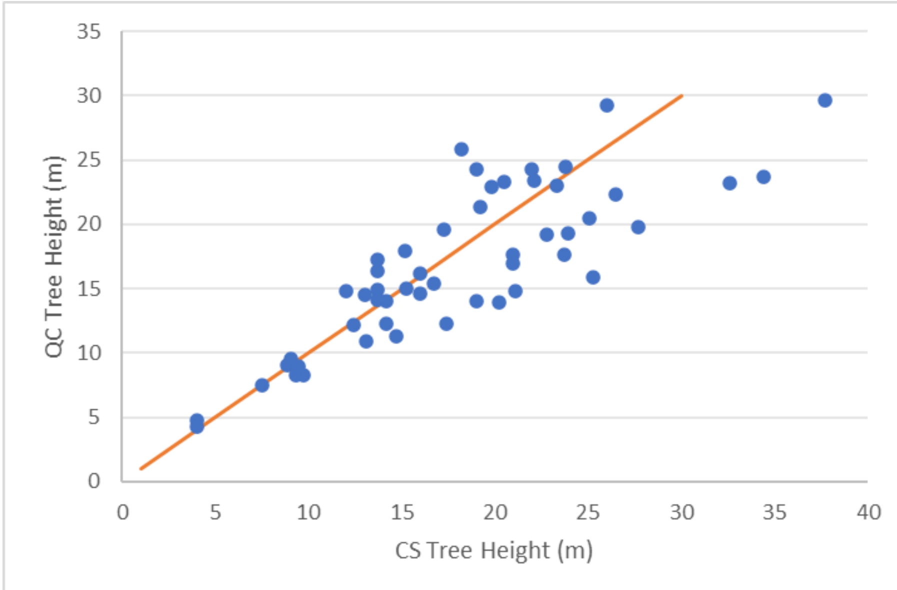

Figure 19: Correlation between tree height data collected by citizen scientists and those collected during the quality control study.

4.15 Tree Diameter for Citizen Science Program

There was a large range of tree diameters measured by the citizen scientists, from approximately 1.42 cm to 90.2 cm. The average diameters were calculated for the test trees before and after ash application, as well as the control trees during the first and second rounds of data collection. The average of the study trees before ash was spread was determined to be 22.97 cm and then increased to 23.36 cm, respectively. The control trees had an average of 22.39 cm at round one of data collection and an average of 24.86 cm at round two (**Figure 20**).

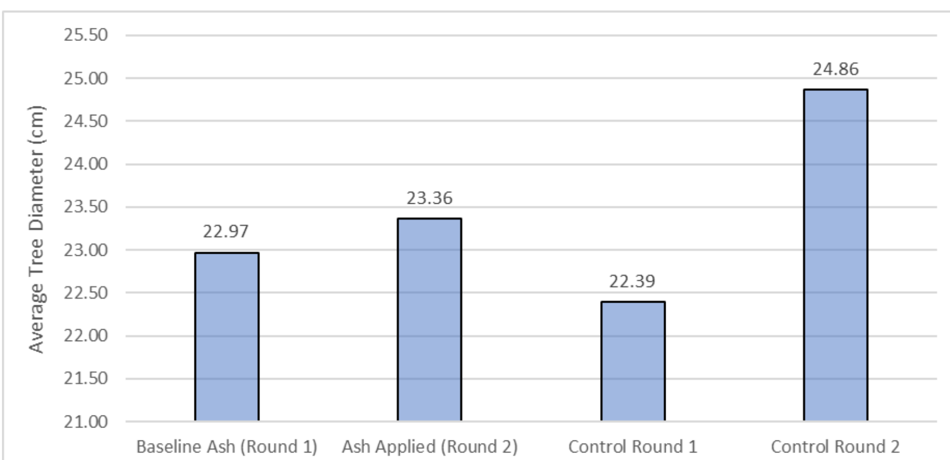

Figure 20: Average tree diameter of trees during round one and round two of data collection of the Citizen Science program.

4.16 Tree Diameter for Quality Control Study

Of the trees assessed in the quality control study, in relation to round two of the citizen scientist study, 54 trees were assessed for diameter and compared to the same trees measured by citizen scientists. The results suggest citizen scientists and Kira Nixon, conducting the quality control assessment had very similar diameter measurements (R-value=0.83) (**Figure 21**). The citizen scientists were provided with inexpensive tailor tape while the quality control diameter measurements were collected with a DBH tape.

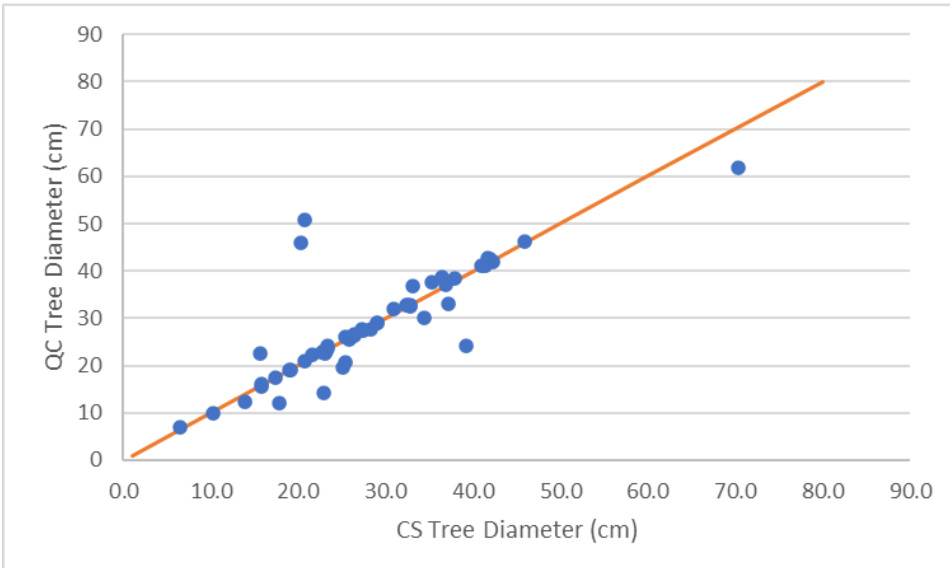

Figure 21: Correlation of tree diameter data collected by citizen scientists and those collected during the quality control study.

4.17 Canopy Cover for Citizen Scientist Study

Canopy cover was not measured by many citizen scientists during the first round of data collection, as deciduous trees were still bare, or leaves were just starting to appear during the time of data collection. The average percent canopy cover from round two was 51% for the trees that received ash and 67% for the control trees.

4.18 Canopy Cover for Quality Control Study

Canopy cover was only assessed during the second round of data, as there was little to no foliage in the spring (round one). Unlike the other metrics, canopy cover measurements differed greatly between the citizen science round two results and those from the quality control assessment. There was a p-value of 0 and an R-value of –0.09 (**Figure 22**).

