NUTRIENT MANAGEMENT IN FOREST MANAGEMENT PLANNING

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Abstract

Nutrient Management in Forest Management Planning

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This research evaluates the degree to which nutrients are included in forest management planning. First, the thesis evaluates forest management plans globally to determine the extent to which countries consider key nutrients (N, P, Ca, Mg and K) in their forest management plans. This is followed by a case study in Muskoka, Ontario, of a pilot wood ash recycling program with the goal of restoring calcium and other nutrients in the forests. This pilot project aims to evaluate the benefits of using wood ash as a forest fertilizer, as evidence that the practice merits approval by the provincial government. A text-based literature analysis of current regulations and the Environmental Compliance Approval (appendix 3) submitted to the provincial government for this project was undertaken as this project is currently a not approved practice by the government. Interviews were completed with key stakeholders and experts in the field to understand the benefits and policy hurdles of this program. Based on the documents analysed in this study, it was concluded that both globally and in Canada, nutrient management is not the focus of forest management plans. With respect to the pilot wood ash program, this thesis concluded that there is not enough data published to make the government departments comfortable with approving wood ash as a soil fertilizer. Nevertheless, there is much community support and many perceived benefits to this project, but more supporting data is needed.

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Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

1.1 Positionality Statement and Underlying Assumptions

I grew up in an urban area in the city of Ottawa. I camped every weekend for most of my childhood, where I developed my love for nature and appreciation for maintaining the ecosystems that I existed in. I spent much of my time outside and was never afraid to play in the dirt or climb trees. I further developed my love for nature in elementary school when we had a presentation on the lifestyle of Owls and the importance of trees in their day-to-day life. That started me on my path of environmental education. I identify as white, middle class, from an urban environment, and well educated, which has allowed me certain opportunities, including conducting this research.

My education thus far has been in a Bachelor of Environmental Studies with a minor in Sociology from Carleton University. I understand the need for a societal approach to fix issues that are present in our community and environment. I viewed the world through a socio-economic lens, emphasizing the inequalities in our society regarding access to resources and environmental degradation. My environmental education informed me about the issues that currently exist in our society and the degradation that humans have caused to our world, with the lasting effects on several ecosystems. I felt that I needed to find societal solutions that could be engrained in our political structure to reduce inequalities and create equal access to natural resources. I focused my senior studies on policy implications of changing the environmental sector, with an emphasis on natural resources.

My professional background in the environmental field comes from two internships. I worked for a non-government organization (NGO), which taught me that environmental restoration and protection needed to be fought for. These internships also changed my perspective on the work that an NGO must do to create change and the need for community champions to make change in this field.

In this research, I consider myself an outsider as I did not grow up in a rural area or with acres of land to manage or in an industry that relies on forest products for economic survival. I understand that my previous biases of finding societal solutions to environmental issues could influence my research outcomes. I have tried to separate myself from the research and view all sides of the findings and how different groups could view the topic.

1.2 Research Questions

This thesis addresses two primary questions:

1. To what extent are nutrients considered in national and international forest management plans?

2. What are the barriers and restrictions to creating a residential wood-ash program and using wood-ash as a forest soil amendment in Muskoka, Ontario?

The research questions were developed to help understand nutrient management in forests at the global scale and how a local residential wood-ash recycling program could be developed to address nutrient issues in Muskoka, Ontario.

1.3 Literature Review

1.3.1 Canadian Forest Cover

In, 2017, Canada reportedly had 347 million hectares of forested land, (Natural Resources Canada, 2019) representing around 9% of the world's total forest area (Allen, 2001). With this abundance of forest resources, Canada is the world's largest producer of forest products. The forestry industry is an essential part of the Canadian economy, with timber harvesting especially significant in the boreal forest (Chaste et al., 2019). Canada's forests have many social, economic, and environmental benefits, and any changes in the forest ecosystem can affect wildlife, biodiversity, and ecosystem services (Natural Resources Canada, 2019). Further, forests play a significant role in providing water and air purification, as well as carbon (C) sequestration (Natural Resources Canada, 2019).

Forests store more C than many other ecosystems and need to be managed to help mitigate climate change effects (Natural Resources Canada, 2019). A loss of forest area will consequentially result in the decrease in C sequestration potential. Therefore, it is vital to preserve Canadian forests to help meet global targets such as the Sustainable Development Goals and the Paris Agreement.

Nationally, the forested area in Canada is quite stable but this varies by province/territory. The highest deforestation rates in Canada are currently taking place in the Prairies, mainly due to the conversion of forests into agricultural lands (Natural Resources Canada, 2019). The leading cause of deforestation in Canada include mining, oil, and gas production (37%), agricultural land conversions (35%), built-up infrastructure (18%), hydroelectricity (6%), and forestry (4%) (Natural Resources Canada, 2019). This equates to approximately 35,000 hectares a year lost nationally to

deforestation (Natural Resources Canada, 2019). To meet the international targets and goals surrounding greenhouse gas emissions, reducing Canadian deforestation rates is important. Of Canada's 347 million hectares of forest, 200 million hectares are managed with long-term management plans spanning over ten years or more (Natural Resources Canada, 2019). This land includes areas controlled for timber production and forest land managed in protected areas.

1.3.2 Sustainable Forestry

Canada

In Canada, provinces and territories have jurisdiction over most of the forests (Natural Resources Canada, 2020a) and each province or territory has its own laws and regulations (Natural Resources Canada, 2020a). However, each province or territory aims to support sustainable forest management principles, developed in consultation with the public, industries, and interested parties, and grounded in scientific research (Natural Resources Canada, 2020a). Most of Canada's forest land, about 94%, is publicly owned and managed by provincial, territorial, and federal governments, whereas 6% is privately owned (Figure 1.1) (Natural Resources Canada, 2020b). Approximately 90% of Canada's forests are owned by provincial and territorial governments **(**Natural Resources Canada, 2020b). The 4% of forest owned by the federal government is mainly national parks, lands owned by the Department of National Defence, and lands held in reserves for or otherwise controlled by, Aboriginal Peoples **(**Natural Resources Canada, 2020b). Private forest lands are typically small family-owned forests and woodlots and large forests owned by forest companies (Natural Resources Canada, 2020b).

The forest laws must address social, economic, and environmental needs (Natural Resources Canada, 2020a). These include land use planning, Aboriginal interests, wildlife habitat protection, regulating timber harvesting, and establishing practices to ensure forest regeneration (Natural Resources Canada, 2020a).

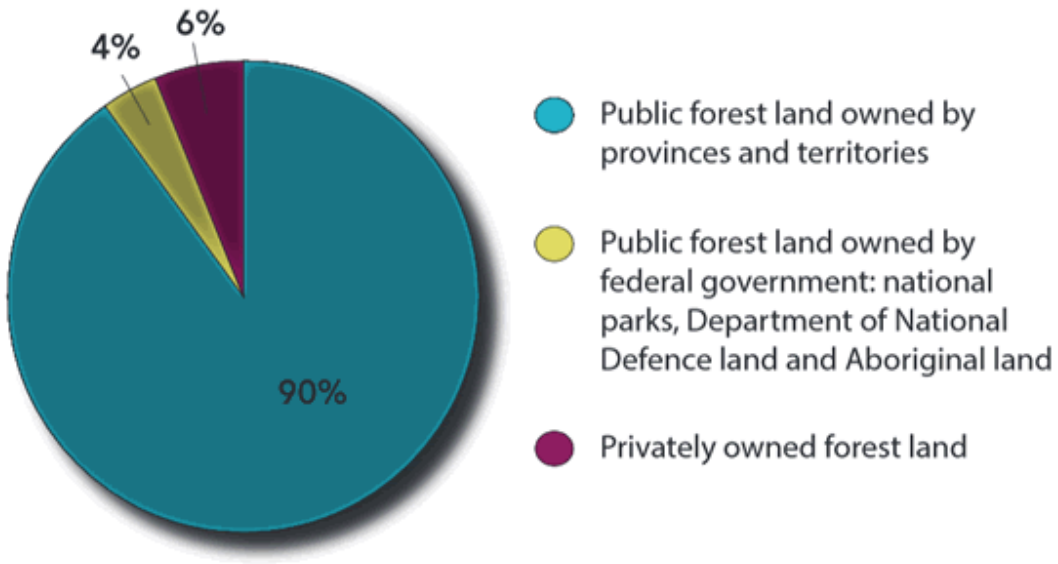

Figure 1.1
Overview of Forest Land Ownership in Canada
(Natural Resources Canada, 2020b).

Forest management planning is the primary tool used to ensure that publicly owned forests are sustainable and healthy (Natural Resources Canada, 2020c). Forest management plans must be approved before harvesting starts, and most harvesting in publicly owned forests is conducted by private forestry companies (Natural Resources Canada, 2020c). The companies must operate under a license with the respective provincial or territorial government (Natural Resources Canada, 2020c). Developing forest management plans ensures that forest sustainability is considered and that the practices support sustainable forestry (Natural Resources Canada, 2020c). Once forest management plans are approved, companies are closely monitored to ensure they comply

with the plans. Monitoring also includes audit compliance of the companies with regulations regarding the protection of soil, water, and non-timber values and services (Natural Resources Canada, 2020c). In 2018, 747,690 hectares of forest were harvested in Canada, but only 356,371 hectares were planted (Figure 1.2). Figure 1.2 shows the current regeneration efforts against the area being harvested in Canada. Shows the difference between the regeneration efforts from harvesting scenarios. Regeneration needs to be taken into consideration in sustainable forestry.

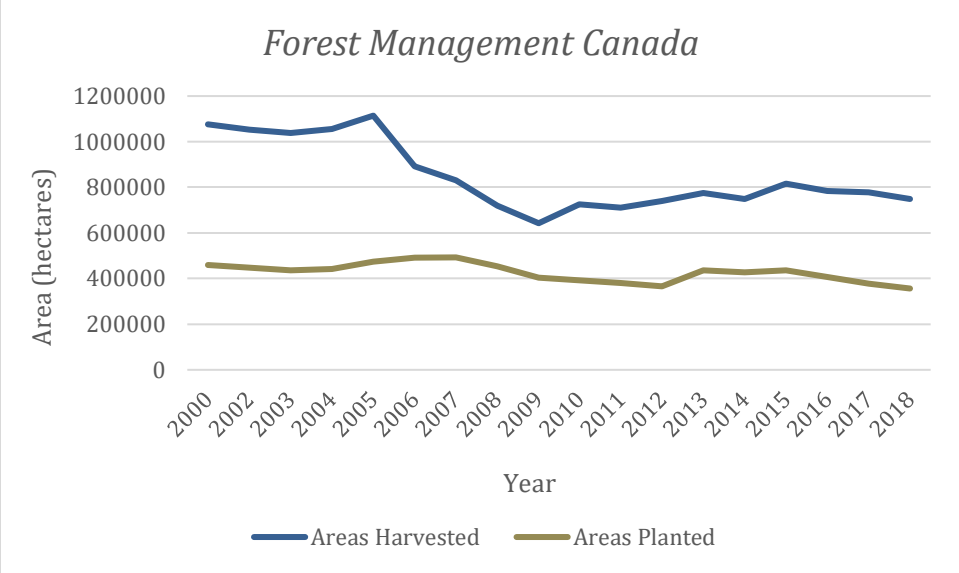

Figure 1.2
Areas (in hectares) Harvested and planted in Canada
Note: (Government of Canada-Natural Resources Canada, 2020).

1.3.3 Forest in Ontario

In Ontario, sustainable forest management is designed to ensure long-term health of forests while providing social, economic, and environmental benefits to Ontario residents (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021c). Sustainable Forest management is designed to keep forests healthy and productive while supporting a solid forest industry that provides jobs and forest products.

It also focuses on conserving biodiversity, enhancing, or protecting wildlife, watersheds, and other values. Finally, sustainable forest management supports many communities in Ontario, provides recreational opportunities and a healthy living environment (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021c).

Forest management plans must be submitted and approved before any forestry activity occurs and the development of management plans includes various stakeholders **(**Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021a). The Ontario Forest management plans must ensure sustainability (social, economic, and environmental), and be prepared by a registered professional forester. Forest management plans are approved for ten years and determine how much harvesting will be done and include opportunities for public involvement **(**Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021a). In 2018, 126,015 hectares were harvested in the Ontario forests (Government of Canada-Natural Resources Canada, 2020). With this, 72,636 hectares (Figure 1.3) were planted for regeneration (Government of Canada-Natural Resources Canada, 2020), which is 58% of the area harvested.

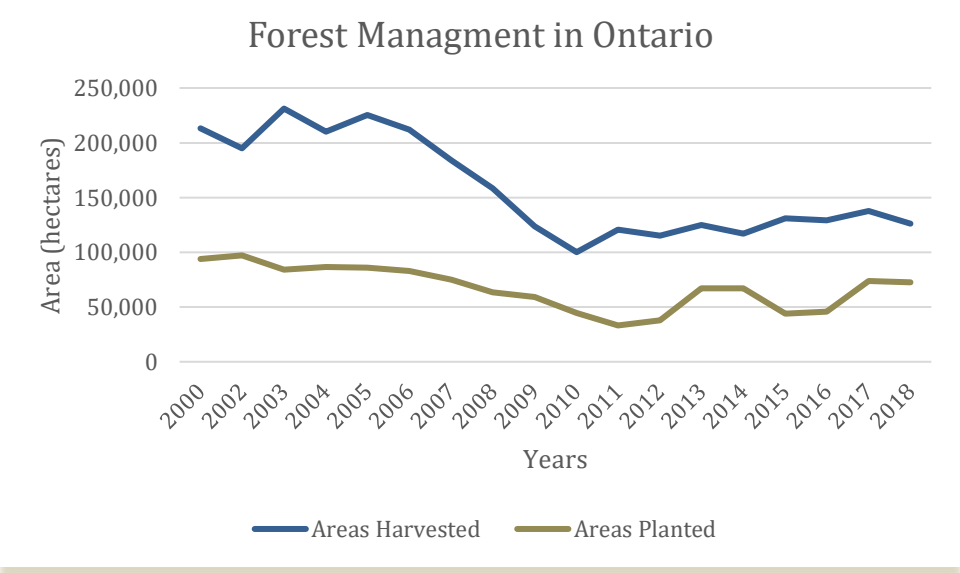

Figure 1.3

Annual change in the area (in hectares) of harvested and planted land in Ontario

Note: **(**Government of Canada-Natural Resources Canada, 2020).

Forest operations are monitored by the Ministry of Northern Development, Mines, Natural Resources, and Forestry to ensure harvesting companies follow approved plans (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021b). The companies must conduct self-monitoring, inspecting, reporting, training, and education and provide inspection reports to the ministry (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021b). Forest health monitoring is also conducted to evaluate the health of the forests in the province. Monitoring includes detecting, identifying, and determining the extent of significant forest disturbances (pests), determining the impacts on forest values, and attempting to predict future disturbances based on historical trends (Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021b). Concerns around forest health are important to acknowledge as forest health greatly affects the forest industry. The major concerns of forest health include extreme drought, forest fires, excessive soil erosion (Murphy et al., 2021), and nutrient depletion (Thangavel et al., 2022).

1.3.4 Nutrients in Forest Ecosystems

Nutrients are elements that are essential for the growth and survival of fauna and flora (Foster & Bhatti, 2006). These include nitrogen (N), phosphorus (P), carbon (C), hydrogen (H), oxygen (O), potassium (K), calcium (Ca), and magnesium (Mg) which are considered macronutrients as they are required in high concentrations. There are other essential nutrients such as boron (B), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and chlorine (Cl), which are micronutrients as they are required at lower concentrations

(Foster & Bhatti, 2006). Nutrient availability strongly influences forest ecosystem function and C sequestration, but nutrient cycling is complex as nutrients have internal and external sources and can be lost from forest ecosystems in a variety of ways, including timber harvesting (Grand & Lavkulich, 2015). Over the past few decades much research has been undertaken to better understand the complex biogeochemistry of nutrients (Kreutzweiser et al., 2008), but this document only considers Ca, Mg, N, K and P, which are the elements most identified as potentially limiting to forest growth and productivity (Foster & Bhatti, 2006).

Calcium

Calcium is an essential nutrient that is required for tree growth and productivity (Grand & Lavkulich, 2015; Lovett et al., 2016; Michalopoulos et al., 2016). Calcium is also typically the dominant base cation in forest soils and helps to buffer against acidification (Grand & Lavkulich, 2015). Calcium deficient symptoms in plants include small leaves and fading foliage colors, and necrotic leaf tops (Bal et al., 2015). Calcium additions to soils have been shown to benefit forest ecosystems. For example, sugar maple (*Acer saccharum*) exhibits increased vigor, growth, seed production, and decreased signs of stress with Ca additions (Lovett et al., 2016). Calcium additions to forest ecosystems also positively affect bird communities (Osman, 2013). Birds rely on the abundance of Ca-rich food (such as snails), and the lack of such food negatively affects their health (Osman, 2013). The availability of Ca-rich foods in forests was also suggested as a potential causal link between high acid deposition and low bird abundances in North America (Osman, 2013).

Magnesium

Magnesium is an essential nutrient that is required for plant growth and plays a crucial role in photosynthesis (Michalopoulos et al., 2016). Magnesium deficiency was suggested as a possible reason for sugar maple decline in the 1980s and 1990s in Quebec (Bernier & Brazeau, 1988) and several studies, primarily in Europe have shown that Mg additions to forest soils can lead to increased forest growth and tree health (Schulze, 1989). Magnesium deficiency causes reduced photosynthetic capabilities, with foliage developing a light green to vivid orange and yellow coloring (Bal et al., 2015). Symptoms may also include interveinal chlorosis and necrosis and rolled edges in the foliage that are particularly evident in sugar maple (Bal et al., 2015). When a species has low Ca and Mg, it may reduce C assimilation (Bal et al., 2015).

Nitrogen

Nitrogen is considered the most limiting nutrient in forest systems, so applying N fertilizers is widely used around the world (Bal et al., 2015). Nitrogen is required in large quantities and is a component of the enzyme Rubisco that is required for photosynthesis (Wang et al., 2014). Nitrogen gas in unavailable to higher vegetation and can only enter forest ecosystems by N-fixation or in small amounts from atmospheric deposition. Industrialization has increased N emissions more than 10-fold (Aber et al. 1989). When N is added beyond biological needs, forest ecosystems become "N-saturated" which can have negative effects such increased nitrate leaching and tree mortality (Aber et al. 1989). Having an optimal amount of N in ecosystems is critical for the productivity of forests. Nitrogen levels affect photosynthetic rates in plants (Osman, 2013) and other fundamental cellular functions (Zheng, 2009).

Potassium

Potassium is also an essential element that is required for plant growth, playing an important role in several metabolic functions (Bal et al., 2015; Michalopoulos et al., 2016; Osman, 2013). Symptoms of K deficiencies in forests include leaves that are abnormally dark green and tend to curl up on the edges (Bal et al., 2015; Bernier & Brazeau, 1988). The foliage can eventually turn chlorotic between the veins and the edges (Bal et al., 2015), affecting photosynthesis rates. In sugar maple, K deficiency will reduce stem and root weight and trees will be less resistant to frost, pathogens, and pests (Bal et al., 2015). Potassium deficiencies were seen in the foliage of sugar maples in several sites in Quebec, which shows the disturbed nutrient profiles in the deciduous forest of the Quebec Appalachians (Bernier & Brazeau, 1988b). Potassium deficiencies were seen often combined with P deficiencies as well in the Quebec Appalachians (Bernier & Brazeau, 1988b).

Phosphorus

Phosphorus is an essential nutrient also required for photosynthesis (Osman, 2013). Like N, P is also highly cycled mainly through litterfall (Sayer & Tanner, 2010). Phosphorus deficiency is characterized by leaf surfaces becoming dark green and dull and seedlings' yellow-green mottles and necrotic tips (Bal et al., 2015). Casson et al. (2011), noted that P deficiency was a concern in Ontario, particularly in sugar maple. Foliar P was found to be significantly lower in trees at acidic sites and P was the most limiting nutrient to sugar maples (Casson et al., 2011). Soil pH is an important control on the P availability through precipitation with acid soluble metals (Casson et al., 2011). Studies suggest that P limitation may become problematic in the future, especially if anthropogenic acid deposition continues to impact forests (Casson et al., 2011).

Nutrient Availability

The availability of nutrients to trees depends on the efficient cycling of nutrients within the ecosystem (Prescott, 2002). Nutrient cycling is defined as the "exchange of elements between an ecosystem's living and non-living components" (Foster and Bhatti, 2006). This includes nutrient uptake and storage in vegetation, litter production and decomposition, nutrient transformations by soil fauna and flora, nutrient inputs from the atmosphere, weathering, and soil export by leaching and transfers (Foster & Bhatti, 2006). Nutrients are returned to the soil in litter following the death of plant tissues and recycled through organisms and taken up by vegetation (Prescott, 2002). The foliage and branches on tree canopies are also a significant nutrient sink and retain nutrients on-site (Prescott, 2002).

Nutrient availability is strongly influenced by the quality and quantity of litter production in a forest (Foster & Bhatti, 2006). Additionally, Foster & Bhatti (2006) state that more than half of the nutrient uptake by forests is typically returned to the forest floor from litterfall and fine root turnover in soils. In some forests, the amount of C and other nutrients returned to the soil from the fine root turnover may equal the amount from the leaf litter (Gordan & Jackson, 2000). The occurrence of canopy removal during forest harvesting is associated with several changes in nutrient cycling (Prescott, 2002). Canopy removal can be caused by more than just harvesting, indirect reasons for removal are death and decay of roots, changes in ground vegetation, or disruption of surface soil (Prescott, 2002), affecting the nutrient cycling in forests.

