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Assessing community forest resources to determine potential for biomass district heating in one rural and one remote First Nation of Northwestern Ontario

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ASSESSING COMMUNITY FOREST RESOURCES TO DETERMINE POTENTIAL FOR BIOMASS DISTRICT HEATING IN ONE RURAL AND ONE REMOTE FIRST NATION OF NORTHWESTERN ONTARIO

by
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A Graduate Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of Master of Science in Forestry

Faculty of Natural Resources Management
Lakehead University

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Major Advisor

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This MScF thesis has been through a semi-formal process of review and comment by my Supervisor, Dr. Peggy Smith, and members of my Supervisory Committee, Dr. Mat Leitch and Dr. Chander Shahi. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

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ABSTRACT

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Keywords: biomass, biomass district heating, First Nations, remote communities, renewable energy, wood properties

The purpose of this thesis is to explore the feasibility of using biomass in rural and remote First Nations for the purpose of supplying biomass district heating plants. The availability of forest resources, including the methods for determining biomass volumes and availability, and the policies which govern access to timber/biomass on Crown and reserve land will be assessed. The thesis is produced in conjunction with a pre-feasibility study conducted collaboratively between Confederation College and Lakehead University in Thunder Bay, ON.

It was found that sufficient forest resources exist to supply woody biomass to a biomass district heating plant (BDHP) in both the rural and remote communities, which can provide heat and hot water to community infrastructure and home dwellings in order to offset electrical use. It was found that there was variability between thermal potential, ash content and species present in the two communities. There was also variability between the wood properties values found in this study compared to the published values for the same species. Although there was a significant difference in species volume, annual growth per hectare and species composition at 95% probability, there was not a significant difference in wood properties. There was also a significant difference between the outcomes of using the Lakehead University Wood Science Testing Facility methods compared to Ontario Ministry of Natural Resources and Forestry Forest Resource Inventory methods related to species volume and composition reported by the different methods, while total volume was the same.

This information is not intended to replace a proper forest management plan, but to provide information to communities so that informed decisions can be made. In fact, accessing the identified available biomass would require an amendment to the forest management plan and may require additional legislated documentation and an approval process or a fibre supply agreement with the forest tenure holder.

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LIST OF ABBREVIATIONS

AANDC - Aboriginal Affairs and Northern Development Canada
AHA - Annual Harvest Area
ANOVA - Analysis of Variance
AOU - Area of Undertaking
ASTM - American Society of Testing Materials
BC - British Columbia
BCR – Band Council Resolution
BDH - Biomass District Heating
BDHP - Biomass District Heating Plant
BIC - Biomass Innovation Center
BNA - British North America [Act]
BTU – British Thermal Unit
CABREE - Centre for Applied Business Research in Energy and the Environment
C-bLUP - Community-based Land Use Plan
CHP - Combined heat and power
CFS - Canadian Forest Service
CFSA - Crown Forest Sustainability Act
CO_2 - Carbon dioxide
CO - Carbon monoxide
DBH - Diameter at breast height
DEM - Digital Elevation Model
EANCP - Ecoenergy for Aboriginal and Northern Communities Program
FAO - Food and Agriculture Organization
FRI - Forest Resource Inventory
FMP - Forest Management Plan
FMU - Forest Management Unit
FNA - Far North Act
GEREMA - Geographical Resource Management
GHG - Greenhouse Gas
GLSL - Great Lakes - St. Lawrence
IRT - Indian Timber Regulations
HORCI - Hydro One Remote Communities Inc.
IESO - Independent Electrical Systems Operators
IFNA - Independent First Nations Alliance
INAC - Indian and Northern Affairs Canada
LIO - Lands and Information Ontario
LUWSTF - Lakehead University Wood Science Testing Facility
LSFN - Lac Seul First Nation
MC - Moisture content
MNRE - Ministry of New and Renewable Energy (India)
MW - Megawatt
NAFA - National Aboriginal Forestry Association
NAN - Nishnawbe Aski Nation

NRCan - Natural Resources Canada
NWT - Northwest Territories
ODT - Oven Dry Tonnes
OFTMA - Ontario Forest Tenture Modernization Act
OMNR - Ontario Ministry of Natural Resources
OMNRF - Ontario Ministry of Natural Resources and Forestry
OMOE - Ontario Ministry of the Environment
ORC - Obishikokaang Resource Corporation
PEI - Prince Edward Island
QUESTCanada - Quality Urban Energy Systems of Tomorrow Canada
RETScreen - Renewable Energy Project Analysis Software
ROR - Run of River
SFMM - Sustainable Forest Management Model
SLFN - Sachigo Lake First Nation
TNG - Tsilhqot'in National Government
TRCC - Truth and Reconcilliation Comission Canada
UNFCCC - United Nations Framework Convention on Climate Change
UW - Underutilized Wood
WSApp - Wood Science App

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CHAPTER 1: INTRODUCTION

BIOMASS AS AN ALTERNATIVE ENERGY SOURCE FOR REMOTE AND RURAL FIRST NATIONS

In rural and remote First Nations in northwestern Ontario communities rely on costly electricity to produce heat and hot water. In some areas where the electrical grid reaches the cost of electricity is much higher when compared to larger urban areas (Arriaga et al. 2013; Arriaga 2015). Where communities are not connected to the electrical grid, diesel generators are used to produce electricity. The use of diesel to create energy has numerous implications that negatively affect the environment and the communities dependent on this form of electrical generation including the contribution of fossil fuels to climate change, high fuel costs, dependency on foreign imported fuels, fuel shortages and limited electrical grid networks, and risk of contamination from spills and air emissions (Albert 2007). Further, the cost of electricity, combined with limited infrastructure, can inhibit development in First Nations. In order to reduce the dependency and usage of diesel fueled generators, reduce the cost of heating in communities, or to free up room on local electrical grids, biomass district heating (BDH) systems were explored as an alternative. Rather than generating electricity via transported diesel for large generators, a biomass district heating plant (BDHP) uses locally-sourced forest biomass burned in a wood boiler and gasification system, which heats fluid and is then piped to different buildings where it can be used as heat or as hot water offsetting diesel-generated heat, which in turn reduces diesel usage. If a BDH plant can be established in a community, there is potential to create local employment through the operation and maintenance of the plant, and through the management and harvesting of forest resources to fuel the BDHP. BDH can be a catalyst for community development in rural and remote First Nations (McCallum et al. 1998; McCallum 2010; Mabee et al. 2011; Arriaga et al. 2013; Arriaga 2015).

Diesel-generated electricity has been in use for decades and has been considered an ideal method of creating energy in remote areas[1] (HORCI 2011) as it does not require stationary power engineers, and operation of diesel-generating plants is relatively simple (Arriaga et al. 2013). A number of community members can be trained in operating the diesel plant, and most operations are done through the use of a computer system. Given its simplicity, reliability and relative ease of operation and maintenance, there is little interest from Hydro One—the organization responsible for the maintenance of diesel-generating facilities—in removing diesel facilities from communities. However, Hydro One is open to the idea of offsetting electrical use by utilizing a supplementary heating method to reduce diesel consumption, which would free up room on the electrical grid (HORCI 2011; HORCI 2013) and assist in alleviating the negative impacts of diesel-generated electricity.

DEFINITION OF RURAL, REMOTE COMMUNITIES

There are many definitions of rural and remote communities in Ontario, Canada, and the world; for the purpose of this study rural and remote communities were determined based on three criteria: road access, available electrical grid, and available natural gas pipelines. Table 1 demonstrates the comparison between rural and remote

---

[1] Electrical generation in the urban and rural parts of Ontario is the responsibility of the Ontario Power Generation (OPG), the Ontario Power Authority (OPA), and Hydro One, a crown corporation. These companies service communities with electrical grid connection. Hydro One Remote Communities Inc. (HORCI) is responsible for providing electricity to 21 communities in remote areas in the northern parts of Ontario.

communities. In Ontario, First Nations are referred to as remote based on two criteria: 1) their distance from major community centers, and 2) their lack of access to all-season road networks and electrical grids (Slack et al. 2003; HORCI 2011; Arriaga et al. 2013). These communities are located in an area referred to as the Far North (OMNR 2014b), and are dependent on diesel generators to create electricity to power and heat their homes. The First Nation communities in northwestern Ontario that are accessible by road and have access to the electrical grid, but lack the natural gas pipelines that would provide cheaper alternative heating and energy solutions to electric heat, are referred to as rural for the purpose of this project.

Table 1. Criteria of rural and remote communities used for this study.

Criteria	Rural Community	Remote Community
Road access	All-season road access	Winter road access; fly-in during summer months
Available electrical grid	Access to provincial electrical grid	Diesel generation for local micro-grid

Figures 1 and 2 show the location of remote communities in relation to natural gas pipelines, electrical grids, and provincial road networks; ice-roads are also shown.