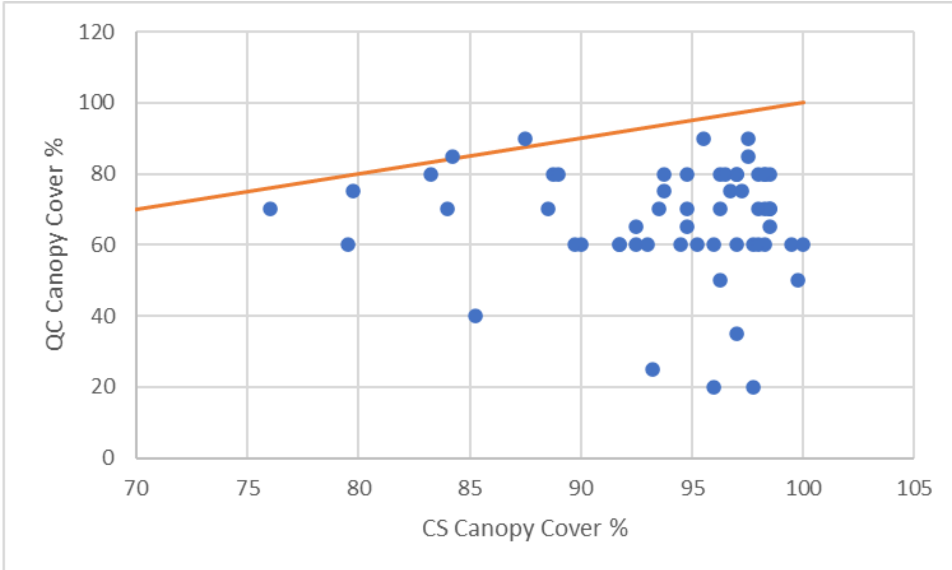

Figure 22: Correlation of percent canopy cover data collected by citizen scientists and those collected during the quality control study.

4.19 Summary of Responses of Phone Survey of Citizen Scientists

Many of the citizen scientists (n= 43) participated in the phone survey which was conducted by FOTMW staff. The results to each question are summarized below:

1. Why did you sign up for the Citizen Science program?

Citizen scientists indicated their motivations for participating in the Citizen Science program. Their motivations, as outlined in **Table 7,** included the program being consistent with their values, the feeling that they have something positive to offer to the program, wanting to be a part of scientific research, as well as wishing to participate due to an effective communication campaign, positive perception of the program and their passion for Muskoka. Some citizen scientists jokingly indicated they were influenced by friends or family to join the program. These motivations fall within various categories relating to the Dragons of Inaction, as described by Gifford, 2011, which outlines seven psychological factors that potentially act as barriers to taking action against climate change.

Table 7: Key motivations for participating in a citizen science program (adapted from Scannell et al. In progress).

Key Motivations for Participating	Examples	Sample quotes from CS	Relevant Dragon of Inaction
1. Consistent with values	Concerned about forest health; desire to "do my part"; engaged in environmental community	"Right thing to do" "Help environment in small ways" "Just cares and wants to give back" "Wanted to help with expanding research, and was part of the group that did original research" "Recognize the potential for a healthy forest"	Ideologies
2. Better or no different than previous use of ash (Using ash for scientific research is a good use of the ash)	Some were already doing similar work like donating wood ash and/or spreading it in their woodlots and therefore little behavioral change was required	"Already spreading ash on property" "Involved in community managed forest"	Habits
3. Have something to offer to program	Likes hands on activity; ability to communicate with many other residents	"Very interested and curious" "Likes to contribute" "Likes to be hands on and helping" "Enjoy being involved"	Structural
4. Positive perception of program features	Appreciate applied science aspects; research report	"Believes in FOTMW program" "Follows AshMuskoka" "Original ash donor" "This is an awesome program" "Likes goals of program" "Interested in results" "Seemed like fun"	Ideologies
5. Connection to Muskoka	Ties to natural environment; local environmental values; sense of stewardship; family ties	"Interested in plants and biology" "Interested in the environment in Muskoka" "We care about trees which are dying, as well as life in the lake" "Concerned about flooding"	Place attachment
6. Effective communication campaign	Decided to participate after hearing about it on the news	"Listened to Norm's talk" "Read about it and found interesting" "Saw talk in Haliburton" "Spoke to Norm Yan at seedling pickup" "Got information at ash drive" "Wants to know more about it"	Limited cognition

2. Prior to taking part in our Citizen Science program, have you taken part in any other citizen scientist programs like iNaturalist or eBird?

By speaking to the citizen scientists, it was revealed that most have participated in other established citizen science programs. The initiatives they participated in included recording nature observations, collecting water samples, or taking part in an annual bioblitz. Some specific initiatives the FOTMW citizen scientists also participate in include: the Lake Partner Program, Water Quality Initiative with Muskoka Lakes Association, Muskoka Watershed Council Algae Monitoring Program, eBird, District of Muskoka Benthic Biomonitoring, Program Feed Watch, FrogWatch, Whip-poor-will Survey, Christmas Bird Count and iNaturalist.

3. What age range are the people who participated?

While speaking to the participating citizen scientists, they were asked if they felt comfortable providing an age range of those who collected tree data. Many citizen scientists collected data alone, and the most common age for these individuals was over 51, at 88%. There was only 3% of citizen scientists who ranged in between ages 19-30 and 31-50, respectively (**Figure 23**). Approximately 6% of participants were under the age of 18, and these individuals were reported as being children or grandchildren assisting of the primary citizen scientist.

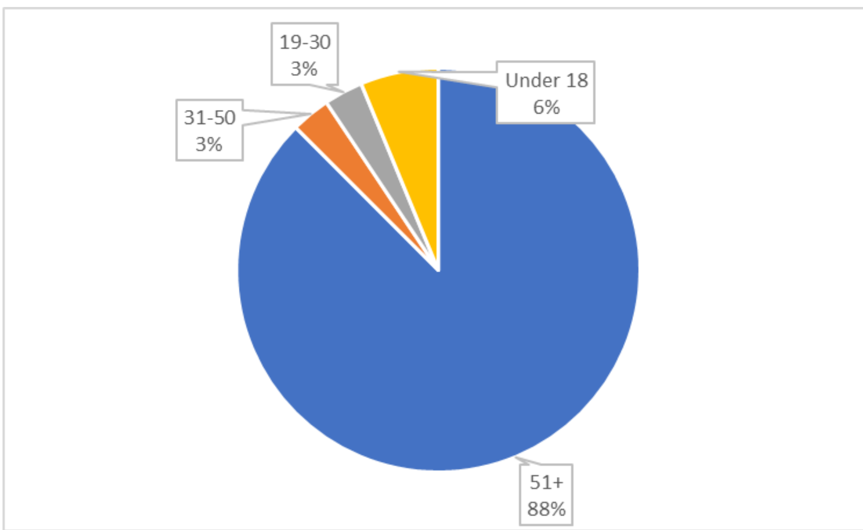

Figure 23: Pie chart illustrating the percentages of various age ranges represented by the participating citizen scientists.

4. What's the education level of the participants?

The survey revealed that most citizen scientists have taken post-secondary education (University and/or College), and many also have higher education (Master's or Doctoral). Specifically, one citizen scientist was a University of Toronto forestry professional, which strongly influenced their participation.

5. Was there anything that wasn't clear in the instructions or advice you have as the program moves forward?

The citizen scientists interviewed indicated that the main difficulties they had during the first two rounds of data collection related to comprehending the instructions, specifically relating to measuring tree height. Those who watched the instructional video had a much better understanding of how to measure tree height compared to those who did not watch it.

The second greatest concern related to how to submit the data. FOTMW did offer a webform on the website, but it did not work well for rural citizen scientists with slow internet speeds, or those with limited experience with technology. The webform was also designed in such a way that citizen scientists were required to duplicate data entries and notification was not provided when data was submitted, which was a source of frustration. Many citizen scientists submitted their data via email or in person to the FOTMW office. Otherwise, citizen scientists indicated the program was well organized and that they enjoyed participating.

5.0 Discussion and Next Steps

Overall, the feeling of those involved in the first year of the FOTMW Citizen Science program is that it went well. FOTMW staff and partners have gleaned new information, as well as affirmed some previous understandings about the benefits of residential wood ash in the Muskoka watershed (and beyond). The plan is to continue in 2023 with the current citizen scientists and potentially invite new participants to start monitoring their trees as well (there is waitlist for 2023). This will further build the data and enhance the understanding of the benefits of residential wood ash on calcium poor soils.