1.3.5 Natural sources and losses of nutrients

Nutrient cycling in forests ecosystems is primarily controlled by climate, site characteristics, and biotic communities (Foster & Bhatti, 2006). Wildfires also play a dominant role in nutrient cycling, especially in boreal forests (Simard et al., 2001). A study in Quebec for example, showed that forest floor extractable Ca and P were higher in burned stands than other stand types (Simard et al., 2001). Mycorrhizae also deserves consideration when looking at nutrient cycling. Mycorrhizal fungi constitute a group of root symbionts that represent a key link between plants and soil mineral nutrients (Thangavel et al., 2022). The role of this fungi is it allows the plants to obtain additional moisture and nutrients from the soil. These fungi are being reported to positively influence plant growth by contributing to soil nutrient cycling, reduction in the loss of nutrients, nutrient up take and biotic and abiotic stress resistance (Thangavel et al., 2022). Having these fungi present allows the plants and trees to have greater access to soil nutrients and allow greater intake of these nutrients.

1.3.6 Human Impacts on Forest Nutrient Cycling

Human actions have disrupted nutrient cycling in forests. Air pollution can negatively affect forest health and productivity by damaging trees, directly or indirectly, through the culmination effects on soil (Battles et al., 2013). Similarly, timber harvesting disrupts nutrient cycling in forests and can have both short-term (<3 years) and longer term (>20 year) impacts (Güner et al., 2021).

Acidic Deposition

Acidic deposition can have large and significant impacts on forest nutrient cycling and availability (Battles et al., 2013). Acidic deposition is formed when sulphur dioxide (SO_2) and nitrogen oxides (NO_x) emissions mix with water vapor and oxidants in the

atmosphere to create various sulphate and nitrogen compounds and eventually fall back to earth in wet or dry form (Visgilio & Whitelaw, 2007). Wet deposition consists of fog, dew, snow, or rain, while dry deposition occurs either as gas or dry particles (Visgilio & Whitelaw, 2007). Regardless of the form of deposition, acidic deposition adversely affects aquatic life, erodes stone buildings, and threatens trees and crops through the soil (Visgilio & Whitelaw, 2007). This can then increase the acidity of the soils and negatively affect the chemical balance of lakes and streams (Shammas et al., 2020).

Acid deposition alters forest soils by accelerating the leaching of available base cations (Ca, Mg and K) and enhancing the accumulation of S and N in soil (Visgilio & Whitelaw, 2007). Leaching of sulphate and nitrate strips forest soils of essential nutrients needed to sustain plant and tree life (Shammas et al., 2020). As such, acid deposition can influence forest vegetation and soils as it weakens the trees' natural defenses against diseases (Shammas et al., 2020). For example, sugar maples are prone to die on sites where Ca and Mg concentrations in the soil are lowest (McNeil & Culcasi, 2015).

Acid deposition was one of the major environmental issues of the late 20th century (Grennfelt et al., 2020). The issues caused by acid rain did not gain societal attention until the 1960s, even though early research on the effects was conducted (Grennfelt et al., 2020). Svante Oden published his carefully documented work in 1968, outlining evidence that long distanced transport and deposition of the acidifying pollutants were causing significant ecological and environmental countries and showed how this pollution traveled distances to other countries (Grennfelt et al., 2020). The Scandinavians first identified this transboundary issue of acid deposition as they were subjected to downwind

acid-producing emissions flowing from Europe, notably the United Kingdom and Germany (Visgilio & Whitelaw, 2007).

In the 1980s, this issue became more relevant as a German scientist Bernhard Ulrich's studies showed that high deposits of atmospheric pollutants had seriously changed the soil chemistry (Grennfelt et al., 2020). On the other hand, lake acidification was the main driver in the United States and Canada, which led to the initiation of monitoring programs (Grennfelt et al., 2020). The governments initially ignored the acid rain problem for years, but the legislation designed to address the issue was eventually implemented when the issue was finally recognized in the late 1960s (Grennfelt et al., 2020; McNeil & Culcasi, 2015). The issue was first absorbed in the late nineteenth century by Robert Angus Smith, who published a book called "*Air and Rain: The Beginnings of a Chemical Climatology*"(Grennfelt et al., 2020). In 1927, Professor Knut Dahl hypothesized the acidification of surface waters and how it would affect fish species (Grennfelt et al., 2020). Following this, Eville Gorham and his colleagues built a foundation of understandings around the causes of acid precipitation on varying ecosystems species (Grennfelt et al., 2020). These findings were not generally recognized until the 1960s, when the issue became more prevalent in mainstream media. Acid rain intersected two major national discourses prevalent at the time. These were environmentalism and energy independence. The environmental debate began due to public outcry resulting from the book *Silent Spring* written by Rachel Carson, which brought to light the adverse environmental and human health effects of the widespread use of insecticides such as DDT (McNeil & Culcasi, 2015).

On the other hand, the thrust to reach energy independence and the ensuing reliance on coal-fired power plants in Canada and the United States exacerbated the conditions that

led to acid rain formation. As a result of this reliance on coal-fired power plants, national SO_2 emissions rose significantly (McNeil & Culcasi, 2015). To try and meet air quality standards, two changes were made that amplified the issue. The first was that particulate removing devices were installed to eliminate particles needed to neutralize sulfuric and nitric acids responsible for acid rain (McNeil & Culcasi, 2015). The second was that power plants installed higher smokestacks to reduce local ground-level pollutants (McNeil & Culcasi, 2015). These smokestacks released the SO_2 and NO_x higher up into the atmosphere (upwards to 1,000 feet from the ground), causing these pollutants to be transported hundreds of miles before being deposited (McNeil & Culcasi, 2015).

Despite the cold war and little communication between the East and West, acid rain served as a rallying point and was a cause for scientific and political collaboration (Grennfelt et al., 2020). This resulted in a treaty under the United Nations' Economic Commission for Europe (UNECE), the Convention on Long-Range Transboundary Air Pollution, signed in 1979 (Grennfelt et al., 2020). This treaty is assumed to have worked as all key air pollution emissions have been significantly decreased (Grennfelt et al., 2020). For SO_2 specifically, emissions in Europe have declined 80% or more since their peak in 1980-1990 (Grennfelt et al., 2020). The negotiation of the 1991 Canada and the United States Air Quality Agreement was in addition to the global agreements and brought a period of cooperation between the two countries towards reducing emissions (Visgilio & Whitelaw, 2007).

Despite the dramatic reductions in acidic deposition acid rain may still have lingering effects on the soil. Since the environmental regulations around combatting acid rain, there has been a gradual recovery of surface waters (Battles et al., 2013). However,

severe depletion of some soil nutrients, such as Ca and Mg may cause persistent issues in sensitive forests (Battles et al., 2013). Some species, such as sugar maples and red spruces (*Picea rubens*), appear particularly sensitive to low Ca levels (Battles et al., 2013).

Timber Harvesting

Timber harvesting is another leading anthropogenic cause for nutrient loss in forest soils. Several different types of logging are practised. The first is whole tree removal (or harvesting), when needles, branches, and uncommercial top wood are also removed with the trunk (Tamminen et al., 2012). Selection harvesting is where an individual or small group of trees are removed at regular intervals from the forest (Treasure et al., 2019). This is commonly used in northern hardwood forests dominated by shade-tolerant species such as sugar maple (Treasure et al., 2019). Stem-only harvesting is when only the trunks are removed from the sites, and the rest is left in the forest (Hamberg et al., 2019). Clear felling is when a managed young forest is thinned at least once before reaching commercial dimensions and one to three times before the final harvest (Tamminen et al., 2012). These different harvesting styles can have different effects on the soil and forest ecosystem.

In general, removing logging residues has been shown to decrease tree volume growth (Smolander et al., 2010). Cutting treatments alter the nutrient cycling because the stem is removed (Güner et al., 2021), decreasing nutrient pools and affecting the nutrient flux between the soil and the plants (Güner et al., 2021). Harvesting can also change the microbial processes related to C and N cycling. This was observed in Norway as the net N and C mineralization rates were lower in the organic layer after whole tree removal

than after stem harvest only (Smolander et al., 2010). One reason for removing the whole tree is its use in bioenergy and the preference to use renewable biomass over fossil fuels (Güner et al., 2021). Apart from the trunk and branches (as those have high economic value and will be removed), the nutrient stocks in roots, needles, and bark were shown to be highest on some species, such as Scots pine (*Pinus sylvestris*) (Güner et al., 2021). This means that leaving these behind and avoiding whole tree harvesting would supply crucial nutrients for the live trees in the forest ecosystem (Güner et al., 2021).

Forest logging residues are a renewable energy source, which can lower the reliance on fossil fuels (Zetterberg et al., 2016), a progressing goal of many countries. However, this affects nutrient concentrations as nutrient concentrations are higher in the logging residues than stem wood (Zetterberg et al., 2016). Hence, N, P, and base cations export become greater during whole tree removal (Zetterberg et al., 2016).

Harvesting of logging residues may be considered a negative fertilizer, where the nutrients are removed from the forest (Tamminen et al., 2012). The additional loss of nutrients during whole tree harvesting may be leading to lower soil productivity and more acidic soils (Zetterberg et al., 2016). There is also a concern that whole tree removal will contribute to surface water acidification associated with the lower concentrations of base cations running off into the water bodies (Zetterberg et al., 2016). Notably, increased harvest intensity seems to affect Ca more frequently than the other macronutrients (Zetterberg et al., 2016).

Sugar maples are susceptible to acidification impacts, primarily through Ca loss in soils and the mobilization of aluminum (Al) (Treasure et al., 2019). Sugar maple seedlings' morphology and foliar chemistry are sensitive to the disturbances caused by

selective harvesting (Treasure et al., 2019). Any form of harvesting can cause damages to the environment, which leaves susceptible species, such as sugar maple, vulnerable.

1.3.7 The Need for Nutrient Amendments

Despite the reductions in acidic deposition, the increasing demand for wood products and biofuel suggests that nutrient limitation may become more prevalent. Nutrient losses occur over decadal (or longer) timescales and natural replenishment may take centuries as recovery is slow (Lawrence et al., 2015; Hazlett et al., 2020). As a result, nutrient amendments may be required to maintain, or promote the health of managed forests. This thesis will look examine the history of anthropogenic causes of nutrient depletion and which countries currently have nutrient amendment programs in place. Specifically. The thesis will analyze forest management plans globally to assess the extent to which countries consider soil nutrients in their forest management plans.

1.3.8 Wood Ash Recycling Program in Muskoka

The Friends of Muskoka Watershed are in the process of developing a wood ash recycling program to help combat the issue of Ca decline in forest and waters. Currently, wood ash is not allowed to be spread in forests or waterways without a permit, which is hindering progress on this issue. This is due to the requirements of the permit to be filled, and extra tests to be done to be able to spread the ash. Permit applications can also take longer to be processed by the government then what an organization would be wanting to wait. Looking at the main barriers and challenges to initiating this project may will provide insight into potential solutions for establishing a regional ash recycling program. This thesis will interview different stakeholders in the residential wood ash recycling

program in Muskoka to identify what they consider benefits and challenges to this project and possible solutions to the challenges.

Chapter 2 Global Policy Analysis of Forest Management Plans

Abstract

Forest management plans globally were assessed to evaluate the extent to which countries consider soil nutrients in their forest management plans. A content analysis of policy documents was undertaken to assess the extent to which nutrients are considered in forest management plans internationally and nationally. The analysis showed that nutrients are not a focus in forest management plans with the notable exceptions being Sweden and Switzerland, that recommend nutrient amendments after harvesting to replace nutrients taken from the ecosystem. Of the ninety-six plans considered in this thesis, seventeen of them considered nitrogen, which was the most common nutrient mentioned in forest management plans, followed by calcium and phosphorus. Nitrogen additions are often recommended for forests that are actively managed for timber. In Canada, nutrients are not a major focus in forest management plans. Avoiding whole tree removal was the most prominent practice used in Canada to conserve nutrients in forest soils. It is recommended that governments who do not currently add nutrient amendments to forests consider adding this practice to keep nutrients within the ecosystem.

2.1 Introduction

Human activities have altered nutrient cycling in forests (Lees et al., 2006). Under undisturbed conditions, the input of nutrients from atmospheric deposition and mineral weathering balance natural losses that occur through leaching and fire (Foster & Bhatti, 2006; Simard et al., 2001). These natural conditions have been altered by human activities in two significant ways. The first is timber harvesting that removes nutrients in the biomass extracted from the site (Ring et al., 2006). The second is acidic deposition that further accelerates leaching losses of the base cations from soil and alters the bioavailability of other nutrients such as P (Lundstrom et al., 2003b).

Several studies over the past 50 years have shown that soil nutrient stocks have changed, apparently caused by human activities (Grennfelt et al., 2020). The decrease in essential nutrients potentially poses a risk to forest sustainability (Schulze, 1989). In some managed forests, nutrient losses are replaced through amendments such as lime, wood ash or fertilizers or minimized through altered harvesting practices (Skogsstyrsen Sweden Forest Agency, 2011). Both nationally and internationally, forest management plans are designed to ensure healthy forests are maintained, but there is no standard global practice for managing forest nutrients.

In this chapter, forest management plans were assessed to evaluate the extent to which countries consider soil nutrients in their plans. Canadian sources were analyzed separately on a provincial and territorial basis. The overall objective of this Chapter was to evaluate the extent that nutrients are considered in forest management plans internationally and nationally, which nutrients are given the most consideration, and under what circumstances are these nutrients considered. The secondary objective of this

chapter is to compare how nutrients are considered in Canadian forest management plans with other forest plans around the world.

2.1.1 Data Sources

In total, ninety-three government documents and three United Nations documents were located and analyzed to critically evaluate the extent to which nutrients are considered in forest management at the global scale. The three United Nations documents were: “Global Forest Resources Assessment 2010-Country Report, Egypt (Federal Ministry of Food and Agriculture, 2020), Philippine Master Plan for Climate Resilient Forestry Development (Food and Agricultural Organization of the United Nations, 2016), and The Russian Federation Forest Sector (Food and agricultural organization of the United Nations, 2012)”.

The ninety-six documents, thirty-eight of which were Canadian, including twenty-two acts and seventy-three plans and regulations. Of the ninety-six documents considered in this study, fifty-one documents mentioned nutrients. Forty-four documents (45% of the documents) did not mention nutrients at all and were excluded from further detailed analyses.

2.1.2 Defining an Act, Regulation and Plan

It is important to define and distinguish Act's, Regulation’s, and Management Plans before continuing with this research. In a Canadian context, the Parliament of Canada comprises three elements: the Crown, the Senate, and the House of Commons (Government of Canada, 2017). Parliament makes its laws in the form of statutes or "Acts". All three elements of Parliament must agree to a bill (a draft Act) to become a law (Government of Canada, 2017). The purpose of an Act may either be of a general,

public nature or private, conferring powers or special rights or exceptions to people or groups (Government of Canada, 2017).

A Regulation is also a form of law and has binding legal effects that usually state general rule (Government of Canada, 2017). Regulations are not made by Parliament but rather by the bodies or persons Parliament has delegated to, such as a minister or administrative agency (Government of Canada, 2017). Authority to make regulations must be delegated by an Act. Acts generally set out the framework of a regulatory scheme and then the designated authority will develop the regulation around this (Government of Canada, 2017).

In Canada, a forest management plan is a regulation and is used as a primary tool to ensure that Canada's publicly owned forests remain healthy and are managed sustainably (Natural Resources Canada, 2020). It has several requirements. The first is that it must outline a strategic vision and commitment to protecting forest values in the area under management. Forest values are the ways a forest holds importance to people, environmentally, socially, or economically (Duinker, 2008). It must also assess the current state of the forest in the area and detail the desired future state of forest values. The plan must also set out management objectives and describe harvesting, regeneration, and other activities to be carried to achieve the objectives (Natural Resources Canada, 2020). All countries have their versions of acts, regulations, and plans, but they tend to follow similar guidelines as the definitions above. Many plans reference Acts in them instead of restating the guidelines, and those acts were evaluated for the purpose of this research.

Forestry organizations can also apply for external certification from the Forest Stewardship Council (FSC), which is a non-profit membership organization that certifies forest. The forest management certification system is voluntary program for those who want to demonstrate responsible forest management (Forest Stewardship Council, 2021). Participants can do this by having their forest management planning and practices independently valuated against FSC's forest management standards (Forest Stewardship Council, 2021). The main evaluation process is an in-depth review of the forest management system of the organization (Forest Stewardship Council, 2021). At the end of the evaluation, the assessment team reports to the forest manager any areas that they do not meet the requirements (Forest Stewardship Council, 2021). If the organization passes, they will be certified for five years and audited on an annual basis (Forest Stewardship Council, 2021).

There are ten principles that the forest organization must comply with. They are compliance with laws, workers' rights and employment conditions, Indigenous peoples' rights, community relations, benefits from the forest, environmental values and impacts, management planning, monitoring and assessment, high conservation values, and implementation of management activities (Forest Stewardship Council, 2021). These standards take the Canadian regulatory expectations a step further. Principle one is compliance with the laws, which is testing the organizations' ability to follow Canadian standards and regulations. Forest stewardship organizations would have the highest steak in nutrient management if it could provide them with higher yields. Adding nutrient management as a part of the principals companies must follow would ensure that nutrient balances remain a priority when harvesting.

2.1.3 Research Question

Research Question: To what extent are nutrients considered in national and international forest management plans?

The objective of this research question was to compare management plans globally. Plans were the main consideration for comparison purposes while refenced acts were also considered. This was to consider both the mandated plans but also the acts that guide the plans. Relevant acts were considered due to their importance for the management plans.

2.2 Methods

2.2.1 Overview

For this chapter, a content analyses of forest management plans and their supporting documents from twenty countries was performed, which resulted in 96 documents being considered. Along with the twenty countries, an in-depth analysis of every Canadian province and territory (excluding P.E.I) was conducted for a local comparison. These management plans and documents were analyzed to determine the extent to which soil nutrients were included in the management practices and the circumstances surrounding the inclusion. Documents were search for key terms and nutrients, which include “calcium”, “nitrogen”, “phosphorus”, “potassium”, and “magnesium”.

2.2.2 Data Collection.

A search was conducted for global forest management policy documents for this part of the study. Initially, a regular Google and a Google Scholar search were performed

for "forest management plans". Unfortunately, this provided thousands of results and the search needed to be narrowed and focused.

A second literature search was undertaken using Google Scholar and Trent OMNI using more specific keywords such as "forest planning," "forest management," “global forest management”, “forest nutrients”, "soil nutrient management," "forest change," “forest ecosystem” and "forest health." This also provided hundreds of thousands of peer-reviewed academic articles to give general background knowledge on the subject. Abstracts of the top results given by the search engines were read to decide if the full article could be relevant to include in the analysis. Abstracts were read and searched for any of the themes “forest growth”, “forest change”, “forest regeneration”, “soil nutrients”, “sustainable logging” and “forest management”. If the abstracts outlined studies on any of these topics, articles were read in more detail to see if they would be useful for the project. Articles were excluded if the abstracts did not outline any of the themes above or if they focused solely on lakes or water bodies in forests and not on the forest itself.

If an article outlined an important study by another practitioner, that study was also found and read using the criteria above. Articles also had to be available at no cost through Trent University’s license for article access and had to be in a peer reviewed journal. This search, review and read iteration was completed several times until there was sufficient background information such that the researcher was seeing the themes starting to repeat themselves. Data saturation started to persist around 20 journal articles into the search (Asner et al., 2010; Battles et al., 2013; Foster and Bhatti, 2006; Gordon and Jackson, 2000; Juice et al., 2006; Halman et al., 2015; Hope et al., 2017; Leys et al.,

2016; Minocha et al., 2010; Nitschk and Innes, 2008; Page et al., 2008; Prescott, 2002; Sayer et al., 2012; Simard et al., 2001; Schulze, 1989; Smolander et al., 2010; Spittlehouse and Stewart, 2003; Sullivan et al., 2013; Tkacz et al., 2008; Wild and Yanai, 2015).

Many studies cited the United Nations (UN) organization (Asner et al., 2010; Environment and Climate Change Canada, 2016; Natural Resources Canada, 2019; Tkacz et al., 2008), and the *Global Forest Resources Assessment 2015 - How are the world's forests changing?* (Food and Agriculture Organization of the United Nations, 2015). This article uses data from 234 countries and territories, representing 98.8 percent of the world's forests (United Nation, 2015). The remining countries and territories were reported as desk studies by the FAO. This report was designed to compare the countries with forest cover to assess how each country is protecting their forests. Countries were selected for this research based on "top ten countries reporting the greatest annual net gain in the forest area" and "countries with the greatest annual net gain in forest area" in this report (Food and Agriculture Organization of the United Nations, 2015). The "countries with the greatest annual net gain in forest area" are Russian Federation, Brazil, Canada, USA, China, Democratic Republic of Congo, Australia, Indonesia, Peru, and India (Food and Agriculture Organization of the United Nations, 2015). "Top ten countries reporting the greatest annual net gain in the forest area, 2010–2015" included China, Australia, Chile, USA, Philippines, Gabon, Leos Peoples Democratic Republic, India, Vietnam, and France (Food and Agriculture Organization of the United Nations, 2015). These lists were chosen based on the research by the United Nations to show how forests are changing in each.

After developing the list of countries, an effort was made to ensure that the selection of countries was not biased. A randomized number generator found online gave the number eleven (which meant eleven countries would be selected to also be researched). An online tool (https://www.randomlists.com/random-country) was used to produce a list of eleven random countries. These countries were also then considered in the research and included Brazil, Paraguay, Peru, Uruguay, Zambia, Guadeloupe, Bolivia, Malaysia, Tanzania, Sao Tome and Principe, and Egypt.

Finally, a targeted search was done for Scandinavian countries (including Norway, Finland, and Denmark), Switzerland and England. These targeted searches arose because the academic articles found in the beginning of the research referenced the work being done in these countries (Ring et al., 2006; Lundström et al., 2006b). The academic articles showcased these countries for their research and work considering nutrients in forests.

Some countries listed above had plans that could not be located online including Brazil, France, China, Vietnam, and the Democratic Republic of Congo. For both Peru and Chile, plans were only available in Spanish, so they were not used in the study.