HIGH COST OF ELECTRICITY

In spite of Hydro One's endorsement of diesel for remote communities, providing diesel-generated electricity to remote First Nations is problematic in a number of ways. The fuel must be either trucked in on the winter road network or flown in when road conditions are not suitable (Golden et al. 2011; Arriaga et al. 2013). This leads to a higher cost of fuel (Gustavsson et al. 2011; Burlando 2012), which results in communities paying a high price for energy, higher than most areas in the province (up

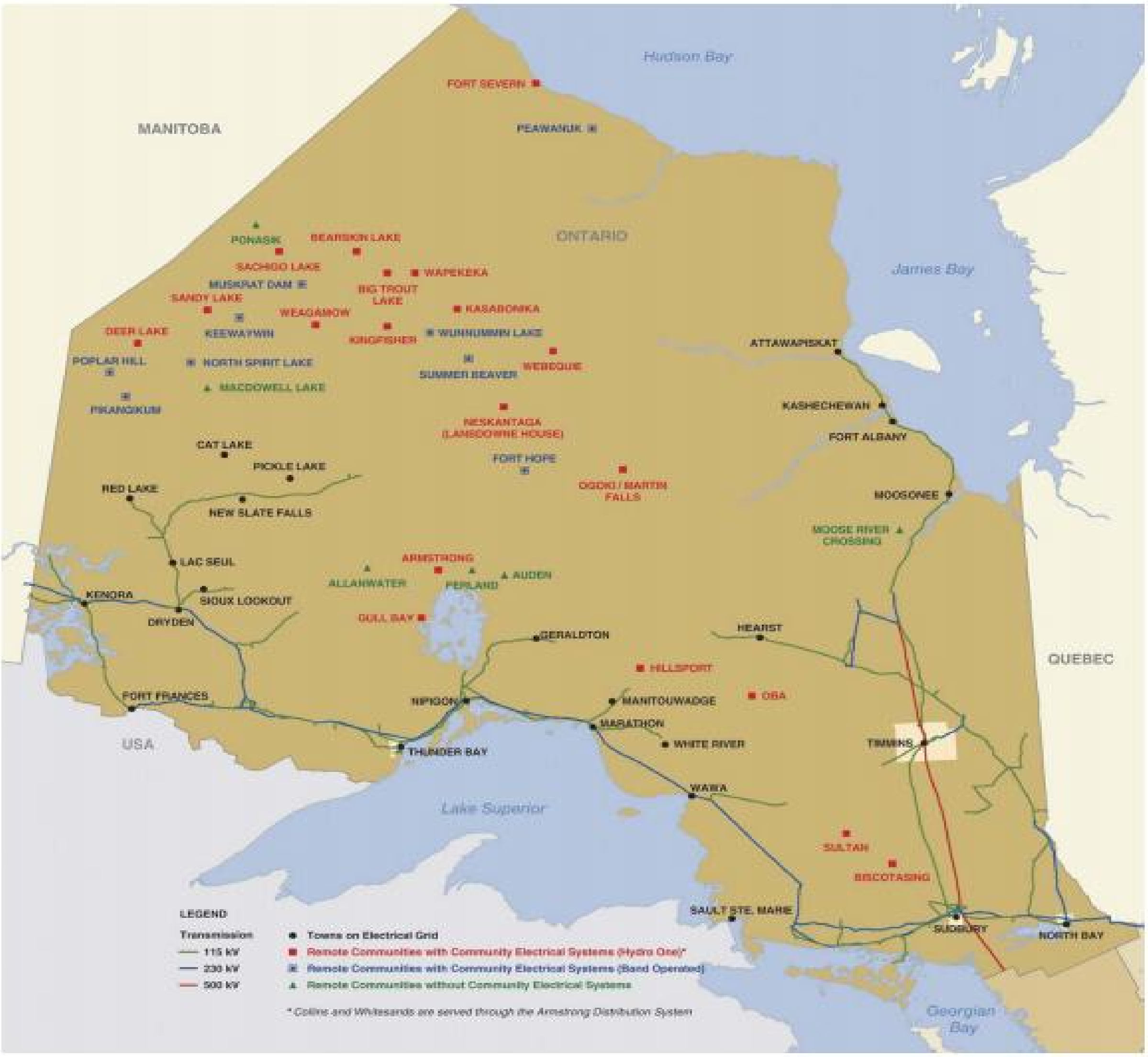

Figure 1. Location of electrical grids and remote communities dependent on diesel-generated electricity (Hydro One Networks Inc. 2013).

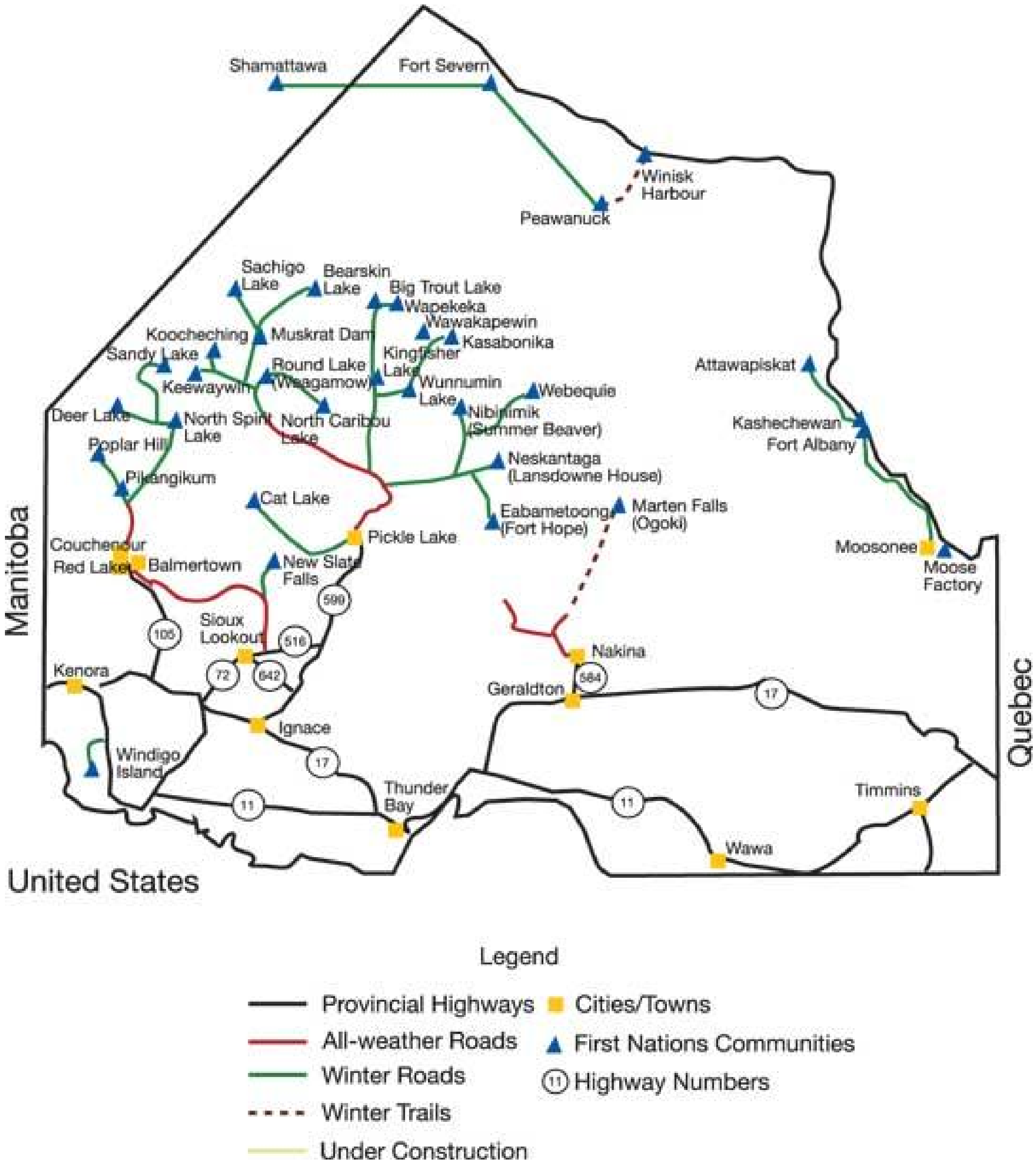

Figure 2. Location of provincial road networks including winter roads (Lemmen et al. 2008).

to $1.2/kWh) (Arriaga et al. 2013). In communities that are already burdened with few employment opportunities and a plethora of socio-economic issues (Arriaga et al. 2013), the high cost of fuel factors into the choices community members and their leadership make in regards to the use of funding. In some instances, the lack of available energy and price of fuel has inhibited communities from building additional housing or business enterprises (Arriaga et al. 2013). Although the cost of electricity is less in rural compared to remote communities, electrical heat is costly and can inhibit growth and development of the communities.

ENVIRONMENTAL CONSIDERATIONS

Diesel generators create carbon dioxide (CO_2) and greenhouse gas (GHG) emissions, posing a risk of contaminating soils and groundwater in the event of a spill or leak (Neegan Burnside Ltd. 2004; Abbasi and Abbasi 2010; Arriaga et al. 2013; Arriaga 2015). Although the majority of these remote fly-in communities are low in population (approximately 500 people in each community), and the emissions per community are low when compared to other areas of the province with large commercial infrastructure, when multiplying the emission levels and risk of spills by the 31 remote First Nations in the Far North dependent on diesel-generated electricity, the risk and hazard to the environment becomes more apparent (; Rice 2011; Statistics Canada 2011; Arriaga et al. 2013).

CURRENT SITUATION FACING FIRST NATIONS

Historically, First Nation communities depended heavily on the forest to provide food, medicines, shelter, security, and as a place to conduct ceremonies (Carlson and Chetkiewicz 2012). With the establishment of the federal reserve system, families were forced out of their homes in the woods and into small villages known as ‘reserves’ (Kinsella 2009; TRCC 2015:1). The subsequent establishment of Indian Residential Schools forbade engaging in age-old traditions and cultural practices, such as hunting and certain coming-of-age ceremonies (INAC 1991; Hurley and Wherret 2010; TRCC

2015:2). The establishment of the reserve system and the Indian Residential Schools resulted in First Nations being disconnected from the traditional lands that had sustained communities for centuries and losing their culture (Albert 2007; TRCC 2015). Present-day impacts include poor socio-economic conditions on reserves, including high unemployment rates (TRCC 2015:194), a loss of traditional knowledge and culture (TRCC 2015:184), and a migration of educated youth to larger urban centers where greater employment opportunities exist (TRCC 2015:193).

In recent years, some communities have begun to reassert their rights to access and use traditional lands and to seek participation in current forest management planning and harvesting (O'Flaherty et al. 2008). A greater say in forest management practices has allowed communities to identify sacred sites that are not to be harvested, along with traditional hunting and trapping grounds, and areas where plants or medicines are collected amongst other considerations which must be addressed in forest management plans (Burlando 2012). This allows First Nations to take advantage of economic development opportunities and share some of the economic benefits that come with forest management and can aid in improving socio-economic conditions (Treseder and Krogman 1999). Although the current methods of including traditional ecological knowledge or the desires of First Nations in forest management and development on traditional lands is far from perfect, it is a step in the right direction. By managing local forest resources to meet community heating needs, First Nations can begin to utilize the natural resources in their traditional territories[2] in a modern application.