Much has been learned about developing and running a citizen science program, how to engage the community, and will of the public. Through the experience of the program, feedback from those involved, as well as from the phone survey and external research, several possible improvements, solutions and recommendations were made and are discussed below along with the citizen science program results and quality control assessment.

5.1 Program Design and Data Collection

5.1.1 Instruction and Training

As previously indicated, citizen scientists who viewed the training video found the written instructions easier to follow, therefore it is recommended that the link to the training video be added as the first step on the instructions sheet (**Appendix A**). FOTMW can also provide additional information on estimated time required to conduct data collection. For example, it is estimated that the whole data collection activity will initially take one hour, while subsequent collections will be no more than 30 minutes. This heightens transparency and sets expectations of citizen scientists, potentially increasing retainment.

5.1.2 Tree Selection

One of the first difficulties citizen scientists, and even FOTMW staff had was locating trees of the same species, similar size in the same environmental conditions which were greater than 6 m apart and in good health. Trees also needed to be over 10 cm in diameter, but this instruction was not on the main instructional page and only located on the tree identification guide. Some citizen scientists were aware of existing research illustrating that wood ash has been shown to increase the growth of samplings (Juice et al. 2006), and therefore they choose smaller trees.

Going forward, it is recommended that FOTMW include an acceptable range of distance between test and control trees, as well as clear instruction of participating tree diameter in both the written instructions and in an instructional video.

5.1.3 Tree Measurements

Many citizen scientists chose trees in dense forest plots, resulting in several issues being identified. First, there was difficulty distinguishing the study trees' canopies from the surrounding forest and therefore citizen scientists were not able to see the crowns for measuring height or percent canopy cover well. These difficulties may have contributed to the higher than expected change in average tree height, specifically for control trees. Secondly in the dense bush, citizen scientists found it difficult to take a photo of the full tree and several citizen scientists took a picture of only the meter stick at the base of the tree.

As a solution, it is suggested that FOTMW make a specific training video on measuring tree height when in a dense forest, as well as how to take the photo and an example of a photo can be included in the instructional package. It is also necessary to extend the length of the entire program, to allow for more opportunities to collect tree height during the same time of year, such as leaf off.

Tree diameter is also a common metric used to measure tree growth in forestry and scientific research. The common belief is that trees should be growing from the beginning of leaf out until the leaf off and that negative values of annual diameter measurements indicate the possibility of human error (i.e., mis-recording of measurements, typos or misinterpretation of field sheets). Decreases in diameter were noted for a number of study trees. Tree diameter can decrease during the growing season due to water stress, recovering the positive increments after the adverse climate conditions ended (Pastur et al, 2007). This could vary widely based on tree species and habitat type.

To address the seasonal and weather-dependent changes in tree diameter, it is recommended that the data collection period be much longer than several months and extend into multiple years and measurements be taken at a consistent time of year.

5.2 Soil Collection and Analysis

The volume of soil collected varied greatly between citizen scientists, suggesting that the amount of soil required was not clear in the instructions. Trent University School of the Environment laboratory recommended approximately half a small Ziploc bag per sample to ensure enough for analysis. As this information was provided in the online training video, as well as photo in the instructional package, it is suggested that additional outreach via one-on-one conversations, email or social media posts be made going forward.

Guidance was lacking on the importance of cleaning soil collection equipment (i.e., trowel) in the instructions provided to the citizen scientists. The importance of cleaning tools between test trees and rounds should be emphasized across all training platforms.

Soil samples submitted to the Trent University School of Environment laboratory were assessed for pH. Wood ash has a very high pH, meaning it is alkaline. The samples collected from the ash used in the citizen science samples had an average pH of approximately 13.81 indicating it has excellent acid neutralizing potential (Someshwar, 1996). The high alkalinity can be accredited to the large concentration of base cations, especially Ca, usually in the form of oxides, hydroxides and carbonates (Campbell, 1990 and James et al., 2014).

The percentage of organic matter increased in the soil between round one and round two slightly. An assumption as to why organic matter increased, is that the seasons changed from spring to summer during this time, when living organisms tend to grow and multiply. The results here, and those reported by others, suggest that the application of ash has little impact on the organic matter in the soil. For example, Reed et al. (2017) conducted a laboratory experiment assessing the impacts of biochar and wood ash on microbial activity and soil organic matter. They found that plant productivity was unaffected and wood ash promoted the retention of soil organic matter.

Nutrient concentrations in the soil samples were also analyzed, and included Ca, K, Mg and Na. As expected, given that there was an average time difference of only three to four months between data collection periods, little change in nutrient concentrations were noted. Though there was a slight increase in the mean values in all nutrients, except Na. The decrease in Na in the soil is a likely result of reducing the surface charge density of the soil and therefore causing exchange with other nutrients, specifically Ca. As described by Sommerfeldt (1984), as soil becomes less acid due to the application of Ca, the Na is exchanged for the Ca, and the Na is leached from the soil. Deighton et al. (2021) found that when ash was applied to central Ontario mineral soils (Haliburton Forest), Na declined through leaching by 14%-44% to below 30 cm in the soil profile.

The small increase in K concentration after ash was applied is consistent with results observed in similar studies, for example Ludwig et al., (2002) noted peak concentrations of K concentrations in mineral soil during the first year after application. The dissolution of wood ash is complicated as each cation dissolves at different rates, however K is the most soluble nutrient in wood ash followed by Ca and Mg (Meiwes, 1995). The soluble potassium hydroxide and potassium carbonate react rapidly with acids, like acidic soil, while less soluble calcium hydroxide and calcium carbonate react more slowly (Campbell, 1990); therefore, K concentrations increase rapidly after ash treatments (Meiwes, 1995).

Ash contains heavy metals, which have accumulated in wood over many decades from local soils, atmospheric deposition and acid rain. Soil also contains heavy metals, which may be further increased due to possible point-source pollution sources, such as proximity to a road, a landfill site, historic wood ash or compost piles. Acid rain further mobilized these metals, potentially elevating the concentrations found in firewood today. Despite the heavy metals in ash, the soil metal concentration results from the Citizen Science program suggest that ash application has had little impact on the soil between the time of baseline data collection and round two of data collection. This finding supports what Syeda and Conquer (in progress) found, where concentrations of several metals increased in the litter layer of soil, but not in the mineral soil of Muskoka sugar bushes two years after ash applications of four and 8 Tonnes/ha. Also, a study conducted by Deighton and Watmough (2020) in south-central Ontario noted that with a residential wood ash application of 6 Tonnes/ha there was minimal to no increase in soil metal concentrations.

Additionally, iron, manganese, boron and zinc are metals, but they are also micronutrients, and like people, trees need these to maintain good health. Trees then may stand to benefit from the addition of these "metals" to the soil (Pitman 2006; Augusto et al. 2008).

5.2.1 Foliage Collection and Analysis

Many trees participating in the Citizen Science program, especially those in dense forests, had canopies that were high and difficult for citizen scientists to reach for foliage collection. This was expected by program organizers, and FOTMW provided a 10 ft extendable tree pruner to citizen scientists or offered to collect foliage on behalf of the citizen scientist. In the future, citizen scientists will be reminded that FOTMW equipment and that staff are available to assist with foliage collection.

To accommodate for not being able to access foliage, some citizen scientists collected foliage from smaller trees that were within 3 m from the test tree. As these trees are smaller, it is expected that impacts to the nutrient and metal concentrations will occur faster than compared to the actual focus mature trees.