To ensure that a complete list of plans was obtained, all forest management plans were downloaded to an external hard drive to ensure inclusion in this research. Any additional act or regulation that was referenced in the original forest management plan that was located and analyzed to ensure that no crucial guideline was missed.

The Canadian search was more straightforward as all provinces and territories were originally considered in this research. Prince Edward Island (PEI) is the only province not being used in this study. This is because PEI did not have just one plan; they

have several submitted and approved plans, but plans are made per property, unlike the other provinces that have overall plans for guidance. This made an analysis of their plans difficult, and it was not easy to compare these plans to other provinces and territories.

All documents were searched using the keyworks “soil”, “nutrients”, “nutrient cycling”, “calcium”, “nitrogen”, “phosphorus”, “magnesium”, “potassium”, “ash”, “slash”, “rotation length”, “whole tree removal”, “tree removal”, “lime”, “fire”, “forest health”, “pests”, “invasive species”, and “amendments”. These keywords are related to the questions being analyzed in these documents. The table of contents was additionally reviewed to see if any section would benefit the study. Plans were then skimmed over in their entirety to search for themes that the keyword search could have missed. This method was used for every research question asked to ensure no data was missed.

2.2.3 Data Analysis

All plans were imported into the NVIVO qualitative statistical analysis software for further analysis. Keywords searched with NVIVO included “nutrients”, “nutrient cycling”, “calcium”, “nitrogen”, “phosphorus”, “magnesium”, “potassium”, “ash”, “wood ash”, “slash”, “rotation length”, “whole tree removal”, “tree removal”, “lime”, “fire”. This was to ensure that all plans that included these themes were not missed in the manual analysis.

2.2.4 Rationale for using the United Nations as a Basis for the Research

Doing an initial search for literature using a couple of academic search engines, such as the Trent University OMNI library system and Google Scholar, where keyword searches were conducted to get starting information on nutrients in soil forests. Keywords

were searched: “wood-ash”, “sustainable forest management”, “nutrient cycling”, “soil nutrients”, “soil management”, “forest management”, “nutrient deficiencies”, and “soil”.

The results produced academic and policy articles that referenced the United Nations' work. These publications used the United Nations as a credible source for their research and global standards, so it was considered a reasonable starting point for my research. Of the original articles found, four articles mentioned the United Nations and, some more specifically, the Food and Agriculture Organization, which published the lists this research is based on (Natural Resources Canada, 2019; Tkacz et al., 2008; Environment and Climate Change Canada, 2016; & Asner et al., 2010). The documents were chosen because the current (2020) document was delayed because of COVID 19, and the data collection was started before January 2021.

2.2.5 Methodological Limitations

There were a few methodological limitations of this research. The first is that some countries were originally selected to be included, but their plans were not in English and therefore not easily accessible to the researcher. A second limitation to this study is that some documents were not available online. When new plans are released, sometimes old versions are archived and only the latest is available. Some plans were also updated after originally being downloaded for analysis so some minor things will be updated in the current version. If noticed before final analysis, the researcher included the new plan, but it cannot be confirmed that one was missed. Lastly, while the search was thorough, it is possible that a secondary plan or act was missed that could provide important information. Some countries have different jurisdictions for specific forest lands and without in-depth knowledge on every country, it cannot be confirmed another

one was out there. Any secondary plan or act found or mentioned was analyzed, but there could always be plans and documents that were not considered for this research.

2.3 Global Considerations

For this study, twenty countries were analyzed. In a few of those countries, such as Canada, England and the United States, multiple smaller regions were also analyzed separately (Figure 2.1, Table 2.1). This chapter has a section that focuses on Canadian forest management plans and places them within a global context.

Figure 2.1
The Countries Considered in Study
This figure shows a map of the global distrubution of the countries considered in this study.

Table 2.1
How Many Plans Are Considered From Each Country And Is It On A National Or Regional Scale?

Countries	Number of Documents Considered	National or Regional Consideration
Sweden	1	National
Germany	1	National
New Zealand	2	National
Switzerland	2	National
Russia	2	National
Finland	2	National
Norway	2	National
Australia	4	National
India	3	National
Denmark	2	National
Indonesia	1	National
The Philippines	1	National
Zambia	2	National
Malaysia	1	National
Tanzania	1	National
Sao Tome and Principe	1	National
Egypt	1	National
United States of America	13	Regional
England	16	Regional
Canada	38	Regional

Note. See Appendix 1 for full references.
This table lists the countries analyzed in this research, the number of documents considered from each country and whether it was a regional or national level plan.

2.3.1 To what extent are nutrients considered in forest management plans globally?

Soil nutrients are becoming an increasingly important issue among forestry professionals as something that policy makers should consider for managing the forest's health (Lundström et al., 2003b). Out of the twenty countries analyzed, fifteen (75%) mentioned nutrients generally or specified one or more nutrients. Countries that included nutrients in forest management plans were Canada, Australia, the United States of America (USA), England, Denmark, Finland, Indonesia, Switzerland, Egypt, Germany,

New Zealand, Russia, Sao Tome and Principe, Norway, and Sweden. The countries that did not mention nutrients included Tanzania, India, the Philippines, Malaysia, Zambia.

Nutrients and nutrient management are expressed in different ways in the forest management plans., Some plans use "nutrient balances" (Federal Office for the Environment FOEN, 2013; Federal Ministry of Food and Agriculture, 2020; Forestry Commission England, 2018; Häusler, and Scherer-Lorenzen, 2001; Ministry for Primary Industries, 2015). These plans consider every aspect of nutrient balancing. A forest nutrient balance calculation compares nutrients inputs with outputs (de Vries et al., 2021). If inputs balance nutrients outputs (or losses), forests are sustainable with respect to nutrients. Nutrient balances are calculated as: Atmospheric Deposition + Weathering – Leaching -Harvest Removal," usually in units of kg/ha. This is a good way to determine soil fertility as it can identify whether possible nutrient amendments are needed (de Vries et al., 2021). Switzerland considers nutrient balances by conserving or improving them by examining withdrawals from the forest, such as limiting full tree harvesting (Federal Office for the Environment FOEN, 2013). They also note the need to compensate for nutrient losses through management practices such as spreading wood ash (Federal Nutrient depletion occurs when the outputs from the soil system exceed inputs (Dalal & Probert, 1997). Some countries specifically mention the nutrient depletion rather than nutrient balancing and management plans are designed to reduce nutrient losses. Sweden is an example of this as they cite nutrient depletion resulting from biomass extractions and whole tree harvesting. They cite that "biomass extraction removes nutrients and acid buffering capacity from the soil" (Skogsstyrsen Sweden Forest Agency, 2011). They also note in their plan that nutrient exports typically double over the rotation period when

whole trees (excluding stumps) are harvested compared to avoiding whole tree removal and leaving behind tops and branches. They also note that soils may become deficient in the long term, and forest productivity would decrease over long periods of time. Nutrient losses are also mentioned in the Australian plan "Australia's State of the Forest Report 2018" (Department of Agriculture, Water, and the Environment, 2018). In contrast to Sweden, Australia credits soil compaction and soil rutting from machinery from forest operations as a possible cause of nutrient depletion. This plan is more concerned with the effects of machinery on the environment, than the effects of nutrient losses associated with tree removal.

Other plans refer to nutrient cycling rather than nutrient balances. Nutrient cycling is defined as the exchange of elements between living and non-living components of the ecosystem (Fosters and Bhatti, 2006). This process includes nutrient uptake and storage in vegetation, litter production, litter decomposition, nutrient transformations by soil fauna and flora, nutrient inputs from the atmosphere and the weathering of primary minerals, and nutrient export from the soil by leaching and gaseous transfers (Fosters and Bhatti, 2006). Florida highlights the importance of soil nutrient cycling in the future desired forest conditions. The plan outlines that this is an end goal for the state to meet since proper nutrient cycling indicates a healthy forest (Forest Services, US Department of Agriculture, 1991b).

Even though some nutrients generalities are mentioned in most of the plans assessed in this research, they are not significant components of forest management plans. Five countries (25% of all countries assessed) did not mention nutrients at all. Others, such as Finland, mention them just once or twice, indicating that forest nutrients

are still not a significant consideration in these plans. Even in the plans that mention nutrients, some only mentioned them regarding sites being "nutrient-poor or rich" and offer no guidance on what should be done to manage them. The following section will look at the specific nutrients mentioned in the plans as some plans do take into consideration specific measures for certain nutrients.

2.3.2 Key Nutrients in Global Forest Management Plans

There are five macronutrients being considered in this research: nitrogen (N), calcium (Ca), phosphorus (P), potassium (K), and magnesium (Mg). Of these nutrients, N was the one that was mentioned most in plans, but it was still mentioned only in eighteen plans (only 17% of the plans analyzed), followed by, Ca which was mentioned in only eight plans (Figure 2.2). Countries historically have faced different environmental issues (such as acid rain) or extensive harvesting, which influences the nutrients that are primary concern.

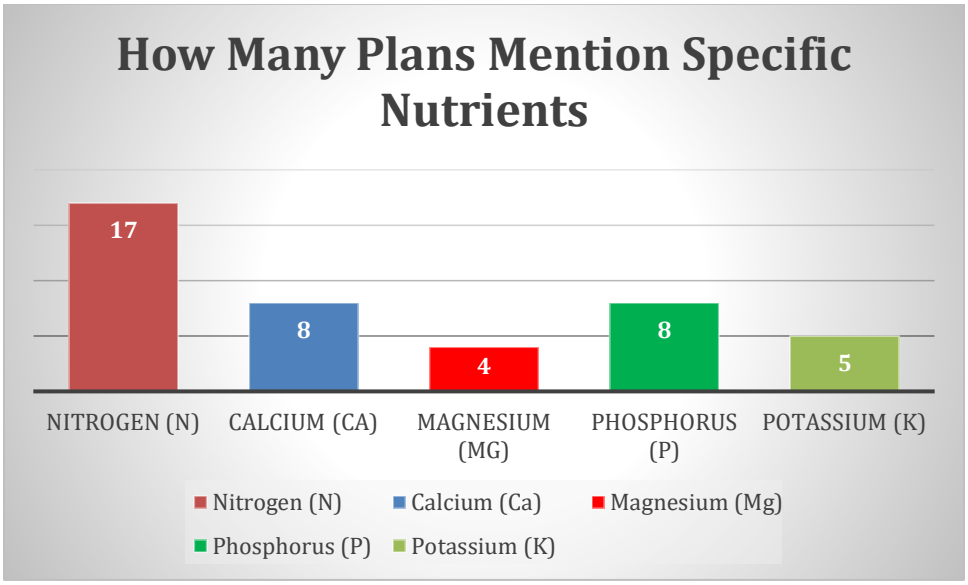

Figure 2.2
Specific Nutrients Mentioned in Forest Management Plans.

Note. This figure compares the different nutrients mentioned in each plan by the number of plans that mention each one. Of the 96 documents examined,

nitrogen was considered in 18%, calcium in 8%, magnesium in 4%, phosphorus in 8% and potassium in 5%.
Information adapted from Alberta Agriculture, Food and Rural Development; ; Department of Agriculture, Water and the Environment, 2018; Department of Environment and Conservation, 2010; Department of Fisheries and Land Resources & Innu Nation, 2018; Federal Ministry of Food and Agriculture, 2020; Federal Office for the Environment FOEN, 2013; Food and agricultural organization of the United Nations, 2012; Forestry Commission England, 2017a; Forestry Commission England, 2017c,Forestry Division, Truro, Nova Scotia, 2018; Government of British Columbia, 2018; Government of New Brunswick, 2014; Government of Quebec, 2020; Government of Yukon, Forest Management Branch, 2013; Legislation Division of the Justice Department of the Government of Nunavut, 2010; Natural Resources and Conservation Services California, 2021; Northwest Territories, Environment and Natural Resources, 2018; Manitoba Conservation and Manitoba Water Stewardship, 2008; Ministry for Primary Industries, 2015; Ministry of Agriculture and Forestry, 2010; Ministry of Environment, 2015; Ministry of Natural Resources, Energy and Environment, 2009; Ministry of Natural Resources and Forestry, 2019a; 2018; Republic of Indonesia, 2000; Skogsstyrsen Sweden Forest Agency, 2011; State of Hawai‘i 2017-Department of Land and Natural Resources, 2017.

Calcium is considered in just eight management plans (Figure 2.2). Five of these plans were Canadian, two from England and the last being Switzerland. Both plans from England (East England-Didlington, Brandon & Elvenden) only mention Ca in relation to their sites having Ca rich soils. Importantly, none of the plans outline any management practices for specific nutrients. Calcium, magnesium, and potassium are only mentioned in Switzerland plans as a comparison to aluminum concentrations in soil solutions. In other words, some plans mention Ca and indicate that it is important but provide no specific guidance for maintaining Ca levels within forest ecosystems.

Phosphorus is also considered in eight plans (Figure 2.2). It is mentioned in two Canadian plans, two in Australia, New Zealand, USA-California, Indonesia, and Egypt. Often P is mentioned only in relation to water quality issues rather than forest sustainability *per se*. Australia mentions P, as well as N, as it pertains to water quality assessment levels. It should be noted that like Australia, Egypt only mentions P and N

when describing the removal of organic phosphorus and organic nitrogen from wastewater (Ministry of Agriculture and Forestry, 2010). Phosphorus is mentioned just once in the California plan, in the appendix of a survey that landowners must fill out asking if they apply P to their land (Natural Resources and Conservation Services California, 2021). Indonesia mentions P, K, and N in the context of describing soil conditions when submitting plans. Therefore, it can be determined that even though P is mentioned in management plans, it is not a main concern.

Potassium is considered in only five management plans (Figure 2.2), two from Canada, and the others from Sao Tome and Principe, Indonesia, and Switzerland. Switzerland's and Indonesia's mention K in connection with other nutrients with no specific concern raised. Sao Tome and Principe only mention K in relation to the pH of the soil, stating if the pH is closer to neutral, it should contain a "good amount of potassium" (Ministry of Natural Resources, Energy and Environment, 2009). Even though K is occasionally mentioned, it is not a significant consideration in forest management plans globally. Similarly, Mg is only mentioned in Canadian plans and once in Switzerland and in this assessment was the nutrient that was considered nutrient in forest management plans.

Of the nutrients considered in this Chapter, N is the one that is mentioned most often, with seventeen plans (18% of plans evaluated) referring to it. Of these seventeen plans, seven are from Canada, with ten international plans although the reasons for referring to N varied. In some management plans, N is considered in the context of forest carbon storage. For example, Australia's "State of the Forest" plan briefly mentions N and its relevance to carbon storage (Department of Agriculture, Water, and the Environment,

2018). This plan suggests that carbon stocks generally decline in soils that have recently lost N (Department of Agriculture, Water, and the Environment, 2018). Russia also highlights N in the context of carbon storage as it is mentioned that carbon stocks in forests will increase if there is sufficient N present in the soils (Food and Agricultural Organization of the United Nations, 2012).

Nitrogen additions to forests that are actively managed for timber is another theme that is present in several plans. Sweden highlights the importance of having both N additions and wood ash to help combat nutrient depletion from whole tree harvesting (Skogsstyrsen Sweden Forest Agency, 2011). This plan is an example of having different management practices for different regions and concerns. It is mentioned that northern Sweden has low atmospheric N deposition, so that it should be added in regions that are harvested. Whereas ash recycling is an excellent way to combat the loss of acid buffer substances and nutrients due to acid rain precipitation, which is more prevalent in the southern Sweden (Skogsstyrsen Sweden Forest Agency, 2011). Sweden considers nutrient issues in plans by including multiple nutrient management strategies; however, they only specifically mention N in the plans and not the other essential macronutrients such as K, Ca, and P that are considered in this Chapter. In contrast to Sweden, California asks owners the extent of N additions they add to their forests and if they do it to match the needs of the forest (Natural Resources and Conservation Services California, 2021).

While N is often considered the liming nutrient for forest growth, in regions that have received high levels of atmospheric N deposition, there are concerns that the forest may reach N saturation (Aber et al., 1991). Nitrogen deposition from industrial or agricultural activities is a prime reason this is happening (Aber et al., 1991). This differs

from purposely adding fertilizer as this is unintentional leaching into the soil. Germany is an example of this as they outline how these high N inputs have both an acidifying and fertilizing effect (Federal Ministry of Food and Agriculture, 2020). Since it is not controlled (like Sweden controlling nitrogen additions), it is over-fertilizing the forest soils in Germany, which can reduce species richness and push soils to the breaking point of resilience (Federal Ministry of Food and Agriculture, 2020). This effect is in combination with whole tree harvesting and production of bioenergy in the forest, causing more adverse effects (Federal Ministry of Food and Agriculture, 2020). Norway also considers N_2O emissions from N mineralization in their soils (Norwegian Ministry of Climate and Environment, 2019). This, however, is only mentioned in their plan and is therefore not a major management consideration.

In Switzerland, it is noted that because N emissions come from different sectors (including transport, industry, and agriculture), the issue of N saturation is subject to national and international regulations, which means soil protection should be a national, not regional, issue (Federal Office for the Environment FOEN, 2013). This is contradictory to Canada as forest regulation, for the most part, is not a national task. The Canadian government has given majority of forest control over to the provincial and territorial governments.

2.4 Canadian Focus

This section compares forest management practices in the Canadian provinces and territories to understand variability across regions. Each province and territory have their own regulations for forest management. Further sections in this research (Chapter 3) will focus on a case study from Muskoka, Ontario.

2.4.1 Main Objectives of Forest Management Plans in Canada

A comparison of provincial government forest policy can help to illuminate the main goals of various regions across Canada. The comparison helps us to understand the underlying rationale of provincial government policy. For instance, having only economic verses strictly environmental motivators for human actions will change how a province conducts forest management. Even though these often overlap in practice, focusing mainly on the economic gain over environmental sustainability has its trade-offs and *vice versa* (Pedersen et al., 2020). Focusing on economic gains will strain the environmental ecosystems and provide society with the resources they need (Pedersen et al., 2020). However, focusing on environmental conservation will protect ecosystems and leave society without all the resources they want in the short-term (Pedersen et al., 2020).

Thirty-eight Canadian plans were analyzed, covering all provinces and territories excluding P.E.I. Plans were examined for mention of forest nutrients and nutrient management practices in the country. Forest management primarily falls under provincial jurisdictions and thus the provincial and territorial polices were examined. Crown Lands are the exception as they are managed differently from private and provincial lands. Regulations for Crown lands are provided by Natural Resources Canada, a federal government department, while the other forested lands are under provincial designation.

The Provinces' and Territories' Forest Management Policies (see Table 2.2) outline their main objectives, and I have developed categories for these objectives, dividing them into four considerations. Economic considerations include timber harvesting, non-wood forest products (such as sap), and silviculture practices. The environmental considerations include conservation, protection, biodiversity, protected species, wildlife habitats, soil, and water protection. Social considerations in plans

includes tourism and cultural/Indigenous protection. Lastly are the global considerations, which includes carbon storage, global market and trades, international agreements, and climate change adaptation.

Economic considerations are the main objectives in all Canadian forest management plans. Environmental considerations are a primary objective in most (10 of 11) of the plans (Table 2.2). Social considerations only appear as main objectives in plans from six provinces and territories, indicating that it is a less significant consideration compared with environmental and economic goals. Global considerations are the least considered category with only two provinces or territories mentioning it.

Forests in Canada are overwhelmingly managed for economic reasons. Alberta, for example, uses sustainable forest management practices to ensure the long-term availability of timber harvesting from forests (Alberta Government, Agriculture, and Forestry – Forestry Division, 2010a). Newfoundland and Labrador are similarly committed to creating an ecosystem-based forest management plan that protects the forest and cultural integrity while advancing economic opportunities for the sustainable development of the forest-based industries (Department of Fisheries and Land Resources & Innu Nation, 2018). Like Alberta, Newfoundland uses forest conservation practices to ensure sustainability in the forest-based industries.

Table 2.2
Main Objectives of Forest Management Plans in Canada

	Economic Considerations	Environmental Considerations	Social Considerations	Global Considerations	Policy References
Alberta	*				(Alberta Government, Agriculture and Forestry – Forestry Division, 2010a; Alberta Government, Agriculture and Forestry – Forestry Division, 2010b; Alberta Agriculture, Food and Rural Development, 2018).
British Columbia	*	*			(Government of British Columbia, 2018).
Manitoba	*	*	*		(Manitoba Conservation and Manitoba Water Stewardship, 2008).
New Brunswick	*	*		*	(Government of New Brunswick, 2014).
Nova Scotia	*	*			(NS DNR Forest Certification Steering Committee, 2015; Nova Scotia, Natural Resources, 2012;Forestry Division, Truro, Nova Scotia, 2018).
Saskatchewan	*	*	*	*	Ministry of Environment, 2015; Ministry of Environment, 2017; Sakaw Askiy Management, 2018).
Ontario	*	*	*		(Ministry of Natural Resources and Forestry, 2019a; Ministry of Natural Resources and Forestry, 2017a; Ministry of Natural Resources and Forestry, 2017b; Ministry of Natural Resources and Forestry, 2020; Ministry of Natural Resources and Forestry, 2017b; Ministry of Natural Resources, 2010a; Ministry of Natural Resources and Forestry, 2019d).
Newfoundland and Labrador	*	*	*		(Department of Fisheries and Land Resources & Innu Nation, 2018).
Quebec	*	*	*		(Government of Quebec, 2020).
Yukon	*	*			Government of Yukon, Forest Management Branch, 2013; Ministry of Energy, Mines, and Resources, 2004).
Northwest Territories	*	*	*		(Government of Northwest Territories, 2016; Government of Northwest Territories, 2014;Northwest Territories, Environment and Natural Resources, 2018).

Note. Nunavut was not analyzed as only management acts were found for the territory, and the acts do not have the same objectives, making them less comparable. Prince Edward Island was not analyzed as their forest management happens on an *ad hoc* basis.