In addition to the high cost of fuel, diesel shortages and brownouts can leave communities without power for extended periods of time, often during the winter months when low temperatures can be severe and there is an increased use in electrical heating (Neegan Burnside Ltd. 2004; Giddings and Underwood 2007; Gerasimov et al. 2013). Proactive planning must be done in the event that the ice road season is shortened due to changing climactic conditions (Newton et al. 2005; Golden et al. 2014) or a winter season is prolonged resulting in prolonged use of electric heat and diesel fuel. In the event of a fuel shortage, the community has no backup power generators, with the exception of a few community buildings or homes with personal generators, and the community can be without power for an extended time until fuel can be delivered.

When power is lost in these communities, there is often no alternative place to go except to those commercial buildings with backup generators or individual fuel-oil furnaces to provide heat. Even staying in other communities while the power is restarted is difficult as accommodation for a large number of people often does not exist in remote communities. It can also be difficult to find local skilled personnel to fix and repair the generators when they break and to get replacement parts in a timely manner, as they too would have to be flown in (Neegan Burnside Ltd. 2004).

Further complications arise when considering the provincial and federal legislation which the First Nations and partners must adhere to when planning, operating

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[2] Traditional territory is an area that has been historically used and occupied, and continue to be used, by First Nations (see Thom (1999) for a discussion of the difference between Supreme Court of Canada definitions of traditional territory and First Nations self-definition).

and maintaining development projects, such as BDHP, and the associated use of lands and resources (OMNR 2014b; AANDC 2015a). While it is a federal responsibility to monitor actions on First Nations federal lands, provincial legislation governs the use of lands and resources on the surrounding provincial Crown lands. It is this variation in legal jurisdiction that makes planning for a BDHP on federal-reserve lands while using provincial Crown resources complex (Natcher 2001; Wilson and Graham 2004; Miller 2011; Smith 2015).

There are a number of significant challenges to be addressed when assessing the current electrical supply methods in remote areas, which can affect not only environmental health, but also the health and wellbeing of community members. By addressing these challenges, and exploring alternatives to supplement current electric sources for heat and hot water, it is possible for communities to attain energy security and encourage local economic development.

CONFEDERATION COLLEGE PROJECT OVERVIEW

A pre-feasibility study conducted by Confederation College[3] was designed to assess forest resources and community energy use, community infrastructure, policy requirements, emissions testing, engineering reports and cost estimations for one rural and one remote First Nation community to develop a BDHP to provide heat and hot water to the communities. This study is entitled "Biomass Heat as a Catalyst for Community Development" (Miller 2015). Within this project, there are numerous other

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[3] Confederation College is a college of applied arts and technology located in Thunder Bay, Ontario. Confederation College has recently established the OPG BioEnergy Research and Learning Center and provides heat to its main campus through biomass heating using a 150 kW demonstration and research boiler.

studies which include an inventory of the energy use of the community and assessing other alternative energy sources (i.e. wind and solar), to further offset diesel use, a cost-benefit analysis using Renewable Energy Project Analysis Software (RETScreen) to determine the overall cost, initial funding requirements, and total payback time for alternative energy installments; an engineering report including a layout of the proposed BDHP infrastructure including boilers, chip storage and water piping systems; an Environmental and Regulatory Constraints Analysis which includes a review of the policies which will be in affect when installing, operating and maintaining a BDHP system; and an inventory of forest resources on the lands surrounding communities to determine the amount of resources which can be utilized by the community for biomass district heating.

The intent of the larger study is to contribute to sustainable economic growth in northern communities while reducing the amount of atmospheric GHGs, CO_2, air emissions, and environmental contamination. The proposed BDHP and its associated operations provide community benefits, including the development of a skilled workforce that will provide opportunities for employment in areas with high unemployment rates (Slack et al. 2003; Hall and Donald 2009) and the contribution to the growing independence of First Nation communities by helping them to achieve energy security (Albert 2007; Stupak et al. 2007; Arriaga et al. 2013). The research project also provides an opportunity to document current energy policies and usage in remote First Nations and identify factors that may limit the use of forest resources for community heating needs.

The practical and applied information gathered from this research will contribute to the small amount of research surrounding northern forests, including growth and yield equations and thermal values of tree species mapping. Additionally, this information will be utilized by the community in their community-based land use planning (C-bLUP) process. By recognizing barriers, such as policies and regulations, lack of industrial operations, and limited educated personnel to BDH development, it is possible to identify avenues to overcome these barriers and encourage local economic development.

OVERVIEW OF THESIS RESEARCH

This research project is a component of Confederation College's prefeasibility study. The research assessed the forest resources on the lands surrounding each community and determined the stored thermal energy of wood as well as the sustainable harvest volumes that are necessary to power a BDHP appropriate for the communities' energy needs. The research is intended to provide an estimate of forest biomass volumes on the surrounding land base, both reserve and Crown lands, but does not ensure that these areas can be accessed by the community. To address this, a review of both provincial and federal policies and scientific literature was conducted to identify the potential legislative constraints, processes, and requirements to generate recommendations for economic development projects.

The scope of this project will include the forest inventory and volume/energy estimates, harvesting, planning and production requirements, and regulating policies surrounding First Nations' use of provincial Crown forests and federal reserve lands and resources for biomass district heating. The data generated from this study will be in compliance with the current Ontario Ministry of Natural Resources and Forestry (OMNRF) forest management standards and the Crown Forest Sustainability Act

(CFSA) and is intended to be utilized by the communities to assist in decision making and community planning processes. The constraints identified should assist both First Nation communities and provincial policy makers with understanding the needs of all parties involved when perusing economic development opportunities related to forest resource use in rural and remote communities.

STATEMENT OF PURPOSE

The purpose of this study is to assist rural and remote communities in northern Ontario to become more sustainable by identifying potential forest development opportunities to utilize their natural resources for community heating needs. Specifically, the purpose of this study is to assess one rural and one remote First Nation community's natural resources to determine whether or not sufficient woody biomass is present on the surrounding land base to determine the annual harvest area (AHA) which can be sustained in perpetuity to provide fuel for a BDHP. This may in turn stimulate development in the local economy and contribute to energy security in remote and rural areas of Ontario.

Objectives

The purpose of this research will be met by addressing the following research objectives:

a. To develop a procedure for assessing a remote community's forest resources;
b. To determine the sustainable harvest levels in rural and remote communities barring land access and policy considerations; and
c. To assess the biomass potential of the forest resources;

Research Questions and Null Hypotheses

In order to meet the objectives, the following thesis questions were addressed:

1. Is there a difference between the outcomes from forest inventory procedures provided by the OMNRF and those executed in this study? Null Hypothesis: There is no difference between the outcomes forest inventory procedures provided by the OMNRF and those executed in this study.
2. Is there a difference between the forest resources available to the remote compared to the rural First Nation community? Specifically, wood volumes and species composition will be compared. Null Hypothesis: There is no difference between the forest resources available to the remote and rural First Nation communities (volume, species diversity)
3. Is there a difference between the gross thermal thermal potential for tree species found within the remote and rural communities? Null Hypothesis: There is no difference between gross thermal thermal potential for tree species between remote and rural communities.
4. Is there a difference in the selected wood properties of tree species measured in this study compared to published values? Null Hypothesis: There is no difference in selected wood properties of tree species measured in this study compared to published values.

CHAPTER 2: LITERATURE REVIEW

NATURAL RESOURCES IN RURAL AND REMOTE AREAS OF NORTHWESTERN ONTARIO

In Ontario, there are four distinct forest regions—the Carolinian (deciduous) forests, the Great Lakes-St. Lawrence forests (GLSL), the boreal forest, and the Hudson Bay Lowlands (Figure 3) (OMNR 2014c). Each forest region is characterised by different tree species compositions. The majority of forest operations take place in the boreal forest and the GLSL forests which occupy a combined total of approximately 64 million hectares (Perera et al. 2001: 30). The boreal forest is a zone which extends circumpolar, with its southern boundary in Ontario beginning north of Lake Superior and extending north to Hudson Bay and James Bay (Brandt 2009), encompassing roughly 42% of Ontario's land base (Carlson and Chetkiewicz 2012; Smith 2015). The majority of rural and remote First Nations in Ontario are located within the Hudson Bay Lowlands and the boreal forest of the Canadian Shield (Driben 1986; Carlson and Chetkiewicz 2012). The boreal forest in Ontario is comprised of white and black spruce (*Picea glauca and Picea mariana* respectively*)*; trembling aspen (*Populus tremuloides*), largetooth aspen (*Populus grandifolia*); tamarack (*Larix laricina*); white, red and jack pine (*Pinus strobus, Pinus resinosa and Pinus banksiana*), and cedar (*Thuja occidentalis*).

Figure 3. Forest Regions of Ontario (OMNR 2014c).

The northern range of the boreal forest and Hudson Bay lowlands have experienced little economic growth and development since the time of early settlers and logging operations (Driben 1986; The Far North Science Advisory Panel 2010). The boreal forest, subject to frequent fire and insect outbreaks, tends to naturally regenerate itself approximately every 80 years (Ward and Mawdsley 2000; Krawchuk et al. 2012) making it an ideal candidate for large-scale forest operations. However, because of its northern location, the boreal forest tends to grow slower when compared to southern locations (Krawchuk et al. 2012) and is viewed as ecologically sensitive due to the high water levels in some regions, particularly in the Hudson Bay lowlands (OMNR 2009: Krawchuk et al. 2012).

Forest resources is a blanket term to describe “a stock or supply” of natural materials found in a forest (OMNR 2004). Forest resources encompass standing timber, also known as merchantable timber, as well as woody by-products of harvesting or milling, such as sawdust, slabs, and undesirable wood, and non-merchantable species, including shrubs, saplings, seedlings, and woody vegetation (OMNR 2004; Puddister et al. 2011). Forest resources in the past were primarily used to produce lumber and pulp for commercial operations and firewood for local heating and cooking needs (Abbassi and Abbassi 2010; Puddister et al. 2011). As technology advances and the number of products produced from trees is expanding, there exists a greater opportunity to use wood waste or manufacturing residues (Hesselink 2010). Biomass district heating can provide an opportunity to redirect wood waste to be used for community heating needs.

What is Biomass?