The chemical analysis of the foliage suggested little change between those trees that received ash, and those that did not receive ash. These results were expected because in most instances, the time between round one (when ash was spread) and round two (when foliage was collected) was approximately three or four months, and not sufficient time to see a reaction from the ash addition by the trees. Additional monitoring is suggested (a minimum of a third round of data collection). Similar research conducted in Muskoka maple sugar bushes using residential wood ash illustrates an increase in nutrients in mature tree foliage samples by year two by as much as 60% by year two (Syeda and Conquer (in progress)). If the Citizen Science program continues into summer 2023 and beyond, an increase in nutrients concentration in the foliage is expected.

Unlike the nutrient concentrations between the test and control trees, there did appear to be a difference in the concentrations of the heavy metals arsenic and aluminum in the foliage samples. These metal concentrations were lower in the trees that received ash. The hypothesis behind this is that the rapid change in pH in the soil from the residential wood ash decreases the availability of heavy metals (Tsai and Schmidt, 2021) and in poorly buffered soils, positively charged hydrogen loading can enhance dissolution of reactive forms of soil Al, exacerbating base cation leaching from the vegetation (Lawrence et al. 1995). To see such a fast response in the citizen scientist's trees was unexpected, so additional analysis of foliage samples is suggested.

5.3 Data Submission

A concern regarding data submission found during the first year of the Citizen Science program is that some citizen scientists submitted their data and soil or foliage samples after the proposed timeline (**Table 5**). As this was the first year of the program, there were participants who joined the program late, and therefore some round one data was not submitted until the beginning of July. For the second round of data, citizen scientists were contacted by phone, email and/or through social media requesting data be submitted during the second week of August. Most citizen scientists complied with this request, though for various reasons including being away from home or ill, some did not.

Going forward, FOTMW will ensure to provide deadlines for when field sheets, photos and samples should be returned. This will help improve organization and accuracy of analysis. To further assist in data and sample organization, each citizen scientist will be provided with their unique identification number (i.e., CS 45) which will appear on field sheets, photos and sample submissions. Additionally, in the future all field sheets will be digitized files. Consistency of using an identification number will also limit confusion when different citizen scientists act as "data recorders" from round to round, which when done makes it difficult to match submissions.

Citizen scientists were left to label their trees as they desired, though the suggestion of Tree 1: Ash (test tree), and Tree 2: No Ash (control tree) was provided. In some instances, this labeling scheme was reversed, or trees were given letters or names (i.e., A, B or T(test) or C (for control), etc.). This variability led to some confusion, especially if a citizen scientist was assessing more than one set of trees. If the Citizen Science program expands in 2023, it is suggested that labeling instructions are provided to improve consistency.

During the quality control assessment portion of the program, there was some confusion on the part of the citizen scientists as to what the intention of Kira Nixon's research was. Some citizen scientists were under the impression that Kira was collecting their second round of data for them and not running a parallel experiment. This led to some not taking measurements. These citizen scientists were contacted by phone and/or email shortly after Kira visited their properties to inform them of the purpose of the parallel study. Once they gleaned a better understanding of the purpose of the quality control assessment, the citizen scientists collected and submitted their data.

5.4 About the Citizen Science Participants

As determined through the FOTMW phone survey of citizen scientists, most of those participating are over the age of 51. FOTMW has struggled to engage people younger than 50 with this program and others. There are many reasons for this issue, including the demographics of the area, which has a large percentage of retired individuals who have time and resources to put towards volunteering. People under the age of 50 are often working, in school or have young families. Additionally, many of the FOTMW board and those currently involved with the organization are over the age of 50, and are encouraging their friends and families to take part, further involving people with similar interests and of a similar age.

West et al. (2021) assessed the motivations as to why people volunteer as citizen scientists and determined that the two dominating values for participating are concern for others or concern for the environment, which were indicated by a high proportion of older people. The third motivating factor was to learn something or further one's career, which was more associated with a younger age group.

West et al. (2021) also make a number of recommendations on recruiting and retaining citizen scientists. One includes tailoring recruitment materials and methods to potential volunteer's values. Others are to design variations of materials to appeal to a range of motivations and involve community leaders associated within a target demographic or ethnic groups, such as well-known high school coaches to inspire young people.

Another suggestion to better engage a younger demographic is to embrace technology, such as the use of smart phone apps. Aristeidou et al. (2021) found that young volunteers with long lasting participation with the iNaturalist app had “research grade” observations, and the involvement of professional scientists can increase accessibility to biodiversity research for youth. Involving young people can aid in sustaining a program or organization, like FOTMW whom depends on volunteers.

The type of volunteering opportunities with FOTMW, such as the citizen science program are relatively time demanding, which may have deterred some people from participating. Providing a variety of volunteer opportunities with different time commitments may attract more people. To further engage the community, as well as to enhance our understanding of residential wood ash, a small additional citizen science program has recently been developed (February 2023) at the FOTMW. This program involves collecting data from private property owners who spread their own wood ash on their woodlots in response to what they have learned from the AshMuskoka program, or because it has been a cultural practice in their family. The program hopes to obtain an estimate of how much of Muskoka forests are being restored by people spreading ash on their own properties.

To further understand the motivations and values of residents in Muskoka and as to why they may or may not participate in the Citizen Science program, or similar initiatives, a Trent University Community Based Research student, Serena Karevich, under the supervision of Dr. Paul Shaffer is conducting in-depth interviews with current citizen scientists, as well as with individuals who expressed interest in the program, but did not participate. Her results, which will be presented in spring 2023, will help to develop a stronger recruiting and retainment plan for the Citizen Science program going forward.

5.5 Quality Control Assessment

In parallel with the second round of data collection, Trent University student, Kira Nixon collected the same data from the same trees from most of the participating properties. Some properties were not included because they did not include soil and foliage collection, the property was inaccessible, or the property owner was unable to accommodate the assessment during that time.

The metrics and protocol were the same between the two studies, except the quality control assessment was completed by a single person (Kira Nixon), with assistance from the FOTMW summer student and traditional forestry equipment was used, including a diameter at breast height measure tape, clinometer, densiometer and auger.

The results from the quality control assessment indicate that the citizen science soil samples represented the pH accurately but tended to have a slightly higher percentage of organic matter. This indicates that the citizen science soil samples collected may have been shallower. The citizen scientists used a small plastic hand trowel which some found difficult to break into the soil and therefore did not go deep into the soil. The metal auger was able to break through the surface layer and collect a sample relatively quickly and easily.

The citizen scientists' measurements of tree height and tree diameter were closely correlated to those from the quality control assessment. This indicates that extensive training, experience or expensive equipment are not required to obtain valuable information for tree height and tree diameter.

Alternatively, canopy cover measurements between the two assessments differed significantly. There are many possible reasons for this, including that this is a relatively subjective metric and can change greatly based on weather, location of the observer and date of collection. The proximity of other trees can also influence one's perception of canopy density. A densitometer may also not be the best tool to estimate tree canopy cover for a single tree. Densitometers are commonly used in forestry in combination with linear transects to estimate canopy closure for entire forest stands (Stumpf, 1993). FOTMW staff should consider removing canopy cover as a metric or determine a different, more accurate method going forward.

6.0 Conclusion

The FOTMW Citizen Science program is believed to be a unique program. There are no known similar studies where citizen scientists actively conduct an experiment on their property while restoring the local watershed. Most citizen science programs involve making observations or collecting data, such as documenting bird sightings. This program involves collecting data for a watershed-scale study, running individual experiments while working to restore forest health.

Incorporating citizen science into the FOTMW ASHMuskoka program unites environmentally minded citizens. By introducing citizens in the community to a potential issue and then offering them a solution - something achievable within this lifetime, at a low cost while aligning with their values, encourages people to participate.

The collection of data is widespread and therefore useful not only for understanding the benefits of residential wood ash, but also for evaluating and monitoring the program itself. This study will provide a baseline or future monitoring for the individual trees on properties of citizen scientists as well as for large scale future regional spreading of ash in forests which are still feeling the impacts of acid rain and resulting calcium loss.