Environmental benefits are also widely considered in forest management plans in Canada, often in tandem with economic considerations (Table 2.2). Many provinces include environmental protection to ensure long-term sustainability for the forests to maintain productivity. Saskatchewan is one example where environmental protection is used to ensure economic gain (Ministry of Environment, 2017). A main objective for the plan is to mitigate the impact of the forest activities on the land and to maximize economic benefits without compromising the state of the forest (Ministry of Environment, 2017). The plan mentions some other primarily environmental goals such as maintaining or enhancing the quantity and quality of soil and water (Ministry of Environment, 2017) while maximizing the economic benefits as well. Similarly, Nova Scotia's first objective is managing for resource production while promoting regeneration of native species as a secondary goal (Forestry Division, Truro, Nova Scotia, 2018). Ontario takes a similar stance with their Crown Forest Sustainability Act citing the purpose "to provide for the sustainability of Crown forests and, in accordance with that objective, to manage Crown forests to meet social, economic and environmental needs of present and future generations" (Government of Ontario, 2019a, pg.2). These examples show how environmental benefits of forest ecosystems are conserved for economic gain and ensuring long term sustainability in Canada.

Social considerations are less prevalent than economic or environmental considerations in forest management plans. An important subsection of social

considerations is the inclusion of Indigenous and Treaty Rights. Saskatchewan includes ensuring Indigenous and Treaty rights are respected in the planning process while protecting forest-based traditional ecological knowledge of the Aboriginal communities and avoid impacting culturally important sites (Ministry of Environment, 2017). The Northwest Territories is also an excellent example as the last objective of their plan is to store, collect and maintain traditional knowledge (Northwest Territories, Environment and Natural Resources, 2018). Camps that teach traditional harvest techniques are promoted in the Territory to ensure the culture is being maintained (Northwest Territories, Environment and Natural Resources, 2018). Ensuring that nature is respected, culture is maintained, and respect for the land and forest continues is an extra step that the Northwest Territories takes in relation to their social considerations (Northwest Territories, Environment and Natural Resources, 2018). Other Provinces and Territories do consider these goals, but not as main objectives in their plans. However, this consideration is vital there as Indigenous communities and people in every province and territory.

Global benefits in this context are less of a consideration in Canada which includes creating globally competitive markets and meeting international targets, with respect to climate change adaptation. Only New Brunswick and Saskatchewan have updated their plans to include global considerations (Table 2.2). In 2014, New Brunswick changed their forest management plan to make a globally competitive and resilient forest sector (Government of New Brunswick, 2014). This plan was created to ensure national and global competitiveness to increase profits. The primary policy elements include forest sector investments, commitment to a healthy forest, and a results-based forestry model

(Government of New Brunswick, 2014). New Brunswick promised to make their crown forests a highly productive source of high-quality products to maximize the profits while still committing to ensure conservation of land and biodiversity of species (Government of New Brunswick, 2014). Global markets are included to ensure higher economic gain. Even though New Brunswick has global considerations, economic factors are the driving force behind the decision-making.

Saskatchewan highlights more than economic gain alone. They have an ecological and cultural-based plan while including global targets. The Prince Alberta Forest Management Plan (2017) recognizes cultural benefits and traditional ecological knowledge and considers the long-term outcome of their management actions with respect to climate change (Sakaw Askiy Management, 2018). Saskatchewan highlights the importance of preparing for possible climate change scenarios while ensuring the health of the forests now.

In conclusion, every province or territory had economic gain as a driving force for forest management. The provincial governments have the primary responsibility to consider the primary objective of forest licenses and maximize profits in the short term (Hotte et al., 2016). This is shown through all the provinces and territories having economic gains as the main objective of their plans. Until it can be shown that environmental efforts will be worth the investment over the long term, this continues to be a barrier to nutrient considerations in the soil.

2.4.2 Forest Nutrient Management Across Canada

In Canada, seven Provinces and Territories consider specific nutrients in their forest management plans. Nitrogen is mentioned nutrient in seven (63%) provinces or

territories, with calcium mentioned in six (54%) (Table 2.3). The provinces and territories that do not consider specific nutrients are Nova Scotia, New Brunswick, Quebec, Nunavut, and Northwest Territories (Table 2.3). Four locations also did not mention general nutrient issues, including British Columbia, Quebec, Nunavut, and the Northwest Territories.

Table 2.3
Extent Nutrients Considered in Forest Management Plans Across Canada.

	Calcium	Nitrogen	Phosphorus	Magnesium	Potassium	General Nutrients
Alberta	*	*		*		*
British Columbia		*				
Manitoba	*	*		*	*	*
New Brunswick						*
Newfoundland and Labrador	*	*				*
Northwest Territories						
Nova Scotia						*
Nunavut						
Ontario	*	*	*	*	*	*
Saskatchewan	*	*	*	*	*	*
Quebec						
Yukon	*	*				*

Note. Adapted from Alberta Agriculture, Food and Rural Development; ; Department of Fisheries and Land Resources & Innu Nation, 2018; Forestry Division, Truro, Nova Scotia, 2018; Government of British Columbia, 2018; Government of New Brunswick, 2014; Government of Quebec, 2020; Government of Yukon, Forest Management Branch, 2013; Legislation Division of the Justice Department of the Government of Nunavut, 2010; Northwest Territories, Environment and Natural Resources, 2018; Manitoba Conservation and Manitoba Water Stewardship, 2008; Ministry of Environment, 2015; Ministry of Natural Resources and Forestry, 2019a; 2018

Calcium

In Canadian forest management plans, Ca is used primarily to describe soil qualities. The Yukon plan specifically refers to research from the University of Northern

British Columbia to gather data on the nutrient profiles of forest sites and uses it to describe the soil qualities. The researchers found nutrients, such as Ca and N, to be deficient in their soils (Government of Yukon, Forest Management Branch, 2013). This is highlighted as a concern because deficient soil nutrient levels could affect forest growth (Government of Yukon, Forest Management Branch, 2013). Though the plan states they consider many nutrients, the plan itself only specifically mentions Ca and N, assuming that is what policy makers consider to be more critical.

Similarly, in Saskatchewan, soil site qualities are described using Ca as a marker for ecosystem health. The Island Management plan mentions Ca when describing site conditions and comments that the calcium carbonate (lime) content in the C horizon varies regionally (Ministry of Environment, 2015). Calcium carbonate is also considered in Alberta as a measure for soil conditions. If samples have a calcium chloride ($CaC1_2$) pH of 6.5 or greater or a "water pH" of 7.2 or greater, they should be tested for calcium carbonate ($CaCO_3$) (Alberta Government, Agriculture, and Forestry – Forestry Division, 2010a).

Magnesium

Magnesium is not a major consideration in Canadian forest management plans, as it is only included in plans from four provinces. Of the four, Manitoba notes issues may occur with logging, as logging can decrease Mg and Ca in the soils as it is removed in biomass (Manitoba Conservation and Manitoba Water Stewardship, 2008). In Saskatchewan forests, Mg is only considered to describe soils as it mentions Luvisolic soils are rich in Mg and Ca (Ministry of Environment, 2015). Luvisols are the dominant soils of Central Saskatchewan and are therefore a primary area of focus. Notably, Mg is never mentioned alone in plans, it is always mentioned with Ca considerations.

Potassium

Potassium is only considered in management plans of three provinces (Table 2.3). Of the three, Manitoba notes that K is needed by trees to fuel growth but is concerned with logging practices in relation to K availability after logging (Manitoba Conservation and Manitoba Water Stewardship, 2008). Similarly in Ontario, K is noted as a potential concern following logging as tree growth can be stunted on K deficient soils (Ministry of Natural Resources and Forestry, 2019).

Phosphorus

Phosphorus is the least considered nutrient in management plans in Canada, with only two provinces mentioning P. In Saskatchewan, P (along with K and N) is only mentioned when referring to tests done in the 1980s to look for pollutant inputs that could have affected fish populations in Saskatchewan (Ministry of Environment, 2015). Phosphorus is not mentioned in relation to forestry or outlines any findings from the study. Ontario mentions P as an example of a key nutrient that needed in nutrient cycles (Ministry of Natural Resources and Forestry, 2019). It is mentioned that P be added to yellow birch trees that grow in acidic sandy soils to promote growth (Ministry of Natural Resources and Forestry, 2019). In addition, lime could be added with P to help combat the issue of acidic soils in Ontario (Ministry of Natural Resources and Forestry, 2019). Alberta also references studies that include P in their report but does not focus on the P aspect of the studies and focus on the microbial populations in the study (Alberta Agriculture, Food and Rural Development, 2018).

Nitrogen

Nitrogen is the nutrient that is most considered in Canadian plans (Table 3.1). The biggest concern for N in Canada, is the over the potential for saturation of N in the

environment. This is shown in British Columbia, where a worry with N is that adding too much N fertilizer to the soil will contaminate waterways (Government of British Columbia, 2018). British Columbia has ruled that N cannot be added to land if it will contaminate waterways with over ten parts per million nitrate-nitrogen (Government of British Columbia, 2018). Similarly, Alberta is concerned over elevated N levels in soils and mentions that samples must be taken in the A and B horizons of soil to check for over saturation (Alberta Agriculture, Food and Rural Development, 2018). In Ontario, dead and woody debris is preferred to be left on-site to provide nutrients and help mitigate N pollution (Ministry of Natural Resources and Forestry, 2019). Nitrogen is noted to be a necessary nutrient for forest and aquatic life (Ministry of Natural Resources and Forestry, 2019). The consensus is that N is a needed nutrient in the ecosystem, but it is crucial to not over-saturate the soils and waterways in forests with N, as that will cause problems.

2.4.3 Ontario Background Rational

Special consideration should be noted here about a plan from Ontario used in this research. Ontario released a document titled "*Stand and Site Guide Background and Rationale for Direction*" (2010), which explains in detail the reasons behind decisions made in the "*Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales*" document. The actual management plan does not mention any nutrient issues or considerations. However, in the rationale, they explain in detail specific nutrient considerations for the province. The rational is referenced in the "Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales" document as explanation to the decisions made but does not lay out any regulations itself. Ontario also fails to mention these concerns and outline management practices for nutrients in the original

document. It is outlined in the rationale the importance for the rules but does not follow through with creating management practices. Therefore, this document was not considered in the tables and findings for this research but is mentioned in the explanation.

2.5 Key Management Practices for Nutrient Management Globally

2.5.1 Key Management Practices Considered to Reintegrate Nutrients in Soil

There are five different management practices mentioned in the various plans that affect nutrient cycles. These management practices include the addition of wood ash, alterations in rotation length, leaving slash on site, liming, and avoiding whole tree removal. Not all forest management plans specifically outline the nutrient management practices that should be used, and some countries do not consider management practices for nutrients at all. In this analysis, just eight countries (40%) have mentioned specific management practices to regenerate nutrients in soils out of the twenty countries analyzed (Table 2.4).

Altering rotation length, leaving slash, and avoiding whole tree harvesting are used in logging to ensure sustainability without the need for additional nutrient amendments. Historically, lime has been used to combat base cation losses from soils caused by acidic deposition. Similarly, wood ash is also used to offset Ca deficiencies, but has also been recognized to be used in Sweden as a recycling method to keep products out of the landfills (Skogsstyrsen Sweden Forest Agency, 2011). All five nutrient management practices are used in human interest to continue harvesting sustainability or fix issues caused by human actions, such as acid rain.

Table 2.4

Key Nutrient Management Practices in Global Forest Management Plans

Treatment	Globally	Nationally	Policy References
Ash	Sweden, Switzerland	Yukon	(Skogsstyrsen Sweden Forest Agency, 2011; Federal Office for the Environment FOEN, 2013; Government of Yukon, Forest Management Branch, 2013).
Avoid Whole Tree Removal	Sweden, Australia, Denmark, Switzerland	British Columbia, Newfoundland and Labrador, Ontario, Nova Scotia	(Skogsstyrsen Sweden Forest Agency, 2011; Department of Agriculture, Water and the Environment, 2018; Ministry of the Environment, 2002; Federal Office for the Environment FOEN, 2013; Government of British Columbia, 2018; Department of Fisheries and Land Resources & Innu Nation, 2018; Ministry of Natural Resources and Forestry, 2019a; Forestry Division, Truro, Nova Scotia, 2018).
Lime	Germany	Alberta, Ontario	(Federal Ministry of Food and Agriculture, 2020; Alberta Government, Agriculture and Forestry – Forestry Division, 2010a; Ministry of Natural Resources and Forestry, 2019a).
Rotation Length	Russia, Denmark	Alberta, Ontario, Yukon, Northwest Territories	Food and Agricultural Organization of the United Nations, 2012; Ministry of the Environment, 2002; Alberta Government, Agriculture and Forestry – Forestry Division, 2010a; Ministry of Natural Resources and Forestry, 2019a, Government of Yukon, Forest Management Branch, 2013, Department of Agriculture, Water and the Environment, 2018).
Slash	Australia, Norway	Manitoba, Saskatchewan, Alberta, Northwest Territories	(Department of Agriculture, Water, and the Environment, 2018; Norwegian Ministry of Climate and Environment. 2019; Manitoba Conservation and Manitoba Water Stewardship, 2008; Sakaw Askiy Management, 2018; Alberta Government, Agriculture and Forestry – Forestry Division, 2010a; Department of Agriculture, Water, and the Environment, 2018).

Rotation Length

Rotation length is the time elapsed between two final harvests, where a rotation gives trees in a specific area time to grow naturally without thinning or harvesting

(Roberge et al., 2016). Rotation length is important in any forest management regime and tends to be dictated by the goals of the forest management (Roberge et al., 2016). The time between harvest is usually driven by economic factors as well as tree species growth (Roberge et al., 2016). In general, the longer the rotation period, the less nutrients that are removed form site so lengthening rotation period can help preserve nutrient levels in soils. Rotation length can also depend on the species of tree being harvested. Even if plans do not specifically mention that they have a rotation period, if they harvest forests, it is probably considered in the background if multiple year harvests are planned. Altering rotation length as management option is cited more in Canadian plans than internationally, (Table 2.4). Rotation length does not require adding anything to the soils, only managing the time between harvests which makes it an easier management practice.

Slash

Slash is defined as the left-over product of logging operations. Slash includes branches, bark, wood debris, limbs, tops, and pieces that cannot be used in a product (Prévosto, & Ripert, 2008; Kapitsa et al., 2019). Slash management in forests includes leaving slash behind or burning slash on site. In both cases, nutrients are retained on site. Australia prescribes on-site slash retention rather than slash burning as it is used as more than for nutrient cycling alone. Australia prescribes leaving slash on site to be laid down to protect the soil from machinery (Department of Agriculture, Water, and the Environment, 2018). Slash is seen as a means of minimizing soil damage during human practices.

In comparison, Ontario explains in their background document that slash piles are usually perceived as undesirable, and excess slash piles are burned (Ministry of Natural

Resources, 2010b). Ontario does not see that slash may be a benefit to some types of wildlife and could be redistributed to private lands to provide the habitats (Ministry of Natural Resources, 2010b). Although slash is seen to regenerate nutrients, its other benefits are more desirable to the Ontario government. These benefits include using slash for biofuel as biofuel is a rising energy source (Ministry of Natural Resources, 2010b).

Liming

Liming is another nutrient management technique that has been used historically to restore Ca or maintain soil base saturation. Liming can reduce the effects of acidification by increasing the soil pH and exchangeable Ca concentrations in the forest floor and upper mineral soils (Melvin et al., 2013). Liming was rarely mentioned (3 of 16 locations) in the forest management plans (Table 2.4). Of the three mentioned, the German plan only states that support for compensatory measures for acidifying inputs like forest liming is maintained (Federal Ministry of Food and Agriculture, 2020). Alberta, Canada, states that lime could be added if it was more suitable to produce plants (Alberta Government, Agriculture and Forestry – Forestry Division, 2010a). Apart from that, some plans mentioned that lime is already in their sites or that their soil contains natural limestone. It is assumed that liming may be mentioned less because many plans were updated recently, meaning liming could have been done previously and considered in plans during the acid rain crisis, but now have been updated. Academic studies showed that liming was used historically in Europe, Finland, and Sweden to restore soils before the acid rain concern (Lundström et al., 2003b). In Europe, liming was used to improve nutrient contents in the soil over 100 years ago (Lundström et al., 2003b). It was noted that liming was done because it was recognized that forests were losing nutrients from

cattle grazing and bedding (Lundström et al., 2003b). Finally, liming is mentioned in Florida, USA, but not in relation forests, only concerning waterways, stating that lime could be added to waterways in controlled ecological studies (Forest Services, US Department of Agriculture, 1991c).

Avoiding Whole Tree Harvesting

Whole tree harvesting is seen as harmful to the forest ecosystem, as it disrupts ecosystems (Skogsstyrsen Sweden Forest Agency, 2011). Whole tree harvesting is defined as harvesting of the stem, taking 75% or more of the branches in thinning and final felling (Akselsson et al., 2007). Having whole tree removal could increase soil acidification and cause nutrient depletion (Skogsstyrsen Sweden Forest Agency, 2011). Avoiding whole tree removal is when parts of the trees, usually stumps and roots, are left behind to retain more nutrients on site (Akselsson et al., 2007). Avoiding whole tree removal is a more common practice globally as it is noted in Sweden, Australia, Denmark, Switzerland, and Canada (Table 2.4). Maintaining nutrients in the forest is difficult with whole tree harvesting as nutrient exports typically double over the rotation periods when whole trees are harvested (Skogsstyrsen Sweden Forest Agency, 2011). Avoiding whole tree removal could be seen as a more accessible, less costly measure as it does not require extra additions, just leaving behind certain parts of the tree to allow for nutrients to stay in the cycle.

Wood Ash

Wood ash is defined as the powdery substance that comes from burning wood in high heat, such as boilers or fireplaces (Augusto et al., 2008). Wood ash can be highly variable depending on the nature of the original product and the process of combustion as

different products will contain different nutrient and mental concentrations (Augusto et al., 2008). Wood ash has a high pH, meaning it gives ash a high acid-neutralizing capacity (Augusto et al., 2008). In Canada, it is more commonly used on agricultural sites and less so in forests. The Yukon is an exception as the prescribe ash from fires for forests. It is cited that ash can return significant nutrients to the forest floors, so for that reason, wildfires are responsible for nutrient cycling (Government of Yukon, Forest Management Branch, 2013).

In comparison with Canada, Sweden, and Switzerland both allow off-site ash to be spread as a soil amendment that should be done after harvesting (Skogsstyrsen Sweden Forest Agency, 2011; Federal Office for the Environment FOEN, 2013). Ash can be used to compensate for logging practices such as whole tree harvesting (Skogsstyrsen Sweden Forest Agency, 2011). Nitrogen is volatilized in the combustion process of burning wood, so ash is a good amendment to be applied to areas that have an abundance of N but deficient on other nutrients. Similarly, N additions could also be added with ash if multiple nutrients are limited in sites (Skogsstyrsen Sweden Forest Agency, 2011).

In Sweden, wood ash recycling has become more prominent because of the high taxes and fees for landfilling (Lundström et al., 2003a). Overfilled landfills have become a rising issue in many countries and diverting products from landfills is something that is desired (Lundström et al., 2003a). Apart from the economic gain from not landfilling ash, studies have shown the benefits of using ash in forests, such as the pH being considerably enhanced by treatment in the mineral soils of 0-10 cm (Lundström et al., 2003b). These same results were shown in Switzerland as the pH, cation exchange capacity (CEC), and

base saturation increased after only two months following 4 tons per hectare treatment (Lundström et al., 2003b).

All of these nutrient management practices are examples of acting with human interest being a background factor. When humans interfere in a natural forest, practices are used to ensure long-term sustainability. With this same mindset, including nutrient management into forest management strategies would allow society to fix the damage that has been caused to the forest soils. However, ensuring harvesting practices are sustainable (for economic reasons) by encouraging nutrient management should not be the only reason why these practices are done. It should be conducted any time damage has been done to the soils or the natural nutrient cycling is disrupted.

2.5.2 Circumstances Advising Nutrient Amendments

The forest management plans do not generally go into detail describing the circumstances when nutrient amendments should occur. The most common circumstance for amendments is to support harvesting. In both Sweden and Switzerland, nutrient amendments must be done after any form of harvest to give the soil back the nutrients extracted (Skogsstyrsen Sweden Forest Agency, 2011; Federal Office for the Environment FOEN, 2013). Some plans, such as in Ontario, use logging methods that minimize nutrients loss, such as harvesting in the winter (Ministry of Natural Resources, 2010a). Russia credits bad harvesting practices for the nutrient losses in soils as forest mortality takes place as a decrease in growth and deterioration of forest health conditions (Food and Agricultural Organization of the United Nations, 2012). All four of those countries agree that poor harvesting practices are an issue for forest nutrients.

Weather conditions are another consideration when looking at harvesting and the need for nutrient amendments. In wet conditions in Australia, slash is placed on extraction roads during harvesting to minimize soil damage (Department of Agriculture, Water, and the Environment, 2018). If weather conditions are not optimal, amendments are done to ensure minimal damage. Since slash tends to be used for more than nutrient amendments, using it in these conditions help more than nutrient deficiencies.

Lundström et al (2003) found that from full tree harvesting of the stem, branches, and tops, a comparable mass of 4 tons per hectare of wood ash is removed from sites in Sweden. The idea of using wood-ash as an amendment in whole-tree harvesting situations is that the same quantity should be recycled back to the forest (Lundström et al., 2003b). Sweden proposes that wood ash treatment be used at every whole tree removal site in Southern Sweden and at every second rotation in the middle and north of Sweden, where the effects of soil acidification are limited (Lundström et al., 2003b). Sweden has tested to see where soils have been affected by acid rain the most and changed the treatment advisory based on this. That is why southern Sweden has different advised treatments compared to central and north of Sweden.

Looking to the future, Sweden mentions adapting forest management plans to include shorter rotation periods to account for current and future climate change issues (Skogsstyrsen Sweden Forest Agency, 2011). Planning for the future and having adaptability in plans is essential as the climate is changing drastically. As more climate crises are publicized, it allows for new policy trends to emerge, as these are highly variable to public pressures and mainstream media (Michaels et al., 2006).