BDHcan use a combination of wood from different sources once it is converted into a usable form (Demirbas 2003). NRCan (2014) defines biomass as “a biological material in solid, liquid or gaseous form that has stored sunlight in the form of chemical energy.” This does not include coal or petroleum which has been converted over a long period of time from an organic matter. For the purposes of this study, biomass will refer to woody materials from forested lands. In industrial forest management, “merchantable timber” refers to the stem/trunk of the tree that is then converted into lumber (OMNR 2009). The stem/trunk and tops, branches, and stumps of these trees, trees with undesirable growth forms, as well as the non-merchantable shrub and tree species account for above-ground biomass (Penner et al. 1997). Slabs, sawdust and other mill residues can also contribute to the amount of available biomass if it is not already utilized (Bradley 2006; NRCAN 2014). Proper integration of biomass harvesting through agreements between mills and forest harvesting companies is essential for communities utilizing BDH.

Biomass can also be obtained by meeting other forest management objectives, such as the creation of fire breaks to prevent spread of wildfires, or the removal of dead, dying and diseased trees (Neegan Burnside Ltd. 2004) which can prevent the spread of insect outbreaks (Stupak et. al. 2009) and further reduce the down woody debris, which can promote wildfire growth and spread (Johnson et al. 2015). Figure 4 presents various sources of biomass, all of which can be sources of woody material for a BDHP if not currently being allocated to local mills.

Communities and forest industries alike have yet to capture remaining biomass from harvest or mill operations, barring the amount that is to be left on site for nutrient cycling (Bradley 2010). Some mills, like the Resolute Forest Product pulp mill in Thunder Bay, Ontario, utilize waste wood from their operations to supply their mills with power and sell excess energy to the grid (Bradley 2010). However, this model is not applied in many areas across Ontario. Although the use of beehive burners, like the one in operation at the McKenzie Sawmill in Hudson, Ontario, has not been specifically outlawed in Ontario, policies aimed at reducing air emissions and developing proper waste management systems, in combination with an economic benefit to alternative disposal methods, may contribute to the elimination of such beehive burners (Bradburn 2014).

Figure 4. Sources of Biomass (BIC 2014).

There exists an opportunity to capture and redirect the flow of waste wood from sawmills and forest operations to biomass district heating plants and provide an economic benefit/incentive. By capturing biomass from existing operations or as a secondary output of meeting other forest management objectives, the need to harvest and chip whole trees for use in a BDHP is reduced and can provide an opportunity for waste management for industrial forest operations.

Can Biomass be Used and Produced Sustainably?

Biomass as a form of wood fuel was the primary fuel source across the globe until the 19th century when fossils fuels became more widely used (Abbasi and Abbasi 2010). In developing countries, such as Brazil and India, biomass continues to be a major source of energy (Lora and Andrade 2009; MNRE 2009; Abbasi and Abbasi 2010). In developed countries in Europe biomass is also utilized as wood pellets and in Scandinavian and Nordic countries woody biomass is utilized for energy and heat production (Gerasimov et al. 2013). As global climates are changing, there is increasing interest in reducing the use of fossil fuels which emit CO_2 which was stored millions of years ago and contributes now to changing climates (Abbasi and Abbasi 2010). According to the United Nations Framework Convention on Climate Change (UNFCCC), biomass is considered renewable if it originate from forested lands and one of the following conditions applies:

> "(a) The land area remains a forest; and (b) Sustainable management practices are undertaken on these land areas to ensure, in particular, that the level of carbon stocks on these land areas does not systematically decrease over time (carbon stocks may temporarily decrease due to harvesting); and (c) Any national or regional forestry and nature conservation regulations are complied with." (UNFCCC 2006).

Although the use of biomass as a fuel source has existed for centuries and continues to play a role in energy production across the globe, questions remain whether or not it is economical and sustainable.

The boreal forest is an ideal candidate for forest harvesting: the lifespan of species ranges on average from 80-140 years, which can then be harvested every 80 years; the forest tends to uptake and store carbon until roughly 80 years when the stands begin to degrade and decay, emitting carbon. The boreal forest is also subject to natural stand-replacing disturbances (fire and insect infestation), which burn or decay, further releasing carbon into the atmosphere (Johnson et al. 2015). Thus, if the boreal forest is to play an important role in the storage of carbon and prevention of CO_2 release, harvesting and converting the wood into lumber or paper is a way to store carbon in the long term (Pukkala 2014). On one hand, harvesting biomass for energy has many benefits. It provides an avenue for harvest by-products and non-merchantable species or wood forms that do not meet mill specifications (Dornburg and Faaij 2001; Demirbas 2005; Alam et al. 2008). Although it is important to leave some wood onsite for nutrient cycling (Franklin et al. 2007), too much wood left on the forest floor can increase the potential for wildfires (McCullough et al. 1998; Amiro et al. 2001) or the spread of disease (McCullough et al. 1998), or make it difficult for species to regenerate (McCullough et al. 1998; Franklin et al. 2007), which has potential to damage existing and future stand development (Bonan and Shugart 1989).

Additionally, the amount of energy produced from harvest wastes can contribute to energy production (Abbasi and Abbasi 2010), which has potential to offset the use of fossil fuels. Because trees store carbon in the form of wood, the burning of biomass emits the amount of carbon that has been stored, leading to a carbon-neutral source when considering simply the act of burning the fuel (Abbasi and Abbasi 2010). Comparatively, fossil fuels are emitting carbon that was stored millions of years ago (Abbasi and Abbasi 2010). These fuels contain carbon stored many millennia ago compared to forest biomass which stores carbon emitted in recent years. Fossil fuels are a source of carbon and are adding to the amount of carbon in the atmosphere (Abbasi and Abbasi 2010).

Focusing on the boreal forest of northwestern Ontario, there has been a recent rise in pressure to preserve and conserve the boreal forest (Lintner 2014; Carlson et al. 2015). Harvesting biomass for the purpose of energy has raised concerns from environmental groups, such as Greenpeace, who published a report which criticized the use of biomass for the production of energy (Mainville 2011). The following section describes the concerns raised about the use of biomass as an energy source.

Although biomass has been touted as a carbon neutral fuel (BC First Nations Forestry Council 2008; Abbasi and Abbasi 2010), this conclusion does not take into consideration the amount of carbon emitted through the transportation and harvesting of biomass. Chippers, skidders, chainsaws and haul trucks utilize some form of fossil fuel to operate and thus must be considered in calculating biomass's carbon footprint (McKendry 2002; Demirbas 2003). Although the procurement and production of biomass can provide jobs in rural and remote communities, the use of heavy machinery can lead to an increase in occupational health and safety issues (Albert 2007; Abbasi and Abbassi 2010). This is particularly problematic in areas where access to health providers and emergency services are limited.

Further, Abbasi and Abbasi (2010) noted that biomass may be a carbon-neutral source but is not nutrient-neutral. Some amount of biomass must be left on-site to contribute to nutrient cycling, which provides nutrients for future stands (Rowe et al. 2009). Stupak et al. (2009) suggest that the amount of nutrients left on site after a harvest operation roughly corresponds to the nutrient content of foliage from trees removed from the site.

Although harvesting biomass for local use in remote First Nation communities can support local employment and reduce diesel consumption, it also increases the likelihood of local environmental impacts. Rowe et al. (2009) also found that ecosystems, habitats, and human livelihood (e.g. trapping) are at risk when introducing harvest activities. Abbasi and Abbassi (2010) noted that there is a challenge to extract energy in a clean and cost-effective manner; a challenge that has not yet been addressed, particularly in northwestern Ontario.

However, biomass district heating has proved to be successful in Sweden, Finland, Denmark, and various other places in Europe, including remote communities in the British Isles, Lithuania, and Latvia (Eriksson et al. 2007; Giddings and Underwood 2007; Lund et al. 2009; Rezaie and Rosen 2012; Gerasimov et al. 2013) . A combination of a smaller land base (Giddings and Underwood 2007; Gustavsson et al. 2011) which lends to shorter transport distances, and the higher cost of fossil fuels (Gustavsson et al. 2011) can lead to district heating being a feasible option for meeting community heating needs.

Biomass to Offset Electrical Consumption

As countries across the globe sign on to global commitments or adopt their own strategy aimed at reducing GHGs, Canada and its provinces are beginning to develop their own policies, which contribute to the reduction of CO_2 and GHG emissions. In Ontario, Canada, the provincial government has put in place a piece of legislation entitled The Green Energy Act (2009), that expresses a commitment to eliminating coal power and converting to renewable energy sources, such as wind, solar, hydro, nuclear and biomass. As a result of the Act, Ontario is supporting the generation of electricity through nuclear, solar, wind, and biomass, entirely eliminating coal-fired plants (Gross 2014).

In April 2013, the conversion of the Atikokan Generating Station from a coal-fired plant to a biomass plant marked the beginning of large-scale biomass electricity production in Ontario (Albert 2007; Alam et al. 2008; Alam et al. 2012). Other attempts at biomass district heating in northwestern Ontario have occurred in Geraldton and Grassy Narrows First Nation but an insufficient wood supply, closure of nearby mills, and other factors, led to the decline and eventual shut down of these plants (McCallum 1998).

Despite provincial legislation aimed at reducing CO_2 emissions, GHGs, and utilizing alternative energy sources, the Act does not cover the remote regions of Ontario where small, remote Aboriginal communities exist. Currently, there are no plans in place to remove diesel generators from remote First Nations (HORCI 2012) in favour of a more sustainable, less polluting and less expensive energy source, and remote communities have yet to benefit from clean energy legislation.

In July 2015, a Pan-Canadian Task Force was established in response to the Canadian Energy Strategy was introduced which aims to improve the production, transportation, and regulation of energy use in Canada (Council of the Federation 2015Council of the Federation 2015: 4) through collaboration with industries, researchers, Aboriginal communities and governments on projects which address social and ecological concerns (Council of the Federation 2015: 1). Further, the Strategy aims to provide energy security and contribute to economic growth while maintaining a high standard of social and environmental responsibility (Council of the Federation 2015: 4). The Strategy has ten areas of focus, with a number of goals and corresponding actions which will contribute to meeting the goals (Council of the Federation 2015: 8). The Strategy also identifies off-grid communities as a priority (Council of the Federation 2015:24; Francoeur 2015). The Pan-Canadian Task Force is composed of representatives from the governments of Ontario, Quebec, Newfoundland and Labrador, Manitoba, Yukon and the Northwest Territories whose purpose is to reduce the use of diesel in the creation of electricity in remote communities (Francoeur 2015; Council of the Federation 2015; Brody 2015).