It is the aim of FOTMW to continue to garner support of the public and increase the sense of ownership over their micro experiments and the full watershed, as well as to introduce them to any emerging issues and possible ways to be involved in solutions. Through this engagement of citizen scientists and the community, pressure may increase on the provincial government to reclassify residential wood ash as a forest supplement allowing FOTMW and others to apply it widely. The Government of Ontario currently considers residential wood ash as hazardous waste, limiting its use as a forest restoration and climate mitigation tool.

As the end users of the data, FOTMW recognizes how essential citizen scientists are to operating this program. The hope is that the relationship is mutually beneficial and citizen scientists develop new skills, find enjoyment, and have interest in contributing to a large-scale environmental solution and research initiative. Furthermore, through this research and other on-going environmental monitoring FOTMW hopes to reach the wider scientific community, local and provincial decision makers, as well as the public about the calcium decline problem and the solution of residential wood ash.

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Appendices

Appendix A – Outreach materials

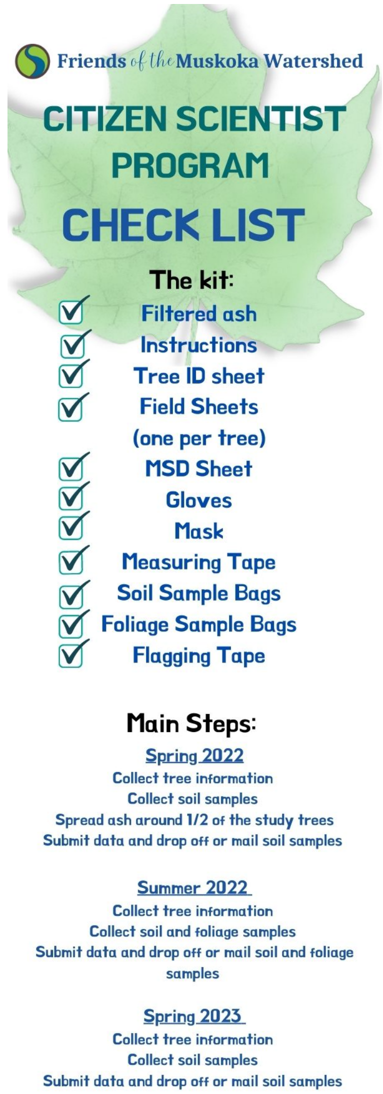

BECOME
A CITIZEN SCIENTIST
Do your part. Keep the forests healthy!
1. Contact our office for more information. Registration will be on our website
2. Retrieve your ash and citizen science package
3. Apply your ash according to the instructions provided
4. Fill out our quick and easy field sheets and mail your samples in our prepaid mail parcels
SPREADING ASH HELPS THE WATERSHED
1. Raises nutrients to pre-acid rain levels in the soil
2. Aids in the health and growth of your trees
3. Helps the fight against climate change
Contact Katie@fotmw.org
Friends of the Muskoka Watershed


Friends of the Muskoka Watershed
Citizen Science
Sr. Sap Inspector
Recording Sap Flow
Measuring Diameter
Collecting Soil Samples
Citizen Science Ash and Kit
SAVE YOUR ASH
MUSKOKA


Volunteers
Ash Filtering
Friends of the Muskoka Watershed
ASHMUSKOKA
Spreading Ash
Donated Ash
SAVE YOUR ASH
ASHMUSKOKA


Muskoka
Scientists Measuring Impacts of Ash
Friends of the Muskoka Watershed
Sap Quantity
Some Heavy Lifting!
Rosseau Lake College Helping

Appendix B – Citizen Science Kit



Friends of the Muskoka Watershed

CITIZEN SCIENTIST PROGRAM

CHECK LIST

The kit:

- ☑ Filtered ash
- ☑ Instructions
- ☑ Tree ID sheet
- ☑ Field Sheets (one per tree)
- ☑ MSD Sheet
- ☑ Gloves
- ☑ Mask
- ☑ Measuring Tape
- ☑ Soil Sample Bags
- ☑ Foliage Sample Bags
- ☑ Flagging Tape

Main Steps:

Spring 2022
Collect tree information
Collect soil samples
Spread ash around 1/2 of the study trees
Submit data and drop off or mail soil samples

Summer 2022
Collect tree information
Collect soil and foliage samples
Submit data and drop off or mail soil and foliage samples

Spring 2023
Collect tree information
Collect soil samples
Submit data and drop off or mail soil samples

Friends of the Muskoka Watershed	Material Safety Data Sheet (MSDS)	Doc No:	1
Wood Ash		Doc Type:	MSDS
	Revised for Citizen Science Program	Date issued	2022-04-14

1. Identification

In this section we give the product name which will be listed on labels

Product Name: Wood Ash (untreated)
Class: Residential (non-industrial)
Synonyms: Ash, fly wood ash
MSDS number: N/A
Product Use Description: soil amendment, scientific research
Company: Friends of the Muskoka Watershed
Main Telephone Number: 705 640 0948 or 705 646 0111
Website: www.fotmw.org
Address: 126 Kimberely Ave, PO Box 416 Bracebridge ON P1L 1T7

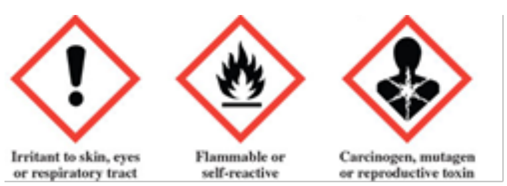
2. Hazards

This section identifies the hazards of the chemical presented on the MSDS and the appropriate warning information associated with those hazards. The different classification of the numbering starts at 1 (most hazardous) and ends at 5 (least hazardous)

Classifications

Flammable: Category 3
Aspiration Hazard: Category 5
Carcinogenicity: Category 5
Specific Target Organ Toxicity (Repeated Exposure): Category 3
Specific Target Organ Toxicity (Single Exposure): Category 3
Skin Irritation: Category 2
Eye Irritation: Category 2
Chronic Aquatic Toxicity: Category 3

Pictograms:



3. Composition and Information on Ingredients

This section identifies the ingredient(s) contained in the product indicated on the MSDS, including impurities and stabilizing additives. This section includes information on substances, mixtures, and all chemicals where a trade secret is claimed.

Main Ingredients:
Mixture of oxides and trace elements varying from fused or vitrified to fine granular solids.

4. First Aid Measures

This section describes the initial care that should be given by untrained responders to an individual who has been exposed to the chemical.

Effects of Overexposure:
Wood ash, depending on the species, may cause allergic contact dermatitis and respiratory sensitization with prolonged, repetitive contact or exposure to elevated dust levels. Wet wood dust is corrosive and may cause burning of the eyes and skin.

Medical Conditions Prone to Aggravation by Exposure:
If an allergy such as dermatitis, asthma, or bronchitis develops it may be necessary to remove a sensitive individual from further exposure to wood ash.

Emergency and First Aid Procedures:
Inhalation: Move individual to fresh air if respiratory symptoms are experienced. Seek medical help if persistent irritation, severe coughing, breathing difficulty or other serious symptoms occur.
Eye Contact: Exposure to wood ash may cause immediate or delayed irritation or inflammation. Wet wood ash can become corrosive and cause burning of the eyes. Immediately rinse eyes with plenty of water. If irritation persists get medical attention.
Ingestion: Rinse mouth and drink a glass of water.

Use of appropriate PPE can limit contact and includes long pants, sleeves, gloves, eye shields, and respirator.

In the case of overexposure, allergic reaction, or other first aid emergency call **911** or Poison Control at **1-800-268-9017.**

5. Handling and Storage

This section provides guidance on the safe handling practices and conditions for safe storage of chemicals.