2.6 Benefits and Gaps Surrounding Nutrient Management

2.6.1 Benefits of Nutrient Management

There are many benefits to having nutrient management in forest management practices. They include better nutrient cycling, minimized nutrient losses, less landfilled products and cost savings associated with avoiding landfilling (Hope et al., 2017), and carbon storage may increase (Brant & Chapin, 1983). This leads to the conclusion that repairing the soils in the full-grown forests will be more beneficial as species planted in infertile soils generally cannot acquire enough nutrients to survive and support rapid growth (Brant & Chapin, 1983). Another benefit of nutrient amendments is the potential increase in forest products. Maple syrup is a forest product that has significant economic impacts in Canadian provinces such as Quebec and Ontario (Statistics Canada, 2018).

There are also some intangible benefits of including nutrient amendments in plans. Nutrient management could prepare the environment for possible dangers that have not presented themselves yet (Ministry of Environment, 2015). Fixing the current environmental damage and taking care of the soils in forests could protect forests from possible challenges in the future, such as climate change (Ministry of Environment, 2015). Another intangible benefit is that the programs could increase community involvement and awareness of the issues if smaller community-based projects are done. If community members had easy to follow guidelines, they could take care of their land using provincially laid out thresholds and guidelines.

2.6.2 The Missing Information on Costs and Benefits of Nutrient Management

Trying to assess the costs and benefits of nutrient management can be tricky since there are many knowledge gaps. Nutrient management is primarily used to prevent future issues so while costs are immediate, benefits may not occur for decades. Benefits are

perceived to been seen over several harvest periods and therefore accessing the cost and benefit of nutrient management is hard for the short term. Cost may vary depending upon forest type, dose and material used. There are competing practices, such as lime and wood ash, that both offer Ca as acid buffers (Augusto et al., 2008; Melvin et al., 2013) but plans that mention one or the other do not explain why. Incorporating knowledge from recent studies is also limiting so old information is often used for designing plans. Another gap between forest management plans and experimental studies is the definitions of key terms and concepts, and the language used does not match. When conducting this research, it was observed that previous knowledge of the key management practices and nutrients is needed to understand the documents. Both academic studies and government documents use different wording, leading to a miss communication between the studies.

2.7 Disconnect Between Academic Studies and Policy Processes

There is a disconnect between policy articles and academic research and publications on nutrient management in forest. There have been many academic studies conducted that evaluate the benefits of nutrient amendments to forest soils (Azan et al., 2019; Deighton et al., 2021a; Pitman, 2006; Watmough, and Aherne, 2008), but those data are not included in many current policy frameworks. There are likely several reasons why some academic studies are not included in forest management plans.

The first reason may be the different language used in academic studies compared with policy frameworks. Different terms are used, and for any discipline, certain terms are used which can be hard to understand if no previous knowledge on the subject is known. Whitty (2015) argues that methods and language should be explained in simpler terms to be assessable by wider audiences. Authors and editors can transform papers

making a simple point using methods easily understood by policy makers (Whitty, 2015). It is hard to decipher what is being said in the academic's vocabulary, so changing this would allow the research to be assessable to more people (Hurleya et al, 2016).

The release of academic articles also creates a barrier. Policy changes can be fast compared to academic standards. Policy decisions could be made in weeks or months if situations need, such as in the acid rain crisis (Whitty, 2015). Whereas academic research can take years to conduct and get published, which means that policy documents are based on research that may not be up to date. Academic research needs to be completed ahead of the needed policy change to be included. A secondary issue is that it is rare for all the evidence needed for a policy change to come from one study or one discipline (Whitty, 2015). Multiple studies across multiple disciplines are needed for policy makers to see all sides. Policy decision-making should consider more than only systematic research (McKenzie et al., 2020). It should balance competing social interests, resolve power conflicts and appease groups with different values (McKenzie et al., 2020). Having multiple disciplines and parties interested in an issue could help policy makers make a more informed decision and appease the different parties.

How the different parties view a problem can also cause difficulty. In the academic world, research is designed to fill a specific gap in knowledge, or look at mechanisms, and this comes with its own process (McKenzie et al., 2020). This is done by understanding current research, repeatable methods, documentation, and control through the peer review process (McKenzie et al., 2020). In contrast, policy makers use the term research more loosely to mean an investigation that generates the knowledge to solve a problem (McKenzie et al., 2020). Another barrier to the disconnect between

disciplines is having access to the academic studies. Even if the studies are conducted ahead of policy change, many studies are published in fee-for-access journals and are not accessed by everyone (Hurleya et al., 2016).

2.7.1 Solutions

There are possible solutions for the disconnect between disciplines. The first is educating researchers about the policy process (Phibbs, 2016). Academics often have a limited understanding of the policy process as it is not taught to them and how this process reaches different disciples and jurisdictions (Phibbs, 2016). If academics were taught this process, they might be able to alter their publications to be applied in the policy-making process, and avoid using complex terms that are specific to that field when they could be explained in plain language (Phibbs, 2016). A second solution could be having incentives for researchers to work with policy makers and write reports that would be beneficial for the policy process (Phibbs, 2016). Changing a report or re-writing the work in a different format could be beneficial, but there is no incentive for researchers to do this with the time investment it takes. Incentives could either come from universities or the government (Phibbs, 2016); researchers may be more inclined to help fix this issue.

2.8 Conclusion and Recommendation

Most countries assessed in this study do not include nutrient management practices in their forest management plans. Some plans mention nutrients in passing or as a describing characteristic for the soils but do not consider nutrient amendments. Knowing that nutrient amendments can help the environment and save the government landfill space, including nutrients in the plans would be beneficial. Having healthy forests can benefit C storage, tree growth, and reduce landfill usage (Hope et al., 2017; Brant &

Chapin, 1983). Landfilling products such as wood ash can be a waste when there are benefits to recycling it in forests and reduce more landfill requirements (Hope et al., 2017). Countries such as Sweden and Switzerland recognize these benefits and have acted upon them with nutrient amendment practices in their plans (Skogsstyrsen Sweden Forest Agency, 2011; Federal Office for the Environment FOEN, 2013).

In conclusion, the review of forest management plans suggests that there is no widely accepted practice for nutrient management in soils. Even among the provinces and territories in Canada, the policies differ significantly, and none of them include extensive nutrient management. Some countries include adding amendments to the soil, such as ash (in Sweden and Switzerland) or lime (in Germany), but no one practice has become widely practiced. With the differing approaches and policies, it leaves an unclear message as to what should be done. However, academic and policy articles show that there is a benefit to nutrient management and that soils are degraded from human practices over the years (Skogsstyrsen Sweden Forest Agency, 2011; Federal Office for the Environment FOEN, 2013; Hope et al., 2017; Brant & Chapin, 1983).

The next Chapter examines the challenges to establishing an experimental wood-ash recycling program that may solve many of the issues found in the Muskoka, Ontario region. This case study is also an example of how researchers, NGO's and policy makers must work together to figure out a move forward as this is new territory for both groups.

Chapter 3 Case Study on the ASHMuskoka Project

Abstract

In this chapter a case study was conducted on a new pilot wood ash recycling program in Muskoka, Ontario. The Friends of Muskoka Watershed started a pilot program (ASHMuskoka) to use the wood ash burned in residents' houses as a forest fertilizer to restore calcium on land and in the waterways. An analysis of the current regulations and policy application submitted to the government of Ontario that surround this project was completed. Interviews were conducted with key stakeholders and experts in the field to understand the benefits and policy hurdles of this program. The current regulations are seen as the biggest barrier for the Friends of Muskoka Watershed to make this program widespread. For government agencies, the biggest hurdle to approving this program is the lack of scientific data supporting this project. Without the data to confirm the expected benefits, government agencies are reluctant to approve a program for fear that it could cause damages to the environment.

3.1 Introduction

3.1.1 Issue of Calcium Decline

Calcium decline has several ecosystem consequences and affects the health of many species (Ryan et al., 1994; Yao et al., 2011). Acid rain and forest harvesting both contribute to Ca decline in forests and surface waters (Battles et al., 2013; Güner et al., 2021). In terrestrial ecosystems, the Ca pool in sensitive soils in Ontario have substantially declined since the peak of acid deposition in the 1960s (Ott and Watmough, 2021). Calcium is an essential nutrient and some taxa such as sugar maples (Watmough, 2002), daphniids, and crayfish (Arnott et al., 2017) are particularly sensitive to falling Ca levels.

3.1.2 Terrestrial Ecosystems

Acid deposition has leached large amounts of Ca from soils and caused an array of problems (Grennfelt et al., 2020). In soils, both the leaching of acid anions such as sulphate and nitrate, as well as the mobilization of Al remove Ca from soils (DeHayes et al., 1999). In regions characterized by low weathering rates, the rate of loss exceeds the rate at which base cations can be replenished and soils acidify (Watmough, 2002). As soils acidify, the mobility and availability of aluminum and other toxic trace metals such as cadmium (Cd) and zinc (Zn) in the soil increases (Watmough, 2002), which could be detrimental to plant health (Casson et al., 2011; Visgilio & Whitelaw, 2007). The loss of Ca (and other base cations) reduces the storage in soil, reducing the availability of nutrients for roots to uptake (DeHayes et al., 1999). In addition, the uptake of base cations from soils by growing forests and subsequent logging is responsible for the continuing decline of Ca as base cations are removed from site that would otherwise be recycled (Arnott et al., 2017). Calcium decline has adverse impacts on forest ecosystems

(Watmough and Ahern, 2008). For example, low Ca availability has been associated with freeze damage in red spruce trees (DeHayes et al., 1999). Sugar maple growth is also poorer in acidic soils with low Ca levels (Bal et al., 2015; Watmough, 2002).

3.1.3 Aquatic Ecosystems

As soils acidify and acid deposition changes, Ca inputs to surface water have also changed with lake Ca levels falling by more than 40% in some lakes in central Ontario since 1980 (Reid and Watmough, 2014). Jeziorski and Smol (2017) similarly noted a decline in Ca concentrations in many soft water boreal lakes due to acid deposition and timber harvesting. As every aquatic plant and animal requires Ca, there is a growing concern for the effects of widespread Ca decline in the lakes in Ontario (Jeziorski and Yan, 2011).

Calcium is an essential nutrient needed for cellular function, the vertebrate endoskeleton, and is a component of the invertebrate exoskeletal structure (Jeziorski and Smol, 2017). In surface waters, low Ca levels may have implications for biota with high Ca requirements and may increase the sensitivity to ultraviolet radiation (Jeziorski et al., 2015; Watmough and Aherne, 2008). With the decline in Ca, the reduction of lake water pH negatively affects the growth and survival rates of aquatic biota by lowering reproductive success, which leads to a local population extirpation of certain species (Jeziorski and Smol, 2017). For example, in changes in pH and Ca levels in central Ontario lakes have been linked to the near extirpation of native crayfish (Jeziorski and Smol, 2017). To ensure the sustainability of aquatic ecosystems, ensuring Ca stays in the ecosystem is essential.

3.1.4 What is Wood Ash?

Wood ash is the powdery substance from burning wood in high heat, such as boilers or fireplaces (Augusto et al., 2008). There are two types of wood ash used currently: industrial (bottom ash or fly ash) and non-industrial wood ash (NIWA), including residential wood ash. Industrial wood ash has been commonly used as a soil amendment in Europe (Augusto et al., 2008) but is less common in North America. In Canada, industrial sources of wood ash are plentiful as Canadian pulp and paper mills produced up to 0.75 million tonnes of wood ash in 2002 (Azan et al., 2019). Industrial wood ash tends to have a pH value ranging from 8.9 to 13.5 (Demeyer et al., 2001). Non-industrial wood ash comes from homes, and wood-fired ovens (Azan et al., 2019). The use of NIWA has not been studied on forest soils, and indirectly, lakes (Azan et al., 2019).

The composition and quantity of wood ash depend on the tree species burnt, the combustion temperature (Pitman, 2006), the part of tree combusted (bark, wood, leaves), the type of soil and climate conditions, the conditions of combustion and collection, and the storage of the wood ash (Demeyer et al., 2001). Wood ash is typically rich in most essential nutrients (Ca, K, Mg, Al, iron (Fe), and P) but contains very little N as this is lost during combustion (Pitman, 2006; Deighton et al., 2021a). Wood ash application, however, can increase soil N availability in soil as a rise in soil pH has consequent N mineralization (Pitman, 2006). Non-industrial wood ash is also rich in nutrients, but because it is derived from multiple distinct sources it may exhibit more variability than industrial wood ash. A study done by Azan et al. (2019) found wood ash from Muskoka had 26.8% to 31.9% Ca concentration, K ranged from 6.1% to 10.4%, Mg concentrations ranged from 1.5% to 2.4%, P also ranged from 0.5% to 1.2%.

Regulations related to the use of wood ash are made at territorial and provincial levels in Canada (Hannam et al., 2016) and are concerns over potentially harmful levels of metals in wood ash that may restrict widespread usage (Pitman, 2006). This explains why testing for trace elements of arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), mercury (Hg), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn) before an application is required (Deighton et al., 2021b). Currently, Ontario does not allow wood ash to be spread in forest soils (Deighton et al., 2021b).

Regulations also differ between agricultural and forest settings regarding the use of wood ash in the soils (Pitman, 2006). This is because agricultural soils are maintained as near to neutral pH as possible during cultivation, and fertilizers are used over short periods for immediate effects (Pitman, 2006). Forest soils, however, tend to be thinner, and often more acidic, which leads to different concerns including the increased levels of nitrate being leached or increased heavy metal availability (Pitman, 2006).

3.1.5 Supply of Wood Ash in Muskoka

Having a sufficient supply of wood ash would is essential for creating a recycling program. It has been estimated that Muskoka residents who heat their homes with wood and would be willing to transport their ash to a landfill or transfer station could produce around 235 tonnes of wood ash per heating season (Azan et al., 2019). This could be combined with other NIWA sources such as pizza ovens. Industrial sources could also supplement this (Azan et al., 2019).

Wood Ash in Muskoka

Under the Non-agricultural Source Material (NASM) plan, the government has identified the maximum levels of metals in the ash (Cd, As, Ni, Pb, Cu, and Zn) that are

allowed to be applied to soils. This concentration is known as the content of regular metals (CM) that is a limit set out under the NASM plan that outlines the maximum concentration of metals based on intensity in the material allowed to be applied to the soil (Hannam et al., 2016). The levels cannot exceed a five-year metal loading set out by the government and if the levels of metal concentrations exceed the limit, the levels must be reduced. There are two levels of concentrations set under the NASM plan, CM1 and CM2. If the concentration of any of these metals in the ash exceed the CM level 2, then they cannot be applied to the forests under the NASM plan (Hannam et al., 2016).

If a product falls above the CM 1 but below CM2, there are extra regulations applied to its usage, such as having a minimum depth to ground water and a further proximity to surface water (Hannam et al., 2016). The wood ash from the ASHMuskoka project, was collected, and tested to see the concentrations of nutrients and metals before spreading it in the forest.

The mean pH of the wood ash was between 11.8-13.5 (Table 3.1). In general, ash is high in nutrients such as Ca, Mg, K and P and low in most metals (Table 3.1). Concentrations of all metals analyzed in the ash were below the governmental limits (CM levels 1 or 2) for being soil-applied (Master's thesis, Trent University, Batool Syeda; Ministry of Agriculture, Food and Rural Affairs, 2016) but concentrations of some metals approached or exceeded NASM CM Level 1 values. However, metal concentrations were well below the CM Level 2 values meaning they can be land applied, with regulations.

Table 3.1

Select chemical properties of residential wood ash applied to 3 sugar bushes in Muskoka

	Brook land Farms	SD	Wilf's Sugarbush	SD	Marks Sugarbush	SD	NASM CM Level 1	NASM CM Level 2
pH	13.5		13.3		11.8			
Ca ($g.kg^{-1}$)	306	15.2	273.5	48.4	294.6	46.4		
Mg ($g.kg^{-1}$)	24.2	2.56	22.1	3.5	22.6	3.6		
K ($g.kg^{-1}$)	110	13.1	112.7	21.7	104	20.3		
P ($g.kg^{-1}$)	8.9	1.2	7.9	1.2	7.9	1.2		
Cd ($mg.kg^{-1}$)	2.8	0.4	2.6	0.6	2.6	0.4	3	34
As ($mg.kg^{-1}$)	3.9	6	3.1	7.4	3.8	5.8	13	170
Ni ($mg.kg^{-1}$)	10.5	3.2	8.9	2	7.9	1.5	62	420
Pb ($mg.kg^{-1}$)	24.3	17.4	12.8	3.9	48.5	64.2	150	1100
Cu ($mg.kg^{-1}$)	105	41.9	154	92.1	106	15.2	100	1700
Zn ($mg.kg^{-1}$)	524	110	516	151	440	61.5	500	4200
Mn ($mg.kg^{-1}$)	6310	684	6840	1023	6330	1251		

Note. (Ministry of Agriculture, Food and Rural Affairs, 2016; Syeda, B, 2022). Wood ash samples were taken from the three sugar bush sites in Muskoka that had a wood ash application. These samples were tested for metal and nutrient composition. These sites were compared against the NASM levels of maximum application rates to soils.

3.1.6 Who are the Friends of Muskoka Watershed?

The Friends of Muskoka Watershed (FOMW) is a not-for-profit organization established to help restore the watersheds in the Muskoka area for future generations to enjoy. The FOMW identify environmental threats, develop practical science-based solutions, and connect with policymakers to put solutions in place (Friends of the Muskoka Watershed, 2020a). They also bring awareness to these issues and solutions through educational outreach within the Muskoka community (Friends of the Muskoka Watershed, 2020a).

3.1.7 What is the ASHMuskoka Project?

ASHMukoka is the second phase in the Hauling Ash to Solve Ecological Osteoporosis (HATSEO) project. The first phase used applied research to explore, create, test, and refine an optimal way to collect, store and distribute wood ash (Friends of the Muskoka Watershed. 2020b). The first phase confirmed the viability of using wood ash to replenish the Ca levels in the local watershed (Friends of Muskoka Watershed. 2020b). Phase 1 laid the groundwork for ASHMuskoka, which is phase 2 in the project.

ASHMuskoka is conducting field studies to examine potential benefits and harm associated with NIWA application as well as a socioeconomic assessment of the long-term feasibility of the Program. The project partners with scientists, municipal officers, and property owners in the Muskoka area (Friends of the Muskoka Watershed. 2020b). The project explores the idea that wood ash from local residential stoves can be used to restore the damage that has been caused in the past (Friends of the Muskoka Watershed. 2021a).

3.2 Motivation Behind the Project.

This ASHMuskoka project got its motivation from Dr. Norman Yan, who was approached to chair the new group (Interview 2, personal communication). Dr. Yan took the position when realizing that he could influence this group's work and wanted to pick a project connected to a widespread problem that was not getting the attention it needed (Interview 2, personal communication). Dr. Yan wrote a grant application to the Ontario Trillium Foundation, which funds projects for the public good and community involvement and recognized the environmental projects as public interest. The wood ash project had immediate traction as many people in the Muskoka area generate wood ash and are willing to share it. The community was intrigued by the aspect of becoming gardeners of the forest (Interview 2, personal communication), and the community has been a significant driver of its work. The community has been called an "army of advocates" (Interview 7, personal communication) for this work as they fully support and push the project. The project is in its infancy and still faces many challenges and barriers, not least of which is the issue with permitting. This chapter will research the benefits and challenges surrounding this project and will suggest solutions to these challenges.

3.3 Methods

Research Question: What are the barriers and restrictions surrounding creating a residential wood ash program in Muskoka for use as a forest soil amendment?
Objectives: I am to determine a) the challenges and barriers surrounding using residential wood ash as a forest amendment, b) identify possible solutions to these issues, and c) identify advantages and benefits to using residential wood ash as a forest amendment.

3.3.1 Research Approach

3.3.1.1 Document Review

Internal documents provided by the FOMW included the Ministry of Environment, Conservation and Parks (MECP) guidelines on spreading wood ash, transportation, environmental protection act, the initial application to the MECP, and follow-up applications for the fourth site. The MECP guidelines and initial application were reviewed to help understand project goals, the policy application, and access the application process.

3.3.1.2 Interviews

Interviews with key informants were conducted to provide information needed to address the research question and objectives. Seven semi-structured interviews were conducted, and participants were selected two ways. Firstly, participants were selected based on the criteria of having worked with wood ash as a forest amendment or knowing the policy process of getting a project working with wood ash approved. Participants were sought with knowledge specific to Ontario, but other provinces were also recognized.

Then a snowball sampling method was then used to ask participants if they knew of anyone else who met the criteria of this study, which would be a benefit to the study. This was done to ensure that no one with specific knowledge of the issue was not considered based on the original research knowledge of working individuals.

Interviews were conducted with key informants in three sectors: a non-for-profit environmental organization, government workers, and a forest stewardship organization. The interviews were conducted between February and April 2021, lasting between 50-90 minutes, and were conducted over Zoom due to COVID19 restrictions. Interviews were

then transcribed using the Zoom transcription services as a starting point and then corrected as needed manually by the researcher.

There were three fields of experts or stakeholders that were contacted for interviews for this research. The first is the Friends of Muskoka Watershed employees, as they are the group championing this work. They were sought out for the wealth of knowledge they have on the policy process of this project and the logistical barriers that have arisen since undertaking this project. Since this is a first-of-its-kind project in Ontario, this group had to make trial-and-error applications with the Ministry of the Environment, Conservation, and Parks (MECP) to get approval for spreading.

The second group of interviewees was those working for the government who would have had a stake in this project. There have not been many individuals or departments who have worked on a project involving residential wood ash. These people are considered the experts for this topic in Ontario with their experience managing the current policies to make this project work. The last group of interviewees works for a forest stewardship that has been interested in this project moving forward. This group has considered the logistical and political considerations needed for this project to conduct on crown land. They have also supported the Friends of Muskoka Watershed on their journey to getting this project approved.