Although the interests of provincial governments in reducing diesel use in remote communities is timely and well-intended, there have been mixed reactions from Nishnawbe Aski Nation (NAN) (Brody 2015). NAN has been trying to address the issues of diesel-generated electricity in the 23 remote NAN First Nations for decades and the proposed round table discussion with the Chiefs of Ontario First Nations and the Government of Ontario ignored NAN’s request for a separate negotiating table (Brody

2015). Further, NAN communities, government, and Wataynikaneyap Power, a company owned by 20 First Nations which has been attempting to connect remote communities to the electrical grid and to reduce diesel use in these communities, do not wish to see their progress stifled by provincial negotiations and discussions (Brody 2015) though they support the initiative (Boileau 2015).

Hydro One and the IESO are responsible for the creation and delivery of energy in this region and have developed some programs aimed at promoting the use of renewable energy (HORCI 2012) but these programs have yet to be utilized to their fullest potential. Aboriginal Affairs and Northern Development Canada (AANDC) is a department of the federal government that is responsible for ensuring that the obligations of the Canadian government to First Nations are met (AANDC 2015a). Their mandate is to "improve social well-being and economic prosperity; develop healthier, more sustainable communities; and participate more fully in Canada's political, social and economic development—"to the benefit of all Canadians" (AANDC 2015a). There exist programs within AANDC, such as the ecoENERGY for Aboriginal and Northern Communities Program (EANCP), which are able to provide funding to northern Aboriginal communities for renewable energy projects (AANDC 2015b). This may be viewed as a shift in perspectives around the use of biomass for heat and electrical generation in recent years (Abbasi and Abbasi 2010).

BIOMASS DISTRICT HEATING

In order for Ontario and Canada to fully take advantage of their natural forest resources for biomass heat and energy production, other northern countries with remote communities in Europe can serve as examples. In Scandinavian (Norway and Sweden) and Nordic (Finland) countries, there has been a rise in use of biomass in combined heat and power (CHP) plants or in district heating systems (Stupak 2007) as can be seen in Figure 5 (BIC 2014). An example of a BDH configuration is seen in Figure 6. These countries also have numerous rural and remote communities, many of which are using some sort of bioenergy facility to create energy locally as there is a great focus on promoting the use of technology and locally available resources to provide alternative sources of energy (Stupak 2007). A combination of strong policy, research and development, a lack of local traditional fuel sources (oil and gas), heavily-taxed foreign imported fuels, and a plentiful supply of fibre has led to alternative energy becoming a more viable option (Gerasimov et al. 2013). For example, Sweden, Denmark, and Finland have utilized district heating for many decades and have recently seen an increase in the use of biomass for district heating or CHP generation (Stupak et al. 2007; Giddings and Underwood 2007; Verkerk et al. 2011; Rezaie and Rosen 2012). By improving energy policies, particularly those around the importing and use of small (<3 megawatt (MW)) biomass boilers in Canada and Ontario, the province and the nation can begin to adopt European technologies for alternative energy generation in remote areas.

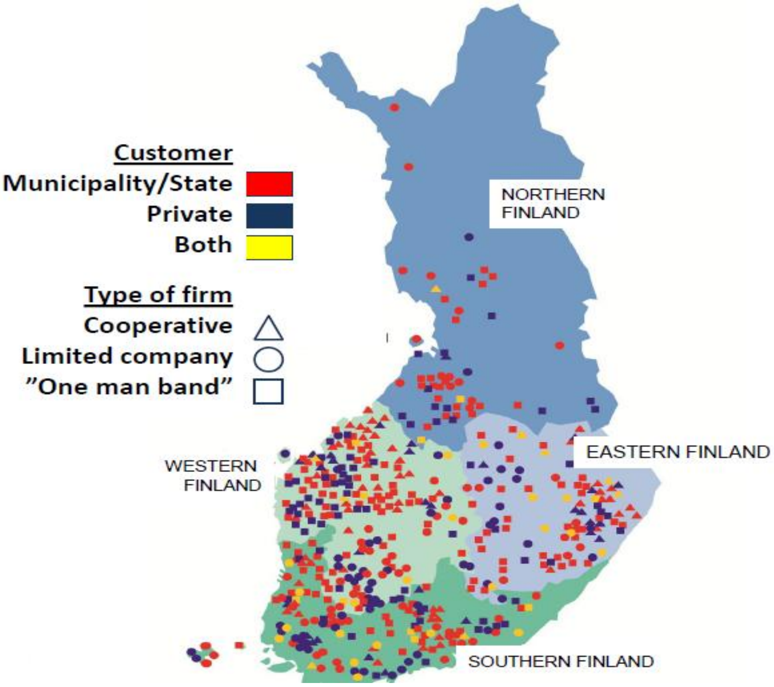


Figure 6. Location of BDHP in Finland (BIC 2014).

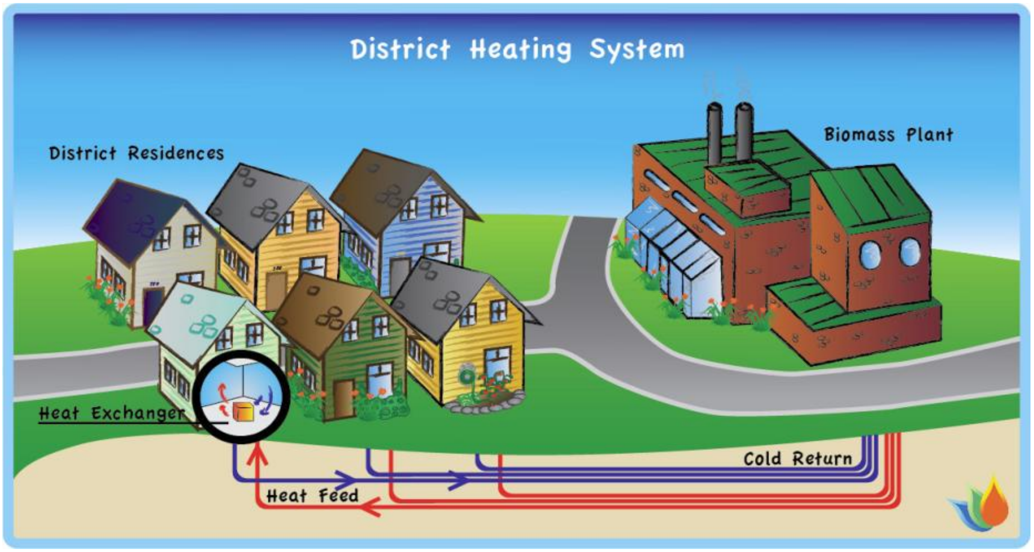


Figure 5. Example of BDHP configuration (BIC 2014).

In order to plan for a community BDHP project, it is important to consider the energy demand of a community, particularly around the use of heat and hot water, and the amount of forest resources available for BDH use (Thompson et al. 2007). This technology can be used as a short-term solution while future alternative energy generation technology can be researched, planned, and installed at a later date. BDH can use a combination of wood from different sources to be burned in a boiler contained within a district heating plant.

It is imperative that the forest resources be converted to a usable form, whether it is wood pellets or wood chips at specific moisture content (Rentizelas et al. 2009). The mix of tree species is also important as it directly relates to the available thermal energy and ash content (Öhman et al. 2002; Baxter 1993; Jamies et al. 2012) which factors into the amount of forest resources needed to operate a BDHP.

In order for a BDHP to operate efficiently, it is important to have the necessary physical infrastructure and human capacity. Necessary infrastructure includes the BDHP itself, along with the equipment required to harvest, haul, chip (or grind), dry, and store the fuel as chips or as pellets. Specifically, this includes: harvesting equipment, whether it is a chainsaw, feller buncher or processing head; hauling equipment, such as a skidder or forwarder, and a hauling truck; a chipper, either portable or on site; and a storage bunker for the fuel (McKendry 2002; Rentizelas et al. 2009). Community members trained in operating the above equipment is also a very important aspect of a successful community operation (Community Energy Association 2013; Council of the Federation 2015). This is especially important in remote areas where supplies and replacement equipment are not easily acquired. For example, if a chip hauling truck falls into disrepair, it may be many months before the winter road system is usable and a new truck brought in. Not only would this be costly, it would delay harvest and production, which may lead to fuel shortages (McCallum 2010).

There are numerous examples of successful biomass district heating operations in Europe and in Canada. Prince Edward Island (PEI), Quebec, Alberta, British Columbia (BC), Yukon and Northwest Territories (NWT) have BDHP operations (Neegan Burnside Ltd. 2004; Biomass Energy Resource Center 2009; McCallum 2010; Germain 2013).

Madlener (2007) describes the various BDH operations in Austria, stating that over 800 BDH plants were in operation by the end of 2003, mainly using wood residues from forest operations or sawmill residues and some agricultural waste such as straw (Stockinger and Obernberger 2014). Over time improvements in the planning and design processes came as a result of the enhanced technical and economic efficiency requirements from funding agencies and authorities (Madlener 2007; Stockinger and Obernberger 2014). The use of BDH systems began in rural Austrian communities in the mid-1980’s as a result of local initiatives and public policy to support the farming and forestry sector (Madlener 2007; Stockinger and Obernberger 2014). McCallum 2010 notes that BDHP started in Finland in the 1950’s and has had numerous successes over the years owing to the reliable and environmentally friendly method of heating, especially in densely populated areas. He also notes that there have been recent programs with aggressive strategies to meet Kyoto Protocol targets and numerous policy frameworks have been developed to support the growth and development of biomass energy in Scandinavia and Europe (Madlener 2007; McCallum 2010).

Charlottetown, PEI, established a district energy system in 1986 following the construction of a district heating plant in 1980 and a district heating network at the University of Prince Edward Island in 1986 (Biomass Energy Resource Center 2009; McCallum 2010). Eventually the systems were consolidated into a larger network. Currently, the operation has 33 employees and roughly six that work in wood chip production (McCallum 2010). The system now includes a CHP plant which provides energy as well as heat and utilizes mainly municipal solid waste, waste wood from forestry operations and oil as a backup or during high peak times (Biomass Energy Resource Center 2009).