Handling: Avoid eye contact. Avoid prolonged and repeated contact with skin. Avoid prolonged or repeated breathing of wood ash. Use property PPE while handling wet wood ash.
Storage: Dried wood ash may pose a combustible hazard. Keep away from ignition sources. Store dry wood ash in a well-ventilated, cool, dry place away from open flame.

6. Exposure Controls/ Personal Protection

This section indicates the exposure limits, engineering controls and personal protective measures that can be used to minimize worker exposure.

Respiratory Protection: Use filtering face approved dust respirator
Eye Shields: Eye shields are required
Protective Gloves: Recommended to reduce skin contact
Other Protective Equipment: No special clothing required unless excessive wood ash is associated with handling. Use clean body-covering work clothing.
Ventilation: Whenever possible local exhaust ventilation should be used. The design and operation of exhaust system should consider the possibility of explosive concentrations of wood ash within the system.
Hygienic practices: Follow good hygienic practices

7. Ecological Information (non-mandatory)

This section provides information to evaluate the environmental impact of the chemical(s) if it were released to the environment.

No data available. Wood ash could be utilized as an amendment to add calcium, potassium, and magnesium to the soil. Heavy metals are within normal ranges for plants growing on areas treated with wood ash.

8. **Disposal Considerations (non-mandatory)**
This section provides guidance on proper disposal practices, recycling or reclamation of the chemical(s) or its container, and safe handling practices.
Dryland disposal is acceptable and is not considered a hazardous waste. Do not dispose in areas of high ground water or where surface runoff is adjacent to waterways. Follow applicable provincial and local regulations.

Field Sheet

One sheet per tree

Citizen Scientist(s): ____________________

Date(Y/M/D): ____________________ Time (am/pm): ____________________

Address: ____________________

Latitude/Longitude or UTMs: ____________________

Weather (% sun/cloud): ____________________

Temperature (°C): ____________________

Description of area (e.g., forest, lawn, hedge row, etc.): ____________________

____________________ Photo of area ☐

Tree #: ____________________ Species: ____________________

Tree Type (ash added or ash not added): ____________________

If application tree, indicate date ash was applied(Y/M/D): ____________________

Tree height (m): ____________________

Tree Circumference (cm): __________ ÷3.1416= __________ Diameter (cm)

Canopy Cover (%): ____________________

Soil collected: ☐ Leaves collected: ☐

Photo of canopy: ☐ Photo of tree with metre stick: ☐

Be sure to follow training video or instructional package when collecting tree data at www.fotmw.org

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Tree Health (e.g., insects, fungi, split, swelling, cankers, etc.):

____

% deadwood in tree canopy <25% ☐ 25-50% ☐ >50% ☐

Additional Comments/Observations:

____

____

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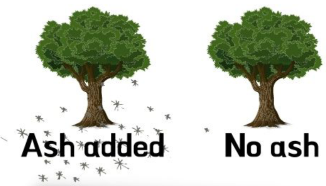
CITIZEN SCIENTIST INSTRUCTIONS

126 Kimberley Ave Bracebridge ON P1L 1Z9 www.fotmw.org

Instructional video found at: www.fotmw.org

Step 1: Locate Study Trees

Select and label two or more trees of the same species, similar size and similar environment. Half the trees will receive ash.



Step 2: Data Collection

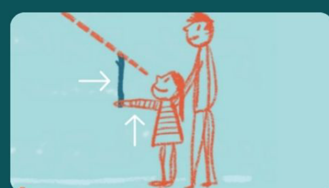
Measure diameter, height and canopy cover and tree health of each tree

Trunk Diameter

1. Mark the trunk at 1.37 m (4 ½ ft) above ground level
2. Wrap the measuring tape around the tree at 1.37 m. Measure the circumference of the tree
3. Use a calculator to divide the circumference by 3.1416. This will give you the diameter – record it on the hard or digital field sheet

Tree Height

1.Place a metre stick vertically against the truck of the tree and take a picture. Make sure to submit the photo with your data



2. Backup to where you can see the full tree. Measure your arm from shoulder to hand and grip the metre stick at this measurement. Hold the metre stick in your outstretched arm parallel to the tree

3. Envision an imaginary line running from your eye to the top of the metre stick

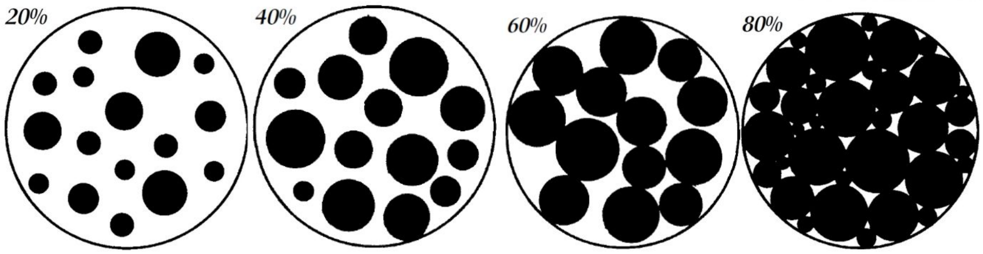
4. Move forwards or backwards until the top of the tree aligns with the top of the metre stick, creating a right triangle

5. Measure the distance from the tree to your location

6. Record the height on your digital or hard copy field sheet. Repeat for each tree.

Percent Canopy Cover

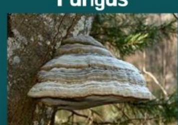
1.Stand directly under the tree and look up. Using the visual percentage cover below as a guide, estimate the percent of leaves or needles blocking the sunlight
2.Remember to make note of where you are standing, as you may be returning
3.Record the percent canopy cover on the digital or hard copy field sheet



Tree Health

Note the following and take photos:
1.If the tree is straight, angled, forked, or swelling at the bottom, the is any fungus or insect infestations and if the tree split (frost crack) or has cankers, galls or burls
3. Estimate the percentage of deadwood, less that 25%, 25-50% or greater than 50%
4. The condition of leaves/needle (spots, holes, discolouration)

Fungus

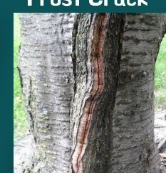


Leaf Spots

Burl

Gall

Frost Crack



Step 3: Spread Ash

1.Measure 3 m out from the trunk in all directions
2. Holding the bucket of ash under an arm scoop out and sprinkle ash on the ground within the 3m circle

Step 4: Data Submission

Submit all data and photos to the Friends of the Muskoka Watershed Citizen Science webpage

Repeat

Repeat steps 2 -5 in July and spring 2023

Video: www.fotmw.org

CITIZEN SCIENTIST INSTRUCTIONS

SOIL AND FOLIAGE COLLECTION

Some Citizen Scientists are asked to collect soil and foliage Soil will be collected in May, July and May 2023 and foliage only in July

Step 5: Soil Collection

1.Collect samples from no further than 3 m from the trunk
2.From the surface of ground, use a hand trowel or spade to dig to a depth of 10 cm. Place that 10 cm soil section in a Ziplock bag
3.Collect 10cm of soil from two other locations and place in the same Ziplock bag (3 soil pits, placed in same bag)
4.Seal the bag and label with your name, the date, sample location and tree number and tree type (ash or no ash)
5.Repeat soil collection for each tree participating in the study and be sure to label each bag
6.Place samples in package and keep in a cool dry place until they are mailed or dropped off to the Friends of the Muskoka Watershed

Step 6: Foliage Collection

Foliage collection may be inaccessible in some instances.
FOTMW staff may be able to help - please contact us.