Interviewees were asked a set of open-ended, semi-structured questions based on themes relating to this area (see Appendix 4). Themes included economics, barriers and challenges, benefits and advantages, and the policy process surrounding using wood ash as a soil fertilizer and creating a provincially approved residential wood ash recycling program for the use of forest distribution.

3.3.2 Methodological Limitations

There are a few methodological limitations to this study. The number of people who work in this field is limited.

Another limitation is due to the COVID-19 pandemic and having to use Zoom for all interviews. Zoom was a good second choice to allow research to continue, but it is less personal and more challenging to judge body language over Zoom. Zoom also does not let the researcher see any in-person materials the interviewee may have with them or their companions. The advantage to using Zoom however is the ability to record the interviews for easy review.

3.3.3 Ethical Considerations

The Trent University Research Ethics Board approved this study, and copies of the approved informed consent form can be found in Appendix 2. This ensured that everyone understood the research and was comfortable with it. Since the initial consent process happened by email and no in-person contact could be made, verbal consent to the researcher was also requested to ensure that the interviewee was the one to give consent. For confidential reasons, names were removed from interview participants for this research.

3.4 Results

3.4.1 Background for Document Analysis

Currently, no plan or regulation allows the spreading of wood ash in forests in Ontario. Since wood ash is considered a waste product, it is not allowed to be spread in forests under the Nutrient Management Act. Presently, due diligence must be done to ensure that no harm is being done to one of the most significant natural resources (Interview 5, personal communication) when new projects are proposed. With no existing

policy and regulatory framework to permit the spreading of wood ash, the MECP had to find a way to allow the pilot study to go ahead under the current regulatory frameworks.

The MECP considered using the non-agricultural source material (NASM) plan or use regulations under the Environmental Protection Act (EPA) (Interview 5, personal communication). The NASM plan assumes that a non-agricultural material will be applied to a farm setting, but this is not the case for ASHMuskoka.

Under the NASM plan, before any applications are allowed, the land must be analyzed for soil pH, available phosphorus, available K, total metals (including Cd, Cr, Co, Cu, Pb, Mo, Ni, and Zn), mercury, arsenic, and selenium. It is also highly recommended but not required that soils be sampled for Mg, Ca, Zn, manganese, and nitrate. All nutrients and metals must have acceptable thresholds for land application, and if any thresholds are exceeded, the project cannot continue (Ministry of Agriculture, Food and Rural Affairs, 2016).

These requirements do not meet the project goals of the ASHMuskoka project. Since the NASM plan regulates farmland, more stringent testing rules are present to ensure no contamination of crops.

The Nutrient Management Act works very well when the rules align with the proposed project (Interview 5, personal communication). Under the NASM plan, there is a blanket rule for all projects, and if the project meets the criteria and fully aligns with the regulation, this plan works very well. In the case of the ASHMuskoka, the project does not fit into all the NASM boxes, meaning a site-specific rule is more acceptable than a permit by rule (Interview 5, personal communication).

3.4.2 Document Analysis

Environmental Protection Act

The Environmental Protection Act aims to protect and conserve the natural environment (Government of Ontario, 2021). The Environmental Protection Act (EPA) stipulates that no person is allowed to discharge into the natural environment any contaminant that exceed the excess levels provided by the regulations (Government of Ontario, 2021). A project can be halted by the government when it is found, on reasonable and probable grounds, that the contaminants being discharged into the environment are an immediate danger to human life, the health of a person, or to property (Government of Ontario, 2021). The purpose of the general provisions is to ensure human and environmental health is maintained. Under the EPA, there is more flexibility for regulations as policymakers can decide on a case-by-case basis for approvals. It is a site-specific approval instead of a permit by rule (such as the NASM plan).

Under the EPA, the government also wants to know the beneficial outcome in addition to more information on the potential harms and sourcing of the wood ash. The policy is established to ensure there will be no adverse effects or impairments to water bodies resulting from the land-based proposals (Government of Ontario, 2021).

Under the EPA, a project must get an environmental compliance approval (ECA), a document administered by the ministry that includes permits, licenses, approvals, and authorizations for the project (Government of Ontario, 2021). A person may apply to the ministry for approval to engage in activities under the protection of the EPA or the Water Resources Act that is not currently prescribed by regulations (Government of Ontario, 2021). The approval can be processed to include more than one site, and unless directed

otherwise, the ECA would regulate all sites in the original application (Government of Ontario, 2021).

There are still concerns under the EPA over some aspects of the ASHMuskoka project. Dust emissions and contaminated run-off from soils are the main concerns. It is unsure how far the product could spread and what damages this may cause.

Friends of Muskoka Policy Application

To get approval to spread wood ash on the original three sites, the FOMW had to submit an environmental compliance approval (ECA) to the Ministry of Environment Conservation and Parks. The approval was "under section 20.2 of Part II.1 of the Environmental Protection Act, R.S.O. 1990, c. E.19 (Environmental Protection Act) for approval of: the use and operation of an Organic Soil Conditioning Site. The Organic Soil Conditioning Site approved herein may accept and temporarily store Residential Wood Ash Waste only, the spreading of which is restricted to maximum of 20 test plots as described in Schedule "A" of this Environmental Compliance Approval as part of a 3-year pilot study" (Appendix 3). All 3 of the sites needed separate approvals from the MECP for the specific site (Appendix 3).

The ECA for this project outlined the location of the site for spreading, definitions of key terms, sit prevention and complaint procedures, operations, storage of the wood ash, record keeping, expiry and set conditions that had to be followed (Appendix 3). Taken from the ECA for this project, these conditions outlined that

> "The portion of the Site approved for spreading or storage is subject to the following setbacks;

a) a minimum of 250 metres from Sensitive Uses, unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 50 metres;
b) a minimum of 250 metres from a Residential area, unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 50 metres;
c) a minimum of 90 metres from a single residence, unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 25 metres;
d) a minimum of 30 metres from a public roadway unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 15 metres;
e) a minimum of 90 metres from private water wells;
f) a minimum of 100 metres from municipal drinking water wells; and
g) a minimum of 60 metres from Surface Water."

(Appendix 3).

All three sites were approved separately, and the owners of the sites also had to abide by these rules. Once the wood ash was spread, the Friends of Muskoka had to keep records of when, where, and how much residential wood ash was spread and stored. Records also had to be kept of the sampling and analysis of the wood ash and test plots soil and foliage, any spills or upset at and of the sites and any issues that arose with environmental problems and what was done to address these. The Friends of Muskoka Watershed informed the MECP of all the research that came from this project and kept in constant communication so the MECPs records were up to date.

3.4.3 Interviews

3.4.3.1 Benefits

Policy Makers

For policy makers, the most significant benefit of the ASHMuskoka project is that it keeps the ash out of landfills. Currently, reducing and reusing products is encouraged in the policy approaches (Interview 3, personal communication; Interview 5, personal communication). Landfill space is limited, and it is not seen as the most beneficial use of

the land to fill it with unnecessary products. Following this, environmental benefits to the forests are also significant. Having increased tree growth, mitigation of acid rain effects, and potentially higher rates of C sequestration by biomass benefit policymakers and future goals of the government (Interview 3, personal communication). Lastly, there is the potential that this project will improve water quality which would be another benefit for policymakers if the studies prove this to be true (Interview 3, personal communication). If forests have a higher level of nutrients, there could be potential for a higher runoff into waterways, which would solve some issues of lacking nutrients in waterways.

Friends of Muskoka Watershed

Out of the three groups of interviewees, the Friends of Muskoka Watershed identified the most benefits stemming from this project. The most significant benefit from this project was the involvement of the public, which included a higher level of public education and awareness of local issues, building stronger communities and relations, and high public participation from the community (Interview 1, personal communication). This higher level of public awareness on the local issues means that the community is learning what the problems are, why they exist and what is needed to help fix them (Interview 1, personal communication). The project has sparked a high level of community willingness to act and be involved, from donating ash to volunteering to help the project (Interview 1, personal communication). The local community has become an "army of advocates," says an interviewee, and they have been a more significant driver behind the project (Interview 7, personal communication). Moving forward, this "army" may be more informed to identify new issues and create new solutions if other projects

arise. Building a community of people who care about the environment and want to act is crucial (Interview 1, personal communication; Interview 2, personal communication). Having this community behind them could favor the FOMW moving forward as having that army of advocates could open a policy window for change (Michaels et al., 2006). The more public awareness of an issue, the greater the chance for policy change (Fifer and Orr, 2013).

Enabling environmental benefits to forests is also crucial. Adding wood ash to the forest would "wake the forest full up in the summer from its sleepiness" (Interview 2, personal communication). A prominent environmental benefit to this project may be the higher C sequestration (Interview 2, personal communication; Interview 7, personal communication). Canada has the two billion tree projects with the goal of sequestering C, but "gardening the forest" and fertilizing current forests may be able to capture eight billion tons of C (Interview 2, personal communication). Many mixed hardwood forests of eastern Canada were affected heavily by acid rain and lack of Ca. Adding wood ash would replenish Ca in soils and allow higher C sequestration (Interview 2, personal communication). With increased tree growth there may be higher water retention (Interview 2, personal communication). Calcium allows trees to be more robust, and lacking Ca would limit the ability to absorb water, which has a flooding link (Interview 2, personal communication).

From an economic standpoint, the ASHMuskoka project could benefit maple syrup production (Interview 2, personal communication). When wood ash is spread in sugar maple forests, it may allow trees to produce more sap full of nutrients and sweetness (Interview 2, personal communication). The trees are thought to be healthier

and would have more leaves than the previous year so that the trees could make more sugar (Interview 2, personal communication). With the idea of healthier trees, there would be more wood accumulation, which would benefit foresters. In Sweden, wood ash additions to the forest are required after harvesting to promote higher wood quality and quantity in the future. Adding wood ash to the forest would in theory "wake the forest full up in the summer from its sleepiness" (Interview 2, personal communication).

Forest Stewardship

There were many benefits given from the employees of forest stewardship. The first short-term benefit was that this project would be doing something about an issue affecting the forests for decades (Interview 4, personal communication). Attempting to solve the issue of Ca depletion in the forest is a great benefit to this project. A significant benefit for foresters is that using Ca supplements in forests may give sugar maples the edge the species needs to overtake the beech population (Interview 4, personal communication). Beech bark disease is a prominent issue in beech-dominated forests as the disease attacks the larger trees, killing them. Once the saplings then reach small tree size, they become very cankered, infected, and die. This cycle then affects the forests for the future forest canopy, for wood products, for aesthetics of the forests, the forest health, and affects habitats for forest creatures (Interview 4, personal communication). This takes away from the picturesque forest canopy that Muskoka is known for. Calcium fertilization may allow sugar maple seedlings to “gain the strength needed” to take over the forest ecosystem and hopefully address some of the consequences of beech bark disease (Interview 4, personal communication). For medium to long term benefits, increased forest growth is predicted, and higher resilience to forest pests, both native and

exotic (Interview 4, personal communication). Increased growth would also allow higher carbon sequestration, which is a significant global theme.

Common Theme

A common theme across all three groups of participants was higher C sequestration (Interview 2, personal communication; Interview 3, personal communication; Interview 4, personal communication; Interview 7, personal communication). This theme was mentioned in 57% of the interviews and within each group. Therefore, it would be considered a significant benefit for all parties involved. Carbon sequestration is a global issue so having a project that would allow higher rates of biomass carbon sequestration would benefit all involved.

3.4.3.2 Hurdles and Concerns

Hurdles and challenges were the most significant category in terms of responses from participants, with policy makers raising the most concerns that would need to be addressed.

Policy Makers

There were many hurdles for this project from a policy makers viewpoint. Policy makers are responsible for ensuring that no undue harm will come to the environment from any project, so they have the most hurdles to jump to ensure due diligence is done. There must be "insurance that the project will positively affect the environment" (Interview 5, personal communication).

The biggest concern policy makers had was regarding human health. Regulators must ensure that the project does not harm humans in any way and the spreading of loose ash could potentially harm humans. Dust emissions could cause health issues to people if

they inhale it (Interview 3, personal communication; Interview 5, personal communication).

Another concern and hurdle for policies is figuring out if the project harms the environment. The theme of having clean ash was brought up several times with a residential recycling program. If asking residents to bring their own wood ash without monitoring the burning method, one cannot be entirely sure that there is no treated lumber being burned, no unwanted chemicals being burned with the wood, no plastic in the burn area (Interview 3, personal communication; Interview 5, personal communication). Stringent testing needs to be done on all the wood ash collected to ensure all residents do not break the rules by accident and follow proper burning procedures. With industrial wood ash, there is less variability and more control over the source of wood and burning measures. The variability of the residential wood ash means that there may not be a "blanket approval" for it. There must be confidence that the wood ash is clean before putting it on the forest floor (Interview 5, personal communication). Residential wood ash may also be limited in supply when in comparison to industrial wood ash. A residential wood ash recycling program relies heavily on the community to be involved, which may not be the case in every region (Interview 3, personal communication). Industrial wood ash would have a higher supply as leftover materials from harvesting could be burned and re-spread.

With this project, there is also a worry that the wood ash dust would get into water bodies nearby (Interview 5, personal communication). Even if the wood ash were to be pelletized or put into a different form, the chance of runoff into water bodies is a reason for concern (Interview 5, personal communication). If the substance was a liquid

material, it could easily flow down slopes and enter surface or ground water. There must be insurance that the material does not have elevated contaminants (Interview 5, personal communication). The government wants to ensure that people are not putting waste material on land and that the product has value to it so that it is worth the spreading (Interview 5, personal communication).

Other concerns that were identified included determining the appropriate dosage rates, the label of the ash, how to run this program, and costs. The ideal dosage rate for wood ash is unclear, so the dosage would need to be determined (Interview 3, personal communication). With this, wood ash has a title of waste from the government, which causes uncertainty around what can be done with it (Interview 3, personal communication). This title would have to be changed in the government regulations if a widespread program were successful. There is uncertainty around this project as it is the first of its kind in Canada, and there are no established guidelines to follow (Interview 3, personal communication; Interview 5, personal communication). Having the wood ash as a waste title leaves regulators at a higher disadvantage to find pre-existing guidelines to fit the ash into. There are clear guidelines as to where cannot be spread; ash cannot be spread near water bodies, for example. However, there is no guideline for where wood ash can be applied (Interview 3, personal communication). Since there is no official guideline, approval can also vary between regions. Policy makers are left to their own discretion, and some may not want to take risks associated with a project like this (Interview 3, personal communication). With a set policy, different departments of the government would need to agree on the treatment. Since this project could fit under the different departments, both the MECP and MNRF would need to agree on the

regulations. If crown land has the potential to be fertilized as well, Natural Resources Canada would need to agree on the policies as well.

There is also uncertainty on the transportation cost of the materials and who would pay (Interview 3, personal communication). Cost is something that forestry companies consider as they would be able to spread wood ash after harvesting. Big investment in nutrient applications could be a cost risk for companies. Even though they have a long-term tenure on the land, the benefits may not present themselves in that time frame (Interview 3, personal communication). Nutrient management is a long-term investment, and results may not be present right away, meaning some companies may not want to take on that cost if it is not mandated.

Friends of Muskoka Watershed

The Friends of Muskoka Watershed saw most of their barriers associated with the lack of regulation from the government and the operational logistics of this project. This project is the first of its kind, which means there has been a trial-and-error process for the Friends of Muskoka Watershed to go through. Their biggest hurdles have been with the policy process of a wood ash recycling program. The approval process took much longer than initially thought, and it was not realized it could take months (Interview 2, personal communication). Since this is a newly proposed soil amendment practice, approval for every step separately (collecting wood ash, storing the ash, transportation, and spreading) was needed, which added extra time and money to the approval process. Every site the wood ash was added to required its own approval from the MECP before ash could be applied (Interview 2, personal communication).

With wood ash having the title as waste (and originally as potentially hazardous), there were many limitations on what could be done with it. For example, it could only be held in one place for six months (Interview 2, personal communication). With this comes the issue of transporting wood ash. Since it is seen as a waste material that could potentially cause harm to humans, there are strict rules on transporting wood ash (Interview 1, personal communication; Interview 2, personal communication). Under the current regulations, a person can only transport their wood ash, so residents are not legally allowed to transport their neighbors' wood ash to a landfill site (Interview 1, personal communication). For the Friends of Muskoka Watershed, there were many applications and hurdles around transporting other people's wood ash (Interview 1, personal communication). The closest policy fit for this project would be operating a waste management system to move the wood ash, which comes with safety regulations from the ministry for transporting a waste product (Interview 1, personal communication). If wood ash were given a different title, working within the policy frameworks might be more accessible. For example, soil fertilizers have different regulations compared to waste products. Soil fertilizers have fewer regulations around applying them to land as they are seen as a benefit to the environment. Since wood ash has not yet been proved to benefit the environment from ministry standards, it makes applying it to land difficult (Interview 2, personal communication).

The cost has been another big hurdle for the Friends of Muskoka Watershed. The pilot project has many unforeseen costs, and getting the funding needed for the Program can be a challenge. Costs associated with transporting a waste product are higher as they need more secure containers and stricter transporting measures (Interview 1, personal

communication). Another unexpected cost with this project was sending the samples to a commercial lab to be tested (Interview 2, personal communication). The government has specific laboratories that they prefer tests conducted at. Even though this project already has a research lab (at Trent University) attached to it, samples had to be sent to a commercial lab for the government reports (Interview 2, personal communication). Government regulations also required some testing that did not make sense for this project, such as nitrogen levels in the wood ash (Interview 1, personal communication). Nitrogen is burned off in the combustion process, so some tests like this extra cost money but did not apply to this project (Interview 2, personal communication).

The cost is also an issue for collecting and sorting wood ash. The activities of collecting the wood ash, sifting it, and storing it are labor intensive, but it currently is the least expensive way to operate (Interview 1, personal communication). More funding could potentially lead to mechanizing the process and expanding the collection area, but those funds do not currently exist (Interview 1, personal communication; Interview 7, personal communication).

Operational logistics caused several more minor hurdles for this project. The first hurdle was getting a willingness to participate (Interview 1, personal communication). Since the policy applications only allow one transfer station to collect ash, people may not be willing to drive hours to drop off a can or two of wood ash (Interview 1, personal communication). A second hurdle was ensuring health and safety for all the employees at the wood ash drives. Sometimes when the wood ash is collected, it is still hot, which poses a risk to employees touching it (Interview 1, personal communication; Interview 7, personal communication). Having hot buckets of wood ash causes a fire risk for the

workers and storing the wood ash at the transfer station. Similarly, participants are asked not to burn other products with their wood ash, which does not always happen. This causes a logistical issue of sifting and cleaning the wood ash before it can be spread in the forests. It also raises the issue of what chemicals could be mixed into the wood ash (Interview 7, personal communication). The last operational hurdle left to be figured out is the ideal dosage of wood ash in the forests (Interview 1, personal communication; Interview 7, personal communication). Dosage rate is being tested by academic studies but is a hurdle currently as widespread approval will be dependent on this being known (Interview 7, personal communication). Finding out a way to spread the wood ash will come after this. The current method of spreading loose ash does not meet standards and proving another way of spreading works is a logistical hurdle. More funding is required to buy and operate these machines that may be needed (Interview 7, personal communication).

The coronavirus (COVID-19) pandemic has also caused some hurdles for this project. These are unforeseen times, and future organizations would hopefully not have to operate a pilot project during a pandemic. With all the lockdowns that Ontario has gone through, many wood ash collection drives had to be canceled for public safety (Interview 1, personal communication). Even though the Friends of Muskoka Watershed had come up with policies to run a distanced and safe wood ash drive, the risk of spreading was too high. The province did not allow these activities to go forward (Interview 1, personal communication). The coronavirus pandemic has also affected the educational aspect of this project. Originally the Friends of Muskoka Watershed wanted to go into school classrooms and teach school-aged kids about the effects of acid rain and the use of wood

ash. However, with the pandemic limiting the amount of in-person interaction allowed, this has been limited (Interview 7, personal communication).

Forest Stewardship

For a forest stewardship company operating on crown land, there are four major hurdles for this project. These hurdles are the operational, business, ministry approval, and formula for spreading (Interview 6, personal communication). The biggest hurdle is the regulations surrounding spreading wood ash on forest soils, which would fall under the ministries' approval. Currently, no legislation allows wood ash to be spread in forests, and forest stewardship companies are cautious about spreading something on crown land without approval in writing from the government (Interview 4, personal communication). Even though that current EA is no longer the rule, the current forest management plans were written under that EA, following those rules (Interview 4, personal communication). Forest management plans take a lot of time and money to create, so it is not feasible to re-write them when spreading fertilizations in forests are not approved yet (Interview 4, personal communication). Technically it is not illegal to spread wood ash in forests, but it is not an approved activity (Interview 4, personal communication). The pilot project has come with many MECP permits, which would be extra work for a forest stewardship company to attempt this on crown land. Both MECP and Natural Resources Canada's approval for this project would be needed to spread ash on crown land in Ontario (Interview 4, personal communication). This also needs to ensure that the wood ash is clean to meet ministry standards (Interview 4, personal communication; Interview 6, personal communication). The ministry will need assurance that no heavy metals in the wood ash would contaminate the crown land.

The second hurdle is the business cost of the wood ash recycling program. It is still unsure the cost of this program and where the money would come from to spread (Interview 4, personal communication). For companies, it is ideal to hire an external party to apply the wood ash, but currently, that does not exist, and it is unsure what the price would be (Interview 4, personal communication; Interview 6, personal communication). The machinery cost may also be high (Interview 6, personal communication). This is not a very mature field, so there are funding issues with it currently (Interview 4, personal communication). There is no immediate monetary benefit to fertilization; it is an investment (Interview 6, personal communication). Even planting a tree has a net present value of zero (Interview 6, personal communication). A company does not make money from a tree until it is fully grown, and there is no guarantee that a tree will go from sapling to a full-grown tree (Interview 6, personal communication).