Strathcona County, AB, installed a biomass district heating system in 2006 to heat community buildings (Germain 2013). The community heating system utilizes mainly waste wood from nearby North Star Pellets and some agricultural feedstocks (QUEST Canada and CABREE 2012; Germain 2013). The project aims to utilize local renewable fuel sources, reduce CO_2 emissions and dependency on fossil fuels, while contributing to sustainable development (Germain 2013). A business case study found that both CHP and BDHP were feasible, but CHP was not plausible due to provincial regulations which prevented the CHP plant from being connected to the electrical grid (QUEST Canada and CABREE 2012) and the requirement for a more extensive environmental assessment at the expense of the community (QUEST Canada and CABREE 2012). The regulations regarding power distribution have since changed with the introduction of the Micro-Generation Regulation 2008 which would make CHP feasible (Electric Utilities Act 2008). However, further research into the identification of potential customers would be required for a business study (QUEST Canada and

CABREE 2012).

In BC, the town of Revelstoke and the Dockside Green harbourfront community in Victoria have installed BDH operations. It was noted that plans for CHP systems were rejected in favour of smaller, heat-only operations which did not require a stationary engineer thus reducing the cost of operations (McCallum 2010). Both systems utilize waste wood from harvest operations.

Further north in Canada, the community of Yellowknife,NWT, installed a district heating plant to heat its community pool, curling rink, and area; its primary fuel source is wood pellets (McCallum 2010). Kluane First Nation in the Yukon installed a BDH system in 1998 to reduce their dependency on outside fuel sources (Neegan Burnside 2004). Wood chips are the fuel for the system and are harvested from First Nations land damaged by a forest fire leaving dead standing trees which provides a good fuel source (Neegan Burnside 2004). Benefits to using BDH in the community include savings in the operating budget, as well as a decrease reliance on fuel suppliers, less planning for fluctuating fuel prices, stimulation of local economy, and the creation of local employment (Neegan Burnside 2004).

One successful example of BDH in a First Nation in Canada is in Oujé-bougoumou, Quebec (Figure 7), touted as the most successful example of BDH in Canada (McCallum 2010). After the community received a large land claim settlement in 1990, they decided to build a new town complete with a district heating system, which serviced the entire community (McCallum 2010). As the town grew, so did the BDHP and a second boiler was installed to meet the community’s energy demands. The biomass is sourced from a nearby mill in the form of sawdust, slabs, and lumber ends

(Neegan Burnside 2004; McCallum 2010). The success of this project can be attributed to a number of actions and planning that ensured smooth operations: a good relationship between engineering consultants and the community who provided training in operating the system; reference manuals complete with detailed maintenance schedules; the

Figure 7. Location of Oujé-bougoumou in Quebec (Wikipedia 2015 [edited]).

consultant provided recommendations that the BDHP have spare parts on hand so that in the event of a part failure, the system will not be down for a long period of time; and a local source of biomass (McCallum 2010). Though the community uses sawdust from a nearby mill, it is acknowledged that not all communities have access to nearby mills to capture waste, it is possible for other communities to use locally-created wood chips, which would in turn create more jobs (McCallum 2010). The use of BDH in Oujé-bougoumou can serve as a model for other rural or remote communities in Canada (McCallum2010).

One First Nation in Ontario that has attempted BDH is Grassy Narrows. In 1997, Grassy Narrows First Nation installed a BDHP, which served the core commercial area of the community which included the school, day care centre, administration building, community hall, and roughly 30% of the residences in the core area (Neegan Burnside Ltd. 2004). When the project began, the community had its own wood chipping operation to supply biomass to the BDHP, which provided a higher quality fuel but proved not to be cost-effective due to transport and shipping costs (Neegan Burnside Ltd. 2004). The community then switched to utilizing waste wood from a local sawmill in Kenora, Ontario, which was available for the cost of trucking and loading. In 2004, the cost of sawmill waste was anticipated to increase as the demand for waste was increasing, so the community began seeking alternate fuel sources. Then the Abitibi Consolidated Kenora mill was shut down in 2005 (Fort Frances Times 2005) and without an alternate fuel source, the BDHP was eventually closed.

Calculating Annual Harvest Area

In order to determine how much wood can be harvested on an annual basis for use in a BDHP, it is important to understand what is considered an Annual Harvest Area (AHA) and how these volumes are calculated. In short, the AHA is the calculation for the rate of harvest primarily used in managed forests that describes the volume of wood which can be harvested in a given year while leaving enough volume (stems) to allow the forest to grow in a manner which can be harvested again in the future with similar volumes (Ford-Robertson 1971; Vanclay 2014). Calculation of the AHA is based on three factors: the standing volume of timber, the growth rate of the forest, and the size of the forest operation (Higman et al. 2013). Where growth and yield information are incomplete or unreliable, conservative levels of harvest must be used to avoid over harvesting (Higman et al. 2013). Harvest levels must not exceed the natural reproductive capacity of the forest if harvesting is to be sustainable (Abbasi and Abbasi 2010). In Ontario, the AHA is calculated for the province as a whole, and the harvest volume is distributed amongst its forest management units (FMUs) (OMNR 2009).

Available Wood Supply and Supply Chain Management

In order to plan for a BDHP operation, it is necessary to establish not only the available wood supply, but also a wood supply chain. An efficient wood supply chain can assist in achieving the maximum value for the product, or benefit to society, without jeopardizing future values and benefits (Pulkki 2001). A wood supply chain consists of a few necessary components: forest land owner/manager; wood procurer, and end user (McLure 2009). Additionally, the supply chain often includes loggers or wood harvesters, trucking firms, forestry consulting firms, and government bodies to oversee operations (McLure 2009).

For a biomass harvest operation, it may be possible to integrate into existing forest operations whereby biomass is harvested as a byproduct or gathered as a waste product from mills (Neegan Burnside Ltd. 2004; Bradley 2006; McCallum 2010; NRCAN 2014; Sacchelli et al. 2013). The two operations could exist concurrently where the merchantable timber is harvested and hauled to a mill, and the tops, branches, and non-merchantable or undesirable species can be chipped and hauled to a BDH facility (Sacchelli et al. 2013) as depicted in Figure 8. Figure 9 depicts an additional opportunity to capture mill waste, such as slabs and sawdust, which can further add to the wood supply for BDH (BIC 2014). It is necessary to ensure that all pieces of the supply chain are acting simultaneously to ensure efficient transport of material and products (Rentizelas et al. 2009) while maintaining ecological integrity (Puttock et al. 1998). There current forest operations do not exist, as would be the case for remote communities, establishing a wood supply chain can be a challenge. The volume of standing wood within a reasonable haul distance from the community and the amount of area which has potential to be considered for harvest must first be determined (Arriaga et al. 2013). From this volume, certain areas and subsequent volumes must be subtracted as they represent inoperable areas or ecologically sensitive areas (OMNR 2009). These can include buffer zones around spawning areas and water bodies, trap lines and cabins, known nesting or denning areas, environmental considerations such as pine marten (*Martes americana*) habitat and caribou (*Rangifer tarandus*) migration corridors, and protected areas such as sites of spiritual significance (OMNR 2009). Inoperable areas

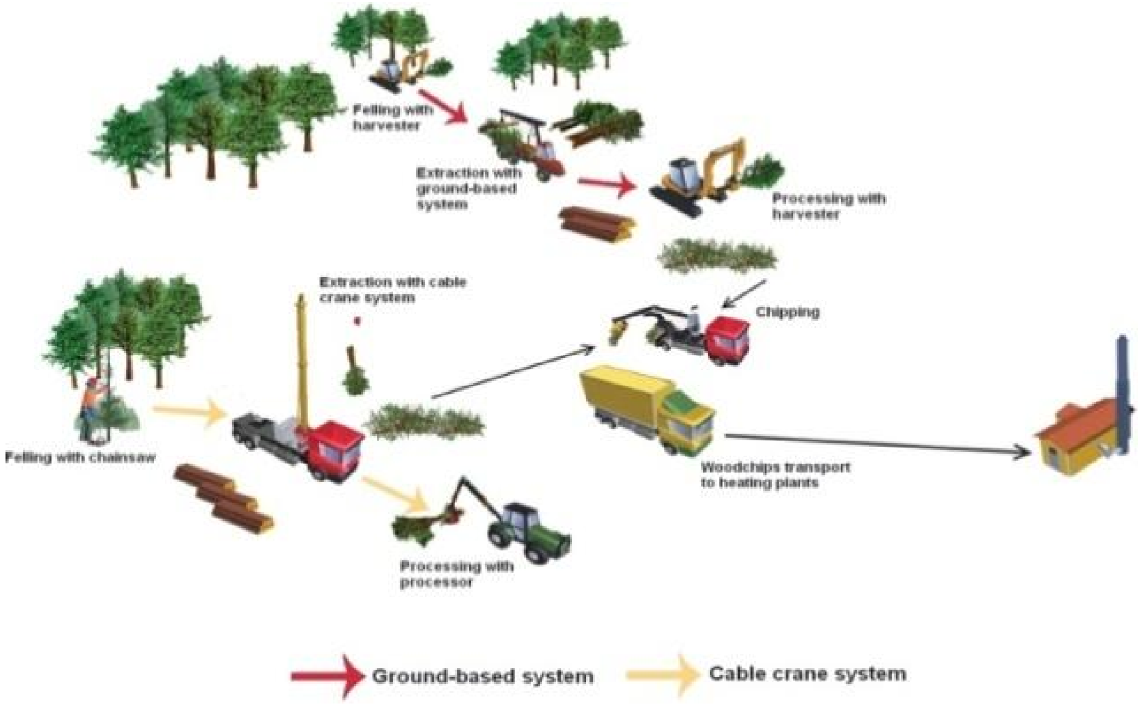


Figure 9. Integrated wood supply chain demonstrating use of harvest residues (Sacchelli et al. 2013).