1.Using garden snips or pole pruners, reach to the middle of the crown and snip clusters of leaves or small conifer branches (the new growth/ tips are required) from various locations around the tree (i.e., three branches or leaf clusters)
2. Place three conifer branches or leaf clusters in a Ziplock bag. Be sure to label Ziplock bag with your name, the date, sample location, tree number and tree type (ash or no ash)
3. Repeat steps 1 and 2 for all participating trees
4.Place samples in package and store in a cool dark place until they are mailed or dropped off to the Friends of the Muskoka Watershed

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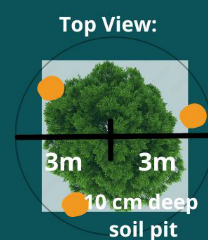

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Friends of the Muskoka Watershed

TREE SPECIES

BECOME A CITIZEN SCIENTIST

Study trees are to be common native species, over 31.42 cm in circumference (10 cm in diameter) and in good health. A minimum of two trees of the same species are required. Native tree species include:

Balsam poplar
(Populus balsamifera)

Basswood
(Tilia americana)

Black ash
(Fraxinus nigra)

Black cherry
(Prunus serotina)

Black walnut
(Juglans nigra)

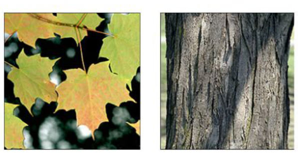
Ironwoon
(Ostrya virginiana)

Largetooth Aspen
(Populus grandidentata)

Red Maple
(Acer rubrum)

Red Oak
(Quercus rubra)

Sugar Maple
(Acer saccharum)



White Ash
(Fraxinus americana)

White birch
(Betula papyrifera)

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Friends of the Muskoka Watershed

TREE SPECIES

BECOME A CITIZEN SCIENTIST

Yellow birch
(Betula alleghaniensis)

Balsam fir
(Abies balsamea)

Black spruce
(Picea mariana)

Eastern hemlock
(Tsuga canadensis)

Eastern white cedar
(Thuja occidentalis)

Eastern white pine
(Pinus strobus)

Jack pine
(Pinus banksiana)

Red pine
(Pinus resinosa)

Tamarack
(Larix laricina)

White Spruce
(Picea glauca)

A minimum of two trees, of similar size, in a similar location and of the same species is required. One tree will be treated with the provided wood ash (the test tree), and the other tree will not (the control tree). Be sure to mark your trees.

There are many tree identification books, some include:

Lone Pine Trees of Ontario: Including Tall Shrubs
by Linda Kershaw
Peterson Field Guide Trees and Shrubs
by George A Petrides
Trees of Algonquin Provincial Park
sold by Friends of Algonquin Park

Appendix C – Quality Control Assessment Materials

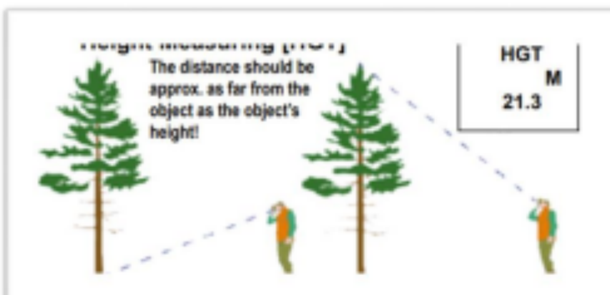
Quality Control - Citizen Science Protocol

1. **Locate study trees on property.**

   Trees are located through the direction of the Citizen Scientists. Trees should be marked and/or flagged. If they are not marked or flagged and labeled – do so.

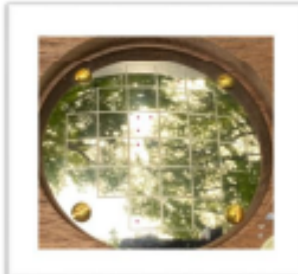
2. Document exact **location** of tree using a hand-held GPS unit (accuracy 5-10m)

3. Use **clinometer** (model ESIID) to find height of tree:
   a. Measure out how far you are from the tree using a long measuring tape, try to stand as far from the tree as it is tall
   b. Press "ON" once, you should see "DIST" when you look through the clinometer
   c. Using the "+" and "–" buttons on the clinometer to enter in the distance of you to the tree
   d. Press "ON" one time, you should see "%" and then look down at the base of the tree
   e. Hold "ON" until you hear a short sound signal
   f. After the signal, look at the top of the tree. If the tree has a thick deciduous canopy, project through the canopy rather than to the top.
   g. The height should be displayed on the clinometer beside "HGT" (all units are in meters)
   h. Record the final height

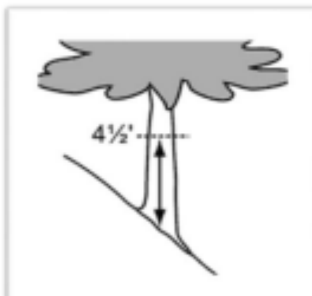


4. Use the **densiometer** to measure canopy density:
   a. With your back against the tree, hold the instrument at elbow height just far enough away so that your head is just outside the grid
   b. Make sure that the densiometer is flat by aligning the clear sphere to the black circle in the bottom right corner
   c. Each square is divided evenly into 4 quadrants, each of those 4 quadrants represents a dot
   d. Count the number of dots that are NOT covered by canopy
   e. Multiply the number of dots by 1.04 to get the percent of overhead NOT covered by canopy (96 dots x 1.04 = 100%)
   f. Record the percent of overhead not covered by canopy down
   g. Repeat these steps facing a different cardinal direction (north, east, south and west with your back against the tree) until you've collected data from all 4 directions, then average the final percentages

   h. Record the final percentage



5. Use **diameter tape** at breast height to measure tree diameter
   a. At breast height (1.37 m), wrap the diameter tape around the tree
   b. If the tree is on a slope, make sure to average breast height from above and below the tree
   c. Record the diameter



6. **Collect soil samples:**
   a. Choose 3 locations within 3 meters away from the trunk of the tree
   b. Use a trowel or spade to dig to a depth of 10cm
   c. Place all three soil sample in the same labeled bag and seal
   d. Repeat for every tree participating in study
7. **Collect foliage samples (only if needed by the CS):**
   a. Using loppers or snips, cut off 3 clusters of leave/needles as close to the middle of the canopy as possible
   b. Place the 3 clusters into a single labeled bag and seal
8. **Measure the tree health**
   a. Note if tree is leaning or has twists in trunk
   b. Look for defects in the colour and shape of foliage

c. Look for insect damage

d. Look for mushrooms and fungi on the trunk and base of tree

e. Look for burl, canker, or galls

CS Quality Control Field Sheet

One sheet per tree

Surveyor(s) ________________________ CS#: ____

CS name: __________ Date(Y/M/D): ________ Time (am/pm): ______

Address: ________________________

Latitude/Longitude or UTMs: ________________________

Weather (% sun/cloud): ________________________

Temperature (°C): __________

Description of area (e.g., forest, lawn, hedge row, etc.): __________

____

Photo of area ☐

Tree #: __________ Species: ________________________

Tree Type (ash added or ash not added): ________________

If application tree, indicate date ash was applied(Y/M/D): ________________

Tree height (m): ______________

Canopy Cover (# of dots not covered by canopy):

North: ______ East: ______ South: ______ West: __________

______________ X 1.04 = ______________

Average number of dots: Percent of Uncovered Canopy:

Tree Diametre (cm): ________________________

Soil collected ☐ Foliage collected ☐

Photo of canopy ☐ Photo of full tree with metre stick ☐

Tree Health Comments (cankers, burls, frost cracks):

____

____

% deadwood in tree canopy <25% ☐ 25-50% ☐ >50% ☐

Additional Comments/Observations:

____

____

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Appendix D – The Ten Principles of Citizen Science