The lesser concerns cover the operational logistics of this project. These concerns include the technique of spreading the wood ash, picking sites for the spreading, figuring out what trails need to be established. Spreading loose wood ash is not an acceptable method for spreading wood for safety risks, so another method is needed (Interview 4, personal communication). Finally, sites will need to be picked to ensure no runoff into waterways and that sites will be accessible by road or trail (Interview 4, personal communication).

Common Themes

There were several common themes between the three groups regarding hurdles and concerns surrounding this project. The most prominent hurdle currently is the policy process of creating this project. Every group expressed concern around the uncertainty of

regulations for spreading wood ash in the forest. Without the proper policy process set by the government, this type of project will be challenging to make widespread. A second important commonality among the three groups is ensuring the quality of the wood ash and ensuring that there are no chemicals or metals in the wood ash to ensure that no harm is done to the environment for this project.

3.4.3.3 Solutions to the Challenges and Hurdles

Cost

The concern of cost was a recurring theme among the participants. There were a few solutions to this issue, with the first being trust funds from forest companies (Interview 4, personal communication). These trust funds were not built for long-term soil reclamation but would be a starting point for forestry organizations (Interview 4, personal communication). Subsidies or tax breaks could also be a possible solution to the cost issue (Interview 3, personal communication). These could come from the government because of the possible benefits this program. Wood ash could also be pelletized and sold to small forest owners and forest companies to help offset the cost of the program (Interview 1, personal communication). Sugarbush operators might be interested in purchasing wood ash if proof could improve sap production quality and quantity (Interview 1, personal communication).

For forest companies who would not usually apply fertilizer, it may come down to federal or provincial regulations (Interview 3, personal communication). A top-down approach of regulating the replacement of nutrients in forest soils may be the solution for figuring out who pays for this program (Interview 3, personal communication). Forest

companies would be regulated to incorporate nutrient amendment in their forest management plans.

Policy Application

A solution for the policy process is to reclassify wood ash as a fertilizer product instead of a waste product. With this and proper testing of the wood ash, guidelines can be developed for organizations to file applications. Guidelines would need to be developed based on the chemical composition of the wood ash (Interview 3, personal communication). These guidelines exist for other soil amendments, such as compost, so that similar rules can be taken and applied to wood ash (Interview 1, personal communication; Interview 3, personal communication). This would be like treating trees as a crop (Interview 3, personal communication).

The project may also change if the wood ash was treated as a soil conditioner with the purpose of calcium restoration in either private or public land. Specific guidelines would need to be laid out for the organization to follow and streamline application processes (Interview 1, personal communication). These guidelines would first need to identify where wood ash should and should not be applied so that the public can be reassured that water will not be contaminated with cadmium, lead, or something similar (Interview 3, personal communication). Guidelines would also be developed in terms of relevance to water or slope (Interview 1, personal communication). Dosage rates would also need to be regulated, taken from academic studies done once they are completed (Interview 3, personal communication).

For this process to become more acceptable, more studies will have to be done on the benefits of wood ash and possible side effects (Interview 5, personal communication).

The more data proving the benefits, the government will develop a bigger comfort, and a more standardized approach can be made (Interview 3, personal communication; Interview 5, personal communication).

Finally, including all governmental departments in the policy process would be beneficial and ensure there are no conflicting policies later (Interview 3, personal communication; Interview 5, personal communication). Having the MECP, MNRF and NRCan collaborate on policies and agree on the guidelines would allow this project to happen widespread (Interview 5, personal communication). Having a more systematic way of connecting all the ministries would cause less confusion down the road. If a site-by-site approval is required at the beginning of the project, it would give potential for these plans to act like a series of mini-policies that could be referenced for further applications.

Health and Safety

There are health and safety protocols that can be put into place to minimize risk to humans. The first is not working on windy days so that wood ash does not blow into eyes and mouths. With this, ensuring all workers wear masks and gloves will ensure that no harmful product may touch the skin or enter the body (Interview 2, personal communication).

Logistics

Logistical hurdles require more extensive planning on behalf of those spreading the wood ash. Work ahead of time from companies to layout paths for the forests and hire workers to operate ATVs to carry the wood ash to the spreading area (Interview 2, personal communication). This would also make it safer for workers to not be carrying

buckets of wood ash through an untrimmed forest (Interview 2, personal communication). Picking recently harvested areas could also solve some logistical hurdles as these areas would have roads and trails previously set up (Interview 4, personal communication).

Allowing Change

The hurdle of reviewing regulations from a government side would require public pressure (Interview 3, personal communication). If this issue was higher in people's minds, it could cause a ground-up push towards policy change (Interview 3, personal communication). When there is a shift to bioenergy, there may be a realization that there is a lot of wood ash to be disposed of and saving landfill space could become a priority for the public and government (Interview 3, personal communication; Interview 5, personal communication). There needs to be an organization or community willing to disrupt "the normal way of doing things" to create a beneficial change (Interview 6, personal communication). Communications would also need to be handled appropriately, so the surrounding communities are informed of the process (Interview 6, personal communication).

What is Needed Moving Forward

Policy Makers

Policy makers had the most requirements that needed to be met for this program to be approved. The first is the proof that there is a benefit to this program and that there is no undue harm to the environment (Interview 3, personal communication; Interview 5, personal communication). There must be proof that the government is not approving a waste product on the land. The proposal must be proved to be net positive for the

environment (Interview 5, personal communication). With this, the dosage rate must be determined along with the ash application process.

Updated sampling must also ensure that the wood ash remains clean (Interview 5, personal communication). Since residential wood ash is not as controlled during the burning process, it needs to continuously undergo testing to make sure that the wood ash coming in does not have contaminants in it (Interview 5, personal communication). Clean wood ash is also important to protect human health. With people handling the wood ash, it cannot have any harmful contaminants in it that would put those working with it at risk (Interview 5, personal communication). Picking every site with caution is also needed moving forward as wood ash cannot be spread near or in waterways (Interview 5, personal communication). Plans need to ensure that no sensitive receptors are impacted (Interview 5, personal communication).

It would also be beneficial to have good public education to clarify that this is being done safely and there is clear communication on the process of this study (Interview 3, personal communication). This way, the public can be assured that the ecosystems near them are not being harmed. There will need to be public momentum to incite a policy change (Interview 3, personal communication). Without this momentum, the issue may not gain enough traction for a complete policy change. Currently, there may not be enough people or organizations looking at this issue and providing data to push a policy change (Interview 5, personal communication).

For policy to change, there also must be proof that there is enough wood ash to complete this type of project study (Interview 3, personal communication). If there is not enough wood ash in the region to achieve the goals of this project, then there is no push

to undergo a policy change. Proof that there is enough wood ash currently to achieve the goals is needed before change can happen.

Friends of Muskoka Watershed

Moving forward, most of the Friends of Muskoka Watershed requirements relate to the policy process and funding. Changing the policy process is most needed for this program moving forward (Interview 2, personal communication). Looking at Sweden, the model there is very different, and the government mandates nutrient amendments and uses the fees from companies to pay for it (Interview 2, personal communication).

Funding for this project is also something that is needed moving forward. Cost is an issue as there is no profit in this type of project at a large scale (Interview 7, personal communication). This type of program would be beneficial if forest health and production increases, but upfront costs could be high. Changing the way the forest economy is set up would be a way to change the mindset on the worth of this project. Ideally, some other organization would take this project over from the Friends of Muskoka Watershed that has a larger capacity for this type of work and could get grants to continue the work (Interview 7, personal communication). This could be done through the municipalities that would collect the wood ash like other recycling products. Then the wood ash could be pelletized and distributed to different forest companies to spread (Interview 7, personal communication).

Forest Stewardship

Forest stewardship companies would need the plan and logistics already prepared and would even potentially need to hire a third party to spread the wood ash (Interview 4, personal communication). There also needs to be clear guidelines from the government

that allow this practice (Interview 4, personal communication). Having clear guidelines on what is allowed will make foresters more comfortable with doing ash applications to forest soils (Interview 4, personal communication).

3.5 Discussion and Future Steps

3.5.1 Key Findings

This thesis aimed to outline the benefits of using wood ash as a recycling product in forests and the current hurdles causing this process to be slowed down. The key findings of this thesis were that there are many potentially foreseen benefits to using wood ash as a fertilizer in forests, which include nutrient regeneration, higher C sequestration, community education and involvement, combatting acid rain and Ca depletion, higher volumes of maple sap, higher volumes of wood accumulation, and being closer to meeting global targets concerning climate action.

Several hurdles are outlined for this project to be fully approved, but the big one is the lack of data and knowledge in this field. This is a first-of-a-kind project in Ontario, and there is a lack of information regarding the risks and benefits. More data are needed from the studies to evaluate the longer-term impacts of ash additions to forests.

Moving forward, having different studies done on the effects of wood ash in forests would be beneficial. If there were different specializations conducting research, a clearer picture could ease policy makers in approving this project. With this, having different disciplines concluding this type of program would be beneficial to different aspects of the environment would be beneficial for policy makers to approve this type of program.

3.5.2 Different Policies for Residential and Industrial Wood Ash

Since there can be variability in residential wood ash, it is recommended that industrial and residential wood ash have different policy applications. Both residential and industrial wood ash need stringent testing to make sure metal limits are not reached, and no chemicals are present in the wood ash. However, industrial wood ash is likely more consistent as a mass amount of wood can come from the same sites, and burning can be controlled more accessible, meaning that less testing can be done on one batch to ensure metal limits are not reached. Residential wood ash comes from several sites, and residents burn their own wood, so ensuring proper burning practices can be an issue. People can burn anything with their wood, so more chemicals may be deposited into the wood ash (Interview 5, personal communication). If residential wood ash underwent stricter testing compared to industrial, it could be ensured it was safe to be spread, and contaminated wood ash could be disposed of.

The same policies are recommended when it comes to the spreading of wood ash. There is no difference in where spreading is allowed since both types of wood ash will follow the same policies. Sites should be explicitly picked to ensure no damage to humans or waterways (Interview 5, personal communication).

3.5.3 Creating Change

Creating societal change is necessary for this program to move forward. A change can come from a change in the political stream or a crisis or when greater public perception is given to an issue (Fifer and Orr, 2013; Michaels et al., 2006). Moving forward, it is recommended that the "army of advocates" that the FOMW has pushes the government on this issue (Interview 3, personal communication; Interview 5, personal communication). There needs to be momentum to incite this change in the government

(Interview 5, personal communication). Having this mixed with a top-down drive would cause faster action for change. This top-down drive could come from a senior government advocate or a major industry advocate.

There is a lack of current incentives for private forest companies to invest in the sustainability of forest soils (Bogle and van Kooten, 2013). Right now, there is no value from planting a tree sapling. There needs to be an investment in saplings to gain off the tree in the future (Interview 6, personal communication).

3.5.4 Recommendation For Policy

It is recommended that a new policy needs to be developed as the existing policy prohibits this type of project. A better policy is needed moving forward. The first aspect of this policy should be to change the title of wood ash away from a waste product to something else that takes away limitations that working with a waste product has. Under the new title, wood ash could receive new regulations surrounding it. These new regulations could outline the differences between using industrial wood ash and residential wood ash and what is needed in both circumstances.

These regulations should also include the circumstances for amendments. This is recommended to start with allowing wood ash in harvesting scenarios, which is currently being done in Sweden. Replacing nutrients that are taken out through logging should be a priority. Using pre-set logging roads would minimize the damage and follow the forest route where logging practices had taken place. This way, no new roads or trails would need to be created to spread wood ash in forests.

Specifications for where wood ash should not be used should also be clearly defined. Spreading wood ash in waterways is still not approved by the government and is seen as

dangerous to waterways so setting perimeters around waterways should be outlined. Regulations should also outline if any key sensitive species that could be harmed by having wood ash in their habitats and outline specific areas to avoid applications, so it does not cause harm to these species.

With this, set guidelines should be created for dosage rates of wood ash in forests. This could be done as a standard smaller dosage, or a scale created based on the amount of logging done. These rates should also outline areas that would need additional amendments, such as nitrogen, and some areas that may not need wood ash.

This policy should also outline the costs of this practice and who should be responsible for paying for each aspect, for example, the harvesting companies using their machinery for the transporting and spreading of wood ash on their sites. This would also minimize the cost of bringing in new machinery to the sites. Costs around companies selling their excess wood ash could also be outlined in this policy to set standards for what prices should be acceptable to sell for and keep markets in check.

3.6 Conclusion

In conclusion, there were many potential benefits to a residential wood ash recycling program. However, more data are needed to be fully confident that this program has more benefits than negatives. Many perceived benefits mentioned from the interview participants still need verification (such as higher carbon sequestration, more flood protection, and higher sap production). These benefits are hypotheses based on initial studies done, but more data and studies will need to be conducted for the government to feel confident.

The most prominent themes that emerged were concerned hurdles for approving this type of program. The policy makers had the most processes that needed more thought as they had to do their due diligence to ensure no harm comes to the environment (Interview 5, personal communication). For the FOMW, many hurdles to overcome include the policy application process itself. The policies are currently designed not to allow residential wood ash to be spread in forests, making a pilot project such as this one difficult to plan and approve. This theme also arose for forest stewardships as they need to have regulations specifically outlining, they are allowed to spread wood ash in forests as they deal with crown lands. For those groups, having the policy process be reviewed and changed is necessary for the future of this program.

For policy makers to be able to approve this program entirely, there need to be more studies done and scientific data to back up all of the benefits that are being hypothesized. If more studies and disciplines were to outline the benefits, the government would be more likely to approve the program (Interview 3, personal communication; Interview 5, personal communication).

A final question that needs to be considered is the program's cost. Funding such a program would need a considerable amount of money that is not feasible for the FOMW. Forest stewardships would prefer not to take on and would be difficult for them to sustain long-term and would require much money from the government to fund. Finding a sustainable way to fund this program is crucial to moving forward.

All interview participants agree that this program could have several benefits to the environment and society. There is some information missing currently to get the program approved, but once provided, it would be a beneficial addition to recycling programs. The

benefit of not having wood ash be put into landfills could save the government money and space down the road. This could be a significant consideration when it comes to approving this program. Showing proof that this would be a benefit could be a deciding factor.

Moving forward, it is recommended that more studies reaching across different disciplines be conducted. If there were studies conducted individually by different researcher bodies, the data would be enough to make a more informed decision about this program's benefits and possible repercussions. It is also recommended to research the benefits of keeping wood ash out of landfills as a reason for this program needing to be approved. With this, having a mass amount of people pressuring the government to approve this program is necessary. Using the policy windows theory and creating a period of time where the policy environment can be disrupted. Using the need for change coming from the current pandemic, there could be also an opportunity to push for change.

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Appendix 1. Global Nutrient Management Plans and Citations

Location	*Citation*
Sweden	Skogsstyrsen Sweden Forest Agency. (2011). *Sustainable forest management in Sweden*. UNECE. http://www.unece.lsu.edu/responsible_trade/documents/2013Mar/rt13_07.pdf.
Germany	Federal Ministry of Food and Agriculture. (2020) *Forest Strategy 2020. Sustainable Forest Management – An Opportunity and a Challenge for Society*, https://www.bmel.de/SharedDocs/Downloads/EN/Publications/ForestStrategy2020.pdf?__blob=publicationFile&v=4
Germany	Häusler, A. and Scherer-Lorenzen, M. (2001) *Sustainable Forest Management in Germany: The Ecosystem Approach of the Biodiversity Convention Reconsidered. German Federal Agency for Nature Conservation, Bonn, Germany*. https://www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/skript51.pdf
New Zealand	Ministry for Primary Industries (2015). *Sustainable Management of New Zealand's Forests.* https://www.mpi.govt.nz/dmsdocument/9530/direct
	Ministry for the Envrionment. (1991). *Resources Management Act 1991*. https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html
Switzerland	Federal Office for the Environment FOEN. (2013). *Forest Policy 2020.* UD-1067-E. https://www.bafu.admin.ch/bafu/en/home/topics/forest/publications-studies/publications/forest-policy-2020.html
	The Federal Assembly of the Swiss Confederation (1991). *Federal Act on Forests.* https://www.fedlex.admin.ch/eli/cc/1992/2521_2521_2521/en
Russia	Ministry of Natural Resources and Environment of the Russian Federation. (2006). *Forest code of the Russian Federation.* http://www.fao.org/faolex/results/details/en/c/LEX-FAOC068489/
	Food and Agricultural Organization of the United Nations. (2012). *The Russian Federation Forest Sector.* http://www.fao.org/3/i3020e/i3020e00.pdf
Finland	Ministry of Agriculture and Forestry. (2014). *Forest Act.* https://www.finlex.fi/en/laki/kaannokset/1996/en19961093_20140567.pdf
	Ministry of Agriculture and Forestry of Finland. (2019). *National Forest Strategy of Finland, 2025.* https://mmm.fi/documents/1410837/2000444/Brochure_National_Forest_Strategy_2025_updated_version.pdf/9e32e0b9-ee2a-b906-8222 8c3a7df5f7d0/Brochure_National_Forest_Strategy_2025_updated_version.pdf
Norway	Norwegian Ministry of Climate and Environment. (2019*). National forestry accounting plan for Norway for the first commitment period 2021-2025.* https://www.regjeringen.no/contentassets/116262fdbff147fab3b0d38b61ed258f/national-forestry-accounting-plan-for-norway_2021-2025_21march2019.pdf
Australia	Department of Agriculture, Water, and the Environment . (1995). *National Forest Policy Statement. A new focus for Australia's Forests.* https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/forestry/australias-forest-policies/nat_nfps.pdf
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Denmark	Ministry of the Environment. (2002). *The Danish National Forest Programme in an International Perspective*. https://naturstyrelsen.dk/media/nst/Attachments/dnf_eng.pdf
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The Philippines	Food and Agricultural Organization of the United Nations. (2016*). Philippine Master Plan for Climate Resilient Forestry Development.* https://forestry.denr.gov.ph/pdf/mp/PMPCRFD_2015_plus_Annexes.pdf
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Northwest Territories	Northwest Territories, Envrionment and Natural Resources. (2014). *Forest Management Act.* https://www.enr.gov.nt.ca/en/services/legislation-and-regulations
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Appendix 2 Consent form for interviews. Approved by the Research Ethics Board at Trent Universityin accordance with the Tri-Council Guidelines (article D.1.6).

Incorporating Nutrients into Forest Management Strategies
Consent Agreement

You are being invited to participate in a research study. Please read this consent form so that you understand what your participation will involve. Before you consent to participate, ask any questions you need to be sure you understand what your participation will involve.

Incorporating Nutrients into Forest Management Strategies

INVESTIGATORS:
This research study is being conducted by Kayla O'Neill, from the Masters of Sustainability Studies and being supervised by Dr. Shaun Watmough from the school of the Environment at Trent University. This research will contribute to the thesis of Kayla O'Neill, in partial completion of the degree.

This study is in partnership with The Friends of Muskoka Watershed organization. The study is being funded by the Ontario Trillium Foundation through a grant given to the Friends of Muskoka Watershed.

If you have any questions or concerns about the research, please feel free to contact Kayla O'Neill at kaylaoneill@trentu.ca. If any issues with the study, please contact Dr. Watmough at swatmough@trentu.ca

PURPOSE OF THE STUDY:

The purpose of this study is to understand the challenges involved in creating a residential wood-ash recycling program in Muskoka, Ontario. This study will focus mainly on the policy implications that surround making this type of recycling program in Ontario.

There has been a notable calcium decline in the Muskoka area, in both the forests and watersheds. Using residential wood-ash to fertilize the forests could be a possible solution to this issue. There are currently many governmental restrictions in place to use residential wood-ash in forests so creating this program could provide a blueprint and case study for other organizations to implement something similar in their area.

This study will interview 5-12 professionals in this field to find out their knowledge on the subject.

WHAT YOU WILL BE ASKED TO DO:

If you volunteer to participate in this study, you will be asked to do the following things:

You will participate in a virtual in-depth (1 hour) interview with me using Trent University Zoom technology.

These interviews will be conducted between March to May 2021. During these interviews you will be asked a series of questions regarding your understanding of the policy process when dealing with residential wood-ash, possible benefits and limitations of this, and the effects of wood-ash on the environment.

You may be asked to clarify after the interview on any of your answers if further clarification is needed by the researcher.

Data

The consent form will be emailed to be directly and must be signed before participating in the interview. Your information will not be released to any other parties. The interview data will be collected using the Trent University's Zoom technology which is secure. The interviews will be transcribed by myself on a password protected, encrypted personal computer. The Zoom interviews will be stores on a secure Trent server. The interviews and transcripts will be destroyed after my thesis has been defended in the summer of 2021.

POTENTIAL BENEFITS:

Your participation in this study will result in no direct benefit to you, although you may value being asked to share your expertise on this subject.

WHAT ARE THE POTENTIAL RISKS TO YOU AS A PARTICIPANT:

Risks or Discomforts:

The risks involved in participating in this study are minimal. You may feel uncomfortable (anxious, uneasy about) about answering any questions if you perceive them as affecting your work or personal wellbeing. You do not need to answer any questions that you do not want to answer or that make you feel uncomfortable. You may skip answering any questions that cause discomfort and you may withdraw your participation temporarily or permanently. In addition, you may worry that your responses will be identifiable. I describe below the steps I am taking to ensure your privacy.

By consenting to participate in this study, you have not waived any rights to legal recourse in the
event of research-related harm.

Confidentiality:

To ensure confidentiality, names will not be used in the thesis or any published work that may come from the study. Random letters will be assigned to each participant that will make them unidentifiable. No demographic information will be published in the work. Your information will not be passed along to any parties and will only be identified by your assigned letters.

You will be allowed to view the transcripts from your own interview to ensure you are comfortable with all the information you gave being used in the study. The transcripts will be stored on a personal, encrypted external hard drive that only the main investigator (Kayla O'Neill) has access to. You will have a period of 30 days after the transcript has been sent to you for review to give comments and feedback to the investigator before data will be included in the thesis. You have the right to remove any information from the transcripts you think will breach your confidentiality.