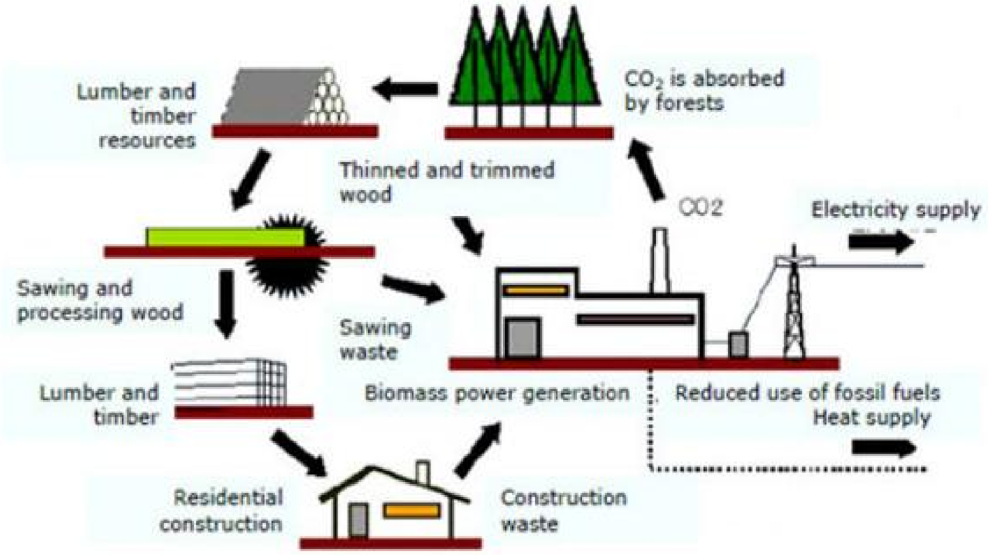


Figure 8. Integrated wood supply chain demonstrating use of by-products for biomass energy use (BIC 2014).

include areas on steep slopes or are inaccessible, such as bogs and wetlands (OMNR 2009). In industrial forest management zones, areas affected by insect or fire are generally removed from the wood supply.

When establishing a biomass wood supply, these areas can be included in AHA calculations as they can provide fibre/biomass for a BDH operation if there is no serious degradation to the wood's thermal properties (Leckie and Gillis 1995; Neegan Burnside Ltd. 2004; Gautam et al. 2010; Hosegood et al. 2011). Once the total area and associated volumes are removed from the total, it is possible to then determine the volume which can be harvested annually on a sustainable basis taking into consideration the amount of time it would take for a stand to regrow (OMNR 2009).

Given that community members in remote communities have training and experience in winter road construction, it would be ideal to develop a winter road network for harvesting during winter months when wetlands are frozen and roads could be developed through these areas with less environmental damage compared to the construction of all-season roads (Pulkki 2003). Further opportunities exist in managing stands to improve forest health by removing the dead, dying and diseased trees from a forest to allow for the growth of a healthier and more productive forest stand (Madlener 2007; Hosegood et al. 2011). These considerations must be taken into account when planning for biomass harvests, particularly in remote areas where access is limited and forest management for health and community is uncommon, yet remains a viable possibility for accessing biomass.

Units of Measure

In order to accurately and consistently measure wood and account for the variation in results, the basis on which wood is dried to must be known. Wood can have differing moisture levels including air dry,oven dry, and green, while tests for wood density and moisture are determined on either a wet basis or dry basis. Air dry biomas refers to the condition of the wood after being harvested and exposed to local atmospheric conditions for a period of time (Rosillo-Calle et al. 2015: 282). When density is calculated using air-dry wood, it is “based on the weight and volume of wood in equilibrium with the atmospheric conditions” and may contain between 8%-12% moisture on a dry basis (Rosillo-Calle et al. 2015: 282). Oven dried wood is obtained by placing the wood in a ventilated oven that is heated above the boiling temperature of water so that all moisture is removed from the sample, achieving 0% moisture content (Rosillo-Calle et al. 2015: 288). Green wood refers to trees that have been recently felled or harvested and has not undergone prolonged exposure to local climatic conditions and generally contains 30-35% moisture on a dry basis Rosillo-Calle et al. 2015: 280). The difference between moisture content calculated on a dry basis compared to a wet basis is how the water weight is expressed as a percentage of the total weight. When using a wet basis, the water weight is expressed as a “percentage of the sum of the weight of the water ash, and dry-and-ash-free matter” (Quack et al. 1999: 3). When calculating moisture content on a dry basis, the water weight is expressed “as a percentage of the dry-and-ash-free matter” (Quack et al. 1999: 3). It is important to identify the basis on which moisture content is measured (Quack et al. 1999: 3) because “the energy value of a unit of woody biomass is inversely proportional to the amount of water it contains" (Rosillo-Calle et al. 2015: 53).

While this study utilizes the units of megajoules per kilogram (MJ/kg), it is important to note that thermal potential can be described using other units, and that biomass products such as wood pellets or chips can be sold in different units such as gigajoules per kilogram (GJ/kg) or British thermal units (BTU).

Wood Density

When evaluating individual species for their value and potential for generating heat, it is important to consider the density of the wood as "both the calorific value and density depend mainly on the moisture of the [wood]" (Ragland et al. 1991). In short, the more water per unit of wood weight, the less wood (fuel) present (FAO 2004). The wood density is relevant to the combustion process as well, particularly the particle density and the bulk density (Kanury1994; Demirbas 2003). The particle density can be defined as the density of the material itself whereas bulk density refers the ratio of dry material to the bulk volume (Ragland et al. 1991). This is important for transportation and storage logistics (FAO 2004).

Density is also dependent on specific gravity and moisture content (MC) (Simpson 1993). When the maximum MC is reached, the cell walls and lumen are filled with water; when the specific gravity of the wood is high, the volume of the lumen is low, there is less space in the wood for water to fill, thus MC is restricted by the space available (Simpson 1993). Sandström et al. (2007) found that disease and rot can lead to a decrease in density which increases the potential for higher moisture content, decreases the thermal value, and increases ash content.

Moisture Content of Wood

When determining how much wood is needed for a community heating project, it is also important to consider the MC of wood. Ultimately, moisture content will affect the energy content of the wood, how well the fuel burns, and the amount of ash remaining after the fuel has been burned (Jenkins et al. 1998). Simpson and TenWolde (1999) state that MC can range between 30% to >200% of the dry-basis weight of wood in trees. Softwoods generally have a greater MC in the sapwood compared to heartwood, while MC in the heartwood and sapwood of hardwood trees is dependent on species (Simpson and TenWolde 1999). However, wood is not separated by heartwood and sapwood when harvested; thus the overall moisture content is most important.

The winter would be the ideal time to harvest (Pulkki 2003) as the lower moisture content would decrease the drying time and fewer nutrients in the wood would reduce the ash content (Jenkins et al. 1998). Drying or seasoning of the wood fuel can take place in several ways: woody biomass can be piled and tarped to prevent dirt from entering as this would increase the ash content increase the speed of drying, and prevent an increase in MC from precipitation (Walki n.d; Fuller 1985; Gustavsso et al. 2011); woody biomass can also be piled at roadside, or nearby the chipping operation or storage bunker to be seasoned (Rentizelas et al. 2009). Wood dried to the specified MC can then be stored in a bunker to maintain MC over time before use in a BDHP. Overall, it is important to have dry wood for optimal efficiency of the BDHP boiler system.

Thermal Potential of Wood

If the purpose of calculating annual harvest volumes is to provide a sufficient fuel source to produce heat in a BDHP, it is important to have an understanding of the thermal potential of the wood. The thermal potential combined with the ash content will assist in determining the optimal species mix for the fuel source (Demirbas 2003). Ragland et al.(1991) stated that: “Specific heat depends on temperature and moisture content but not on density or species”.

Knowing the density of wood, it’s MC and ash content can inform decisions made as to the ideal fuel source. As an example, a species with a low thermal potential and high ash content, compared to that of a high thermal potential and low ash content, would not be ideal as the amount of energy produced from a cubic meter of the former would be less than the latter (Asikainen et al. 2011) and would require a more frequent removal of ashes from the boiler system. In order to reduce the harvest volumes and frequency of ash disposal, it would be ideal to harvest those species with a higher thermal potential and lower ash content (Demirbas 2003). Hakkila (1989) points out that average ash content of bark is 2.97%, while stem wood generally has 0.3±0.1% ash content for softwoods and 0.5±0.3% for hardwoods. If the intent is to use harvest residue in a district heating operation, then wood ash may be an issue. When planning for community heating projects, it is important to consider not only the volume of wood available, but also, and more importantly, the amount of energy per unit of wood available for use.

Ash Content of Wood

Another important factor to consider when determining an ideal fuel source is the amount of ash remaining after the fuel has been burned. After burning wood, the remaining ash is indicative of minerals present in the wood (Demeyer et al. 2001), as well as any debris that was deposited on the wood during transport or removal such as dirt. Ash can create a problem in a BDHP as it deposits “on heat transfer surfaces [of the] boilers and on [the] internal surfaces of gasifiers” (Baxter 1993; Misra et al. 1993; Demirbas 2005), which can impact how efficiently the boilers burn the fuel. Ash has also been shown to degrade the metal internal components of boiler systems (Öhman et al. 2004).

Wood ash has been demonstrated to be effective in potash production, which can be utilized in agricultural practices (Misra et al. 1993) or when applied to soils where harvesting has recently occurred as a way to replace nutrients and elements removed from the soils (Demeyer et al. 2001). However, in Ontario it is currently considered to be a non-hazardous industrial waste product (Environmental Protection Act 1999) and can be disposed of in a landfill. Questions remain about the longevity of the existing landfill sites in communities and whether or not they are able to handle the additional waste generated from a BDHP and whether or not this would negatively affect the site’s capacity (Demeyer et al. 2001; Jamies et al. 2012).

There are a number of potential uses for ash from boilers: as a liming agent for roads or as a replacement for cement in concrete (Abdullahi 2006); spread in the forest as a fertilizer (James et al. 2012, Demeyer et al. 2001); or in gardens as a fertilizer (Naylor and Schmidt 1986; Pitman 2005). Stupak et al. (2007) advise that tops, branches, and rotten wood be used for energy purposes as a supplement to the use of clean bole wood because of the increased percentage of ash as a result of using branches, tops and rotten wood. Regardless of how the ash is disposed, there exists a potential for it to pose a problem which must be considered when planning for biomass district heating in rural and remote communities.