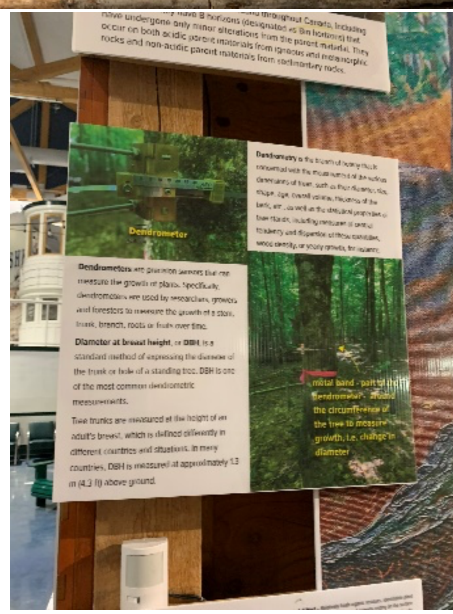
The Ten Principles of Citizen Science

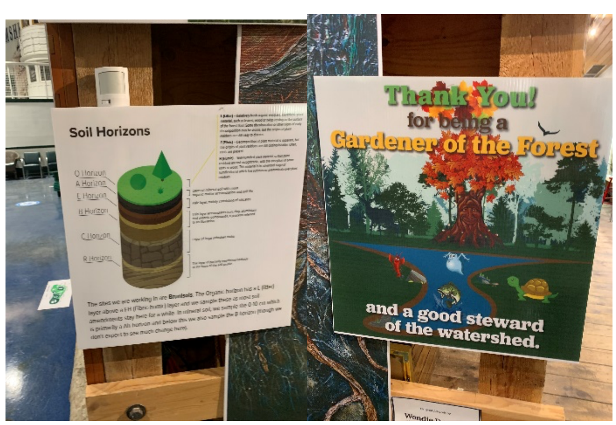
Citizen science is a flexible concept which can be adapted and applied within diverse situations and disciplines. The statements below were developed by the 'Sharing best practice and building capacity' working group of the European Citizen Science Association, led by the Natural History Museum London with input from many members of the Association, to set out some of the key principles which as a community we believe underlie good practice in citizen science.

1. Citizen science projects actively involve citizens in scientific endeavor that generates new knowledge or understanding. Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.
2. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions or environmental policy.
3. Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g. to address local, national and international issues, and through that, the potential to influence policy.
4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analyzing data, and communicating the results.
5. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes are.
6. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for. However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratization of science.
7. Citizen science project data and meta-data are made publicly available and where possible, results are published in an open access format. Data sharing may occur during or after the project unless there are security or privacy concerns that prevent this.
8. Citizen scientists are acknowledged in project results and publications.
9. Citizen science programs are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.
10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.

September 2015, London

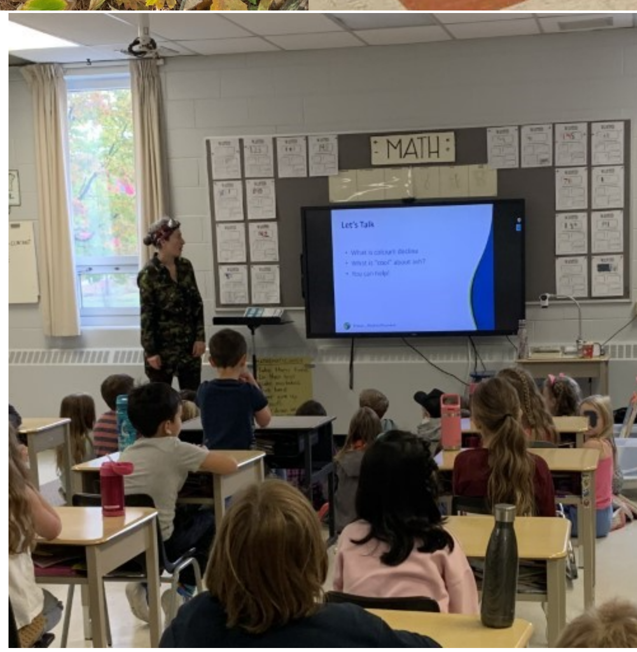
Appendix E – Display at Gravenhurst Steamships and Discovery Centre

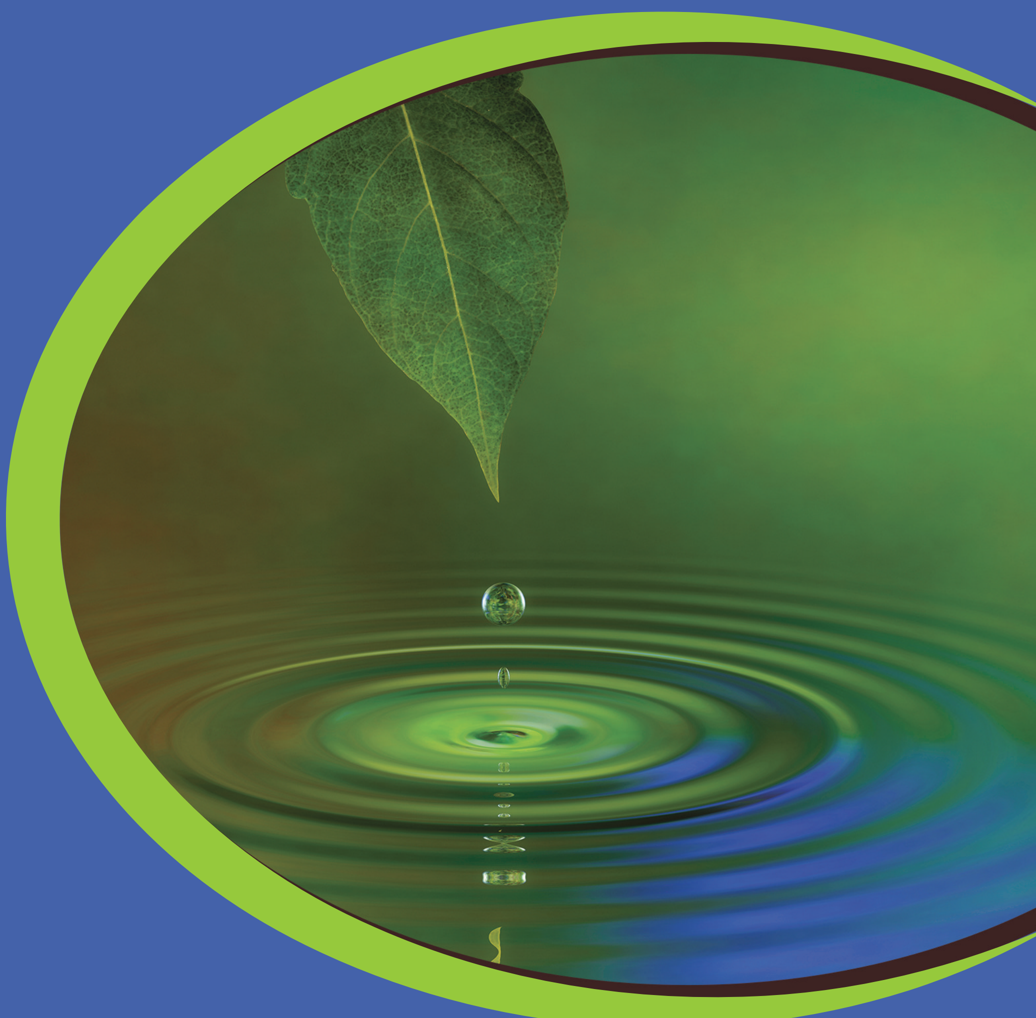




Appendix F – Photos from Events and Presentations


LEGION
Date that is collected:
CITIZEN SCIENTIST
INSTRUCTIONS


MATH
Let's Talk



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