VOLUNTARY PARTICIPATION AND WITHDRAWAL

Participation in this study is completely voluntary. You can choose whether to participate or not. If any question makes you uncomfortable, you can skip that question. You may stop participating at any time. If you choose to stop participating, you may also choose to not have your data included in the study. To have your data not included in the study, you must tell the researchers before July 1st, 2021. Your choice of whether or not to participate will not influence your future relations with Trent University or the investigators Kayla O'Neill & Shaun Watmough involved in the research.

There are no costs to participate in this study and there will be no payments for participating in the study.
By agreeing to participate in this research, you are not giving up or waiving any legal right in the event that you are harmed during the research.

QUESTIONS ABOUT THE STUDY: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact:

Principle Investigator:

Kayla O'Neill
M.A Candidate- Sustainability Studies
Trent University
kaylaoneill@trentu.ca

Academic Supervisor:

Shaun Watmough
Professor and Director of the Trent School of the Environment
Trent University
Phone: 705-748-1011 x7876
Email: swatmough@trentu.ca

Research Ethics Board Contact

This study has been reviewed by the Trent University Research Ethics Board, the study number is 26354. If you have questions regarding your rights as a participant in this study, please contact:

Michele J McIntosh, Chair Research Ethics Board
c/o Office of the Vice President, Research and Innovation
Trent University
1600 West Bank Dr
Peterborough, ON K9L 0G2
705-748-1011 ext. 7896
jmuckle@trentu.ca

Incorporating Nutrients into Forest Management Strategies

CONFIRMATION OF AGREEMENT:

Your signature below indicates that you have read, or have had read to you, the information in this agreement and have had a chance to ask any questions you have about the study. By signing you agree to participate in the study.
You can change your mind and withdraw your consent to participate at any time. I understand that if I agree to participate, I may refuse to answer any interview questions I do not wish to answer, and you may withdraw at any time up to July 1st, 2021 (the time in which the thesis is submitted). You have been given a copy of this agreement.
By signing this consent agreement, you are not giving up any of your legal rights.

_____
Name of Participant (please print)

_____
Signature of Participant Date

1. I agree to be audio recorded by Zoom for the purposes of this study. I understand how these recordings will be stored and destroyed.

( ) Yes

( ) No

2. I agree to be video recorded by Zoom for the purposes of this study. I understand how these recordings will be stored and destroyed.

( ) Yes

( ) No

3. I agree to have my responses from this project stored until the completion of the research
project.

( ) Yes

( ) No

4. I would like to receive and review a copy of my interview's transcript

( ) Yes

( ) No

5. I agree to be contacted about a follow-up interview. I understand that I can always decline the
request.

( ) Yes

( ) No

Please sign below to confirm all the answer you have given above.

_____ _____

Signature of Participant Date

Contact Information:

Principle Investigator:

Kayla O'Neill
M.A Candidate- Sustainability Studies
Trent University
kaylaoneill@trentu.ca

Academic Supervisor:

Shaun Watmough
Professor and Director of the Trent School of the Environment
Trent University
Phone: 705-748-1011 x7876
Email: swatmough@trentu.ca

Research Ethics Board Contact:

Michele J McIntosh, Chair Research Ethics Board
c/o Office of the Vice President, Research and Innovation
Trent University
1600 West Bank Dr
Peterborough, ON K9L 0G2

705-748-1011 ext. 7896
jmuckle@trentu.ca

Appendix 3. Environmental Compliance Approval Draft

ENVIRONMENTAL COMPLIANCE APPROVAL WASTE DISPOSAL SITE –ORGANIC SOIL CONDITIONING APPROVAL NUMBER:

For the Site located at: [Enter Disposal Site Location]

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act, R.S.O. 1990, c.

E.19 (Environmental Protection Act) for approval of:

the use and operation of an Organic Soil Conditioning Site. The Organic Soil Conditioning Site approved herein may accept and temporarily store Residential Wood Ash Waste only, the spreading of which is restricted to maximum of 20 test plots as described at Schedule "A" of this Environmental Compliance Approval as part of a 3-year pilot study.

For the purpose of this environmental compliance approval, the following definitions apply:

1. "**Act**" means the *Environmental Protection Act,* R.S.O. 1990, c. E.19, as amended;
2. "**Approval**" means this entire Environmental Compliance Approval including its schedules, if any, issued under section 20.3 of II.1 of the Act;
3. "**Approved Waste Hauler**" means an individual or corporation that operates under a valid Environmental Compliance Approval for the transportation of Solid Non-Hazardous Waste.
4. *"**Clean Water Act**"* means the *Clean Water Act, 2006,* S.O. 2006, c. 22, as amended.
5. "**Company**" means Friends of the Muskoka Watershed, or its agents or assignees;
6. "**Commercial, Community or Institutional Use**" means any commercial, community or institutional use, including without limitation the use of land for;
    i. an office building;
    ii. a hotel, motel, hostel or similar type of accommodation;
    iii. an overnight camp or overnight campgrounds;
    iv. indoor recreational or sporting activities;
    v. indoor gatherings for civic, religious or social purposes;
    vi. indoor performing arts activities;

g. "**Director**" Act;

means any Ministry employee appointed by the Minister pursuant to Section 5 of the

vii. a railway station, airport passenger terminal or other embarkation or debarkation point for travellers;
viii. a day care centre;
ix. educational purposes, including a school, college, university, private career college or associated residence;
x. a health care facility; or
xi. a penitentiary, jail or other place of custody or detention;

8. "**District Manager**" means the District Manager of the Ministry for the geographic area in which the Site is located;
9. "**Frozen**", when used in reference to soil, means that a layer of soil with an average minimum depth of five centimetres, located within the top 15 centimetres of the soil, is consolidated by the presence of frozen moisture;
10. "**Ministry**" means the Ontario Ministry of the Environment, Conservation and Parks;
11. *"**Nutrient Management Act**"* means the *Nutrient Management Act, 2002,* S.O. 2002, c. 4, as

    amended;

12. "***Ontario Water Resources Act**"* means the *Ontario Water Resources Act,* R.S.O. 1990, c. O.40, as amended;
13. "**Operator**" means Friends of the Muskoka Watershed;
14. *"**Pesticides Act**"* means the *Pesticides Act,* R.S.O. 1990, c. P11, as amended;
15. "**Residential Wood Ash Waste**" means wood ash waste collected from residential properties and stored at the District Municipality of Muskoka's Rosewarn Waste Transfer Facility, Town of Bracebridge, District of Muskoka;
16. "**Residential Wood Ash Waste Disposal Site**" means a Residential Wood Ash Waste Disposal Site, the location and operation of which is approved by the Ministry;
17. *"***Residential Area***"* means an area in which there are three or more lots of not more than one hectare;
    i. that are adjacent to each other or not separated by anything other than a road allowance or right of way; and
    ii. on each of which there is a residential building;
18. "**Sensitive Use**" means Commercial, Recreational or Institutional Use(s), and locations at which people regularly congregate;
19. "**Site**" means a location approved to receive Residential Wood Ash Waste under the Approval;
20. "**Snow-covered**", when used in reference to soil, means that there is a layer of snow with an

    average minimum depth of five centimetres;

21. "**Surface Water**" means water found in lakes, ponds, rivers, streams, wetlands, swamps, artificial watercourses, intermittent watercourses and seasonally wet areas, including ditches and swales;

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ENVIRONMENTAL COMPLIANCE APPROVAL WASTE DISPOSAL SITE –ORGANIC SOIL CONDITIONING APPROVAL NUMBER:

"**Rosewarn Waste Transfer Facility**" means the District Municipality of Muskoka's Waste Transfer and Processing Site located at 1602 Rosewarn Drive, Township of Bracebridge, District of Muskoka;

"**Test Plot(s)**" means maximum of twenty (20), 10 metre by 10 metre area(s) located at the Site in the location(s) declared at Schedule "A".

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS GENERAL
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The requirements of the Approval are severable. If any requirement of the Approval, or the application of any requirement of the Approval to any circumstance, is held invalid, the application of such requirement to other circumstances and the remainder of the Approval shall not be affected in any way; and

The issuance of, and compliance with the conditions of the Approval does not: a.relieve any person of any obligation to comply with any provision of any

applicable statute, regulation, by-law or other legal requirement; or

b.limit in any way the authority of the Ministry to require that certain actions be taken by Friends of the Muskoka Watershed or to require Friends of the Muskoka Watershed to furnish any further information related to compliance with the Approval.

Except as otherwise provided by these conditions, the Site shall be operated in accordance with the application submitted for the Approval and with the supporting documentation submitted to the Ministry as part of the application, all listed in Schedule "A".

The Company, any owner of the property comprising the Site and the Operator shall ensure the Site is operated in accordance with these conditions.

3. The Company shall ensure that any communication/correspondence made in relation to the Site or to the Approval includes reference to the Approval number.
4. The Company shall notify the Director in writing of any of the following changes within thirty (30) days of the change occurring:
    i. change of owner of the property comprising the Site;
    ii. change of Operator; or
    iii. change of Company or Company address.
5. In the event of any change in ownership of the Site, the Company shall forthwith notify in writing the succeeding owner of the existence of the Approval and provide the successor with an

up-to-date copy of the Approval and a copy of such notice shall forthwith be forwarded to the Director.

6. Without limiting the authority provided Provincial Officers under the Act, the *Ontario Water Resources Act,* the *Pesticides Act* or the *Nutrient Management Act,* a Provincial Officer from the Ministry has the authority under those acts, at any reasonable time, without a warrant and with any reasonable assistance, to inspect all areas of the Site except living quarters and to require that any records required to be kept under any of those acts or the Approval be made available for inspection by that Provincial Officer upon request.

SPILL PREVENTION AND COMPLAINT PROCEDURES

7.

i. Prior to operating at the, the Company shall develop written procedures covering the following:

1. spill prevention and clean up in the event of occurrence;
2. procedures for reporting to the Ministry, and municipal authorities as required, in the event a spill occurs at the Site;
3. complaint procedures for receiving and responding to public complaints, including what steps the Company will take to determine the cause of the complaint and what corrective measures may be taken to alleviate the cause and prevent its recurrence;
4. a list of the personnel responsible for operations at the Site
5. a list of equipment, material and personnel that will be available to deal with spills at the Site.

ii. The Company shall ensure that all personnel involved in the operation of the Site are aware of the requirements of the Approval and are trained in the procedures outlined in Condition 7. i of the Approval.

OPERATIONS

8. *The Company must ensure that no unnecessary off-Site effects, such as vermin, vectors, odour, dust, litter, noise or traffic, result from the spreading, storage or disposal of Residential Wood Ash Waste at the Site. This condition does not reduce in any way the Company's obligations to comply with the Act and the Ontario Water Resources Act.*
9. Spills of a pollutant that cause or may cause an adverse effect, that may enter or do enter any "waters", as that term is defined in the *Ontario Water Resources Act*, and that may impair the water quality of those waters, shall forthwith be reported to the Ministry's Spills Action Centre at (416) 325-3000 or 1-800-268-6060) and the Company shall take appropriate remedial action to limit the impact. Information regarding all spills shall be recorded and kept, as per Term and Condition 22 of the Approval.

ENVIRONMENTAL COMPLIANCE APPROVAL WASTE DISPOSAL SITE –ORGANIC SOIL CONDITIONING APPROVAL NUMBER:

10. Residential Wood Ash Waste collected and stored at the Rosewarne Waste Transfer Station shall be transported to the sugar bush site in 75 L galvanized metal cans with lids, securely strapped to wooden pallets. The transportation must be undertaken by an Approved Waste Hauler.
11. To avoid run-off from the Site;
    i. No Residential Wood Ash Waste shall be spread or disposed of at the Site when the

       ground is frozen, ice-covered or snow covered;

    ii. No Residential Wood Ash Waste shall be spread at the Site when there is ponded water on the intended spreading area at the Site;

iii. No Residential Wood Ash Waste shall be spread at the Site when conditions are such that Residential Wood Ash Waste, or water contaminated by Residential Wood Ash Waste, may runoff or discharge from the Site. Conditions which may lead to such runoff or discharge from the Site include precipitation events, snowmelt and flooded or saturated spreading areas.

12. Spreading of Residential Wood Ash Waste is prohibited in areas at the Site with a maximum sustained slope of greater than 50% or on exposed bedrock.
13. Spreading of Residential Wood Ash Waste is prohibited in any areas at the Site where the activity is or would be a Significant Drinking Water Threat as defined under the *Clean Water Act*.
14. Prior to spreading of Residential Wood Ash Waste at the Site, the operator shall ensure the useable spreading area is clearly flagged, digitally designated in GPS such that the designation is readily available upon the request of a Provincial Officer, or similarly marked so as to clearly identify setbacks from sensitive features and any areas where spreading is prohibited pursuant to Condition 13 of the Approval.
15. Residential Wood Ash Waste shall only be spread at the Site at the lower of 8 tonnes per hectare.
16. Blending, mixing and land application of Residential Wood Ash Waste shall only occur on low wind days so as to prevent particulates from becoming airborne.
17. No processed organic waste or other waste, other than Residential Wood Ash Waste, shall be stored, spread or disposed of at the Site.

STORAGE

18. No Residential Wood Ash Waste shall be stored pursuant to the Approval except for twenty (20) 75 litre galvanised metal cans, with lids, equating to a maximum total volume of 1500 litres with an estimated mass of approximately 750 kg at locations identified in Schedule "A".
19. Notwithstanding the pre-determined storage locations in Schedule "A", Residential Wood Ash Waste shall be stored in a location that is at least 100 metres from Surface Water.
20. Residential Wood Ash Waste that is not land applied to the test plots in the fall of 2019 must be promptly removed from the Site and returned the Rosewarn Waste Transfer Facility or other approved waste disposal site.

RECORD KEEPING

21.

The Company shall maintain and keep written records for a period of 5 years detailing the following:

22.

At the end of the 3-year pilot study but no later then the expiry of the Approval (Condition 23) the Company shall prepare and submit to the District Manager a brief report containing at a minimum the following information:

i. a summary of the Residential Wood Ash Waste application methods and quantities that were used in each Test Plot;
ii. a summary of the quantity of the nutrient additions and metals additions to the Test Plots
iii. a summary and assessment of the environut monitoring that was undertaken as part of the 3-year pilot study;
iv. an assessment of tree growth in the Test Plots. This shall include an assessment of the benefits and concerns presented with respect to the use of Residential Wood Ash Waste in promoting tree growth at the Site;
v. a summary of any public complaints received, and actions take, to address those complaints as outlined in item vi of Term and Condition 22; and
vi. a summary of any environmental issues that were encountered during the 3-year pilot study and actions taken to address those issues as outlined in items iv and v of Condition 21.

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a complete and up-to-date record showing, where, when and how much Residential Wood Ash Waste was stored, spread and promptly removed from the Site;

all sampling and analysis of the Residential Wood Ash Waste; all sampling and analysis from the Test Plots' soil and foliage;

any environmental nuisance problems (e.g. odour or dust), containment discharges or other environmental concerns that were encountered. This record shall include the descriptions of the issue encountered and the steps taken to address the issue;

the nature of any spill or upset occurring at the Site and the actions taken to clean-up the spill or upset and the steps taken to prevent a re-occurrence; and

all complaints received related to the Site or its operations and any actions taken to address complaints

EXPIRY:
23. The Approval **Expires** on: **November 30, 2024**.

_____

ENVIRONMENTAL COMPLIANCE APPROVAL WASTE DISPOSAL SITE –ORGANIC SOIL CONDITIONING APPROVAL NUMBER:

SCHEDULE "A"

This Schedule "A" forms part of the Approval:

1. Environmental Compliance Approval Application, dated _____ and received on _____, and signed by _____.

ENVIRONMENTAL COMPLIANCE APPROVAL WASTE DISPOSAL SITE –ORGANIC SOIL CONDITIONING APPROVAL NUMBER:

SCHEDULE "B"
SITE SETBACK REQUIREMENTS

This Schedule "B" forms part of this Approval:
1. The *portion* of the Site approved for spreading or storage is subject to the following setbacks,

1. a minimum of 250 metres from Sensitive Uses, unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 50 metres;
2. a minimum of 250 metres from a Residential area, unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 50 metres;
3. a minimum of 90 metres from a single residence, unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 25 metres;
4. a minimum of 30 metres from a public roadway unless the Residential Wood Ash Waste is injected or incorporated into the soil within 24 hours of application, in which case the separation distance may be reduced to 15 metres;
5. a minimum of 90 metres from private water wells;
6. a minimum of 100 metres from municipal drinking water wells; and
7. a minimum of 60 metres from Surface Water.

The reasons for the imposition of these terms and conditions are as follows:

1. The reason for conditions 1, 2, 3, 4, 5 and 6 is to clarify the legal rights and responsibilities of the Company.

2. The reason for conditions 7 and 9 is to ensure that staff can identify Site problems and deal promptly and effectively with any spills and upsets, and any public complaints that may occur.
3. The reason for condition 8 is to ensure that the Site is operated in a manner which does not result in a nuisance or a hazard to the health and safety of the environment or people.
4. The reason for condition 10 is to ensure that the Residential Wood Ash Waste is transported in a safe and responsible manner and in compliance with the Act and its regulations by persons approved to undertake such activities.
5. The reason for conditions 11 and 12 to ensure that land application restrictions are established based on the slope of land promote the incorporation of Residential Wood Ash Waste down into the underlying overburden. The prohibitions will prevent Residential Wood Ash Waste spreading when there is a risk of runoff.
6. The reason for condition 13 is to ensure Residential Wood Ash Waste application does not take place in areas where the activity is considered to be a significant drinking water threat under the Clean Water Act.

ENVIRONMENTAL COMPLIANCE APPROVAL WASTE DISPOSAL SITE –ORGANIC SOIL CONDITIONING APPROVAL NUMBER:

7. The reason for condition 14 is to ensure that Residential Wood Ash Waste is only applied to approved areas in such a manner as to comply with the listed setbacks and source protection vulnerable area restrictions.
8. The reason for condition 15 is to ensure that maximum loading rates on the soil are strictly controlled under this beneficial use program for Residential Wood Ash Waste.
9. The reason for condition 16 is to ensure no off Site or off Test Plot(s) impacts occur as a result of the handling, mixing, blending or land application of Residential Wood Ash Waste under this Approval.
10. The reason for condition 17 is to ensure that loading rates on the soil are strictly controlled under the beneficial use program for biosolids and other wastes. Fields used for this program cannot be used for biosolids or other processed organic waste spreading, Hauled Sewage disposal, or other waste disposal or vice versa.
11. The reason for conditions 18, 19 and 20 is to ensure Residential Wood Ash Waste is stored in a manner that minimizes the likelihood of spills and that does not present a hazard to the health and safety of people or the environment.
12. The reason for conditions 21 and 22 is to ensure that the Site is operated in accordance with the application and supporting information submitted by the Company, and not in a manner which the Director has not been asked to consider.
13. The reason for condition 23 is to ensure a periodic review of the instrument occurs to ensure the Site operations and associated impacts have not resulted in adverse effects on the land as a consequence of continuous long-term use.

    In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me and the Environmental Review Tribunal within 15 days after receipt of this Notice, require a hearing by the Tribunal. Section 142 of

the Environmental Protection Act provides that the Notice requiring the hearing shall state:

1. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

Pursuant to subsection 139(3) of the Environmental Protection Act, a hearing may not be required with respect to any terms and conditions in this environmental compliance approval, if the terms and conditions are substantially the same as those contained in an approval that is amended or revoked by this environmental compliance approval.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The environmental compliance approval number;
6. The date of the environmental compliance approval;
7. The name of the Director, and;
8. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant. This Notice must be served upon:

The Secretary*****
Environmental Review Tribunal
655 Bay Street, Suite 1500 AND Toronto, Ontario
M5G 1E5

The Director appointed for the purposes of Part II.1 of the Environmental Protection Act Cindy Hood
Director, section s.20.3, E.P.A.
Barrie District Office
Ministry of the Environment, Conservation and Parks
1201-54 Cedar Pointe Dr.
Barrie Ontario, L4N 5R7

ENVIRONMENTAL COMPLIANCE APPROVAL WASTE DISPOSAL SITE –ORGANIC SOIL CONDITIONING APPROVAL NUMBER:

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal Toll Free at: Tel: 1 (866) 448-2248 , Fax: 1 (877) 849-2066 or ERTTribunalSecretary@ontario.ca**

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT [ENTER LOCATION] this [ENTER DATE] day of [ENTER MONTH, ENTER YEAR] [DIRECTOR SIGNATURE HERE]

[Director Name], District Manager, [ENTER OFFICE] District Office Director,
Environmental Protection Act,
Ministry of the Environment, Conservation and Parks []

(enter office address)
(enter office phone/fax/email as appropriate)

Appendix 4. Semi-Structured Interview Questions

-How familiar are you with the nutrient issues in forest soils in central Ontario?
-Does your organization have any policies in place to address nutrient issues in forest soils?
-What do you feel are the greatest barriers/restrictions/roadblocks to use of wood-ash as a soil amendment?

-In regard to the labels given to ash, how do the different labels given to the ash (example; organic waste vs non-organic waste) affect how it can be handled?

- How does this apply to various properties (ex: private woodland, wetlands, agricultural fields etc)?

-Do you feel like the current process for regulating wood-ash additions are cumbersome and do you have any recommendations?

- In an ideal world, what would some of the policies for ash be?

-What do you see as the short-term benefits for using wood-ash in forests?

- Long-term?

-there are some allowed ash spreading for agricultural purposes, what is the difference between agricultural ash spreading and forest ash spreading?

-Is there additional information needed to be provided to be able to allow widespread use of the ash? Are we missing key scientific data? Or are there other roadblocks stopping this type of program?

- What would be required from an approval standpoint to roll out a wood-ash recycling program for forestry across Ontario?

-Is there anything else that you think I should know that you think would be beneficial to this study?