FIRST NATION ACCESS TO TIMBER ON PROVINCIAL CROWN LAND AND FEDERAL RESERVE LANDS

In order for communities to access the surrounding natural resources for their use, it is imperative to understand the policies that affect resource use and how they may constrain the use of a particular resource. The barriers that policy presents can be further exaggerated given the different jurisdiction of the lands and resources—under Canada's Constitution Act, 1982 "Indians, and Lands reserved for the Indians" are the responsibility of the federal government (Constitution Act 1982. 91(24)) while forest resources are a provincial responsibility (Constitution Act 1982 s. 92A). In certain cases, such as the Treaty 9 area, the province of Ontario is a signatory to the Treaty and thus has certain responsibilities (Smith 2015), which can add further complications. The following section aims to illustrate the current policies in place, which may help or hinder a community that is seeking access to natural resources, particularly on traditional lands.

Canadian forest/land management policies have not historically favoured First Nation communities in the past, particularly in natural resources management. This exclusion has resulted in systemic poverty and the loss of traditional livelihoods and knowledge in land management (TRCC 2015), creating a divide between policy makers and the people whom those policies affect (Miller 2011; Hunt and Haider 2011, Gardner et al. 2012). Finding a balance between provincial policies, federal treaties, and First Nations' traditional inherent rights makes land use planning in northern areas complex. A combination of Crown land and reserve land with different laws and jurisdictions, which apply to different areas and resources (Hurley and Wherret 2000; Smith 2015), combined with a difficult historical relationship, makes collaborative planning for future land use difficult.

Despite a low population density (Slack et al. 2003; Hall and Donald 2009), the boreal forest area is home to approximately 70 First Nations communities consisting of members from four Treaty areas—Robinson-Superior Treaty (1950), Treaty 3 (1873), Treaty 5 (1875) , and Treaty 9 (1905-06; 1929-30) (OMNDM 2014; NAN 2015). A map of Treaty areas in Canada can be seen in Figure 10.

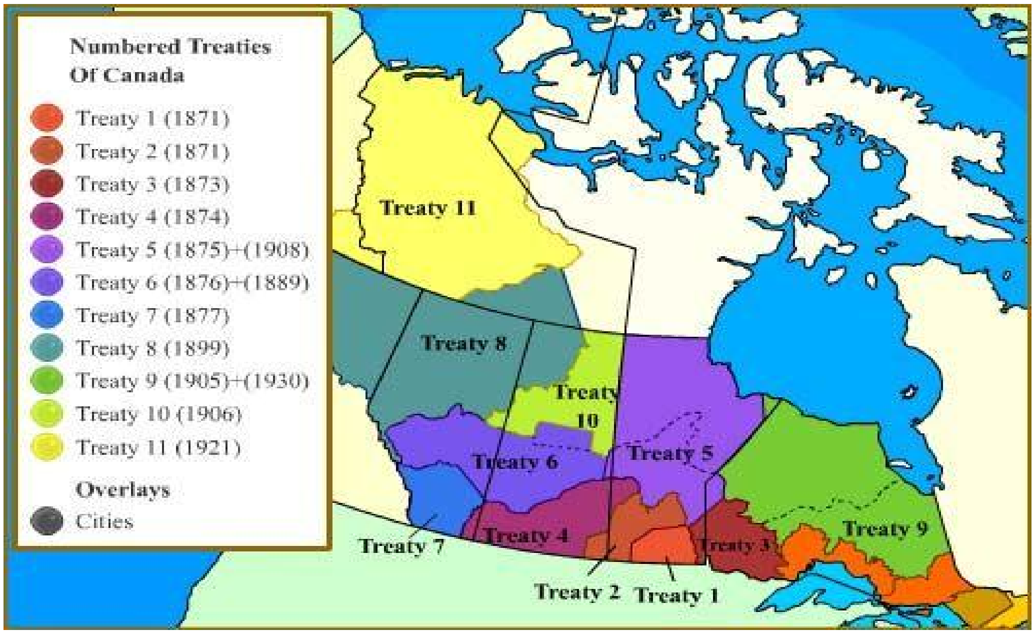


Figure 10. Numbered treaties in Canada (OMOE 2011).

In spite of the treaty rights that guaranteed First Nations continued use of their territories for traditional purposes, Ontario often ignores those rights in their imposition of provincial regulations on First Nations on provincial Crown lands. In the Treaty #3 area, which is in the Area of the Undertaking (AOU), the zone of active forest management in Ontario (NAFA 2015: 17), First Nations are subject to provincial forest management regulations (Brailsford 2011). In the Treaty 5 and 9 areas, the Far North Act (2010) applies. In short, the Far North Act states that development in the region cannot take place until a C-bLUP is in place (The Far North Science Advisory Panel 2010). The Act aims to provide a planning process whereby First Nations and the province of Ontario can collaborate on projects while meeting the social, economic, and environmental objectives described by the parties (The Far North Science Advisory Panel 2010). The question of the application of provincial regulations to First Nations, described as “interjurisdictional immunity”, is an unresolved issue that is being worked out in the courts (Mackenzie 2013).

The focus on the boreal forests of Canada as an ecologically important area has been a recent development (Lintner 2014; Smith 2015). Attention has turned to the boreal forest as conservation groups have declared the northern forests of Canada “the world’s largest ecologically intact area of boreal forest” (Lintner 2014), with the goal to protect a large expanse of the area. In the 1990’s continuing to present day, environmental organizations, forest industry partners and governments have negotiated the continued protection and development of the boreal forest (Cartwright 2003; Youden 2010; Burlando 2012; Smith 2015), resulting in a series of policies aimed at doing so. What failed to happen in these discussions was consultation with First Nations peoples and local communities residing in the area of interest (NAN 2010). As a result of exclusion from the policy development process, NAN (2010) has stated that the legislation does not adequately accommodate the communities under its jurisdiction, nor does it encompass First Nation values and traditional knowledge or provide sufficient opportunities for First Nation involvement (NAN 2010; Youden 2010; Gardner et al. 2012; Smith 2015).

Treaties, the Indian Act, and Supreme Court Decisions

In recent years, the Supreme Court of Canada has come out with a series of decisions which affect land management and the relationship between the federal and provincial governments and Aboriginal peoples, primarily with the acknowledgement that the Crown (both provincial and federal governments) has a fiduciary responsibility to protect the rights of First Nations and act in their best interest (Hurley and Wherret 2000; Smith 2015). The origin of this responsibility is outlined in the original treaties, the Indian Act (1876), and the British North America Act (1876) (BNA). Notably, the BNA in Section 91(24) and Section 92, describes the responsibility of the federal government for "Indians and lands reserved for the Indians" in the former, while delegating responsibilities of lands and resources within provincial boundaries to the respective provinces in the latter (British North America Act 1867; Indian Act 1985; Smith 2015). Smith (2015) stated "how to reconcile Crown-Aboriginal interests in natural resources remains one of the most pressing issues faced by Canadians".

The treaties provide further discrepancies in the requirements and responsibilities of federal and provincial governments. It has become common knowledge that the spirit and intent of the treaties as understood by First Nations is much different than the written text recorded by the Crown (TRCC 2015).

The federal Indian Act (1876) and its regulations (Indian timber Harvesting Regulations 1954; Indian Timber Regulations 1954) define who is an "Indian" and a "Band" and sets out the rules for governance on reserve lands. Essentially, the Indian Act governs matters pertaining to Indian status, bands, and Indian reserves (Hanson n.d.). The regulations covering the use of forest resources on reserve land include the Indian Timber Regulations and the Indian Timber Harvest Regulations. Section 93

(93.a.i) of the Indian Act (1876 or 1985) states that permission must be obtained by the Minister or another authorized representative before any harvesting can occur on reserve land.

The Indian Timber Regulations (C.R.C., c.961) and The Indian Timber Harvest Regulations (SOR/2002-109) are further regulations made under the Indian Act that describe the laws and regulations surrounding timber harvest on reserve land. Numerous costs and permitting regulations are spelled out under these two regulations, which, if not adhered to, can restrict or limit future development in the community.

The Indian Timber Regulations (ITR) discuss the requirements for permitting and approval, associated charges and fees, as well as the methods of acquiring a licence, scaling requirements, record keeping, and any consequences should the regulations not be adhered to (Indian Act 1985). Under the ITR, it is unlawful to cut timber on reserve lands without a license or permit from the federal Minister of Aboriginal Affairs and Northern Development Canada. Permits may be issued to community members to cut timber or fuelwood for personal use, or to a band for band purposes, free of charge (Indian Timber Regulations 1954). However, if the wood is to be sold, consent must be first issued from the Band/Chief and Council through a Band Council Resolution, and the Minister then administers a licence for harvest and sale (Indian Timber Regulations 1954). Dues can be reduced to half of the prevailing rate of stumpage by the Minister (Indian Timber Regulations 1954). If the operation is a medium- to large-scale project (“dues payable pursuant to a licence will exceed $2500”), the federal Minister reserves the right to invite tenders for the licence by means of public advertisement (Indian Timber Regulations 1954). This means that the community may not win the bid to harvest their lands should another company outbid their tender on medium- to large-scale harvest operations.

On one hand, the regulations prevent communities from overharvesting, or any kind of harvesting, until a plan is in place and it is approved. On the other, it does not allow for communities to have autonomy over their resources (Westman 2005). Westman (2005) critiques the management of First Nation reserve land by the federal government through the Indian act, stating that it “does not adequately incorporate contemporary resource management concerns relating to environmental sustability, mixed-use, Aboriginal values or equitable distribution of forest rents.” (Westman 2005). Further, he states that AANDC “does not consistently enforce the act and regulations, does not provide First Nations with resources to intensively manage Reserve forests and lacks internal forest management capacity” (Westman 2005). The failure to address social, environmental, or economic issues in the Indian Act and the Indian Timber Regulations has in the past resulted in timber theft and federal mismanagement of reserve forests (Westman 2005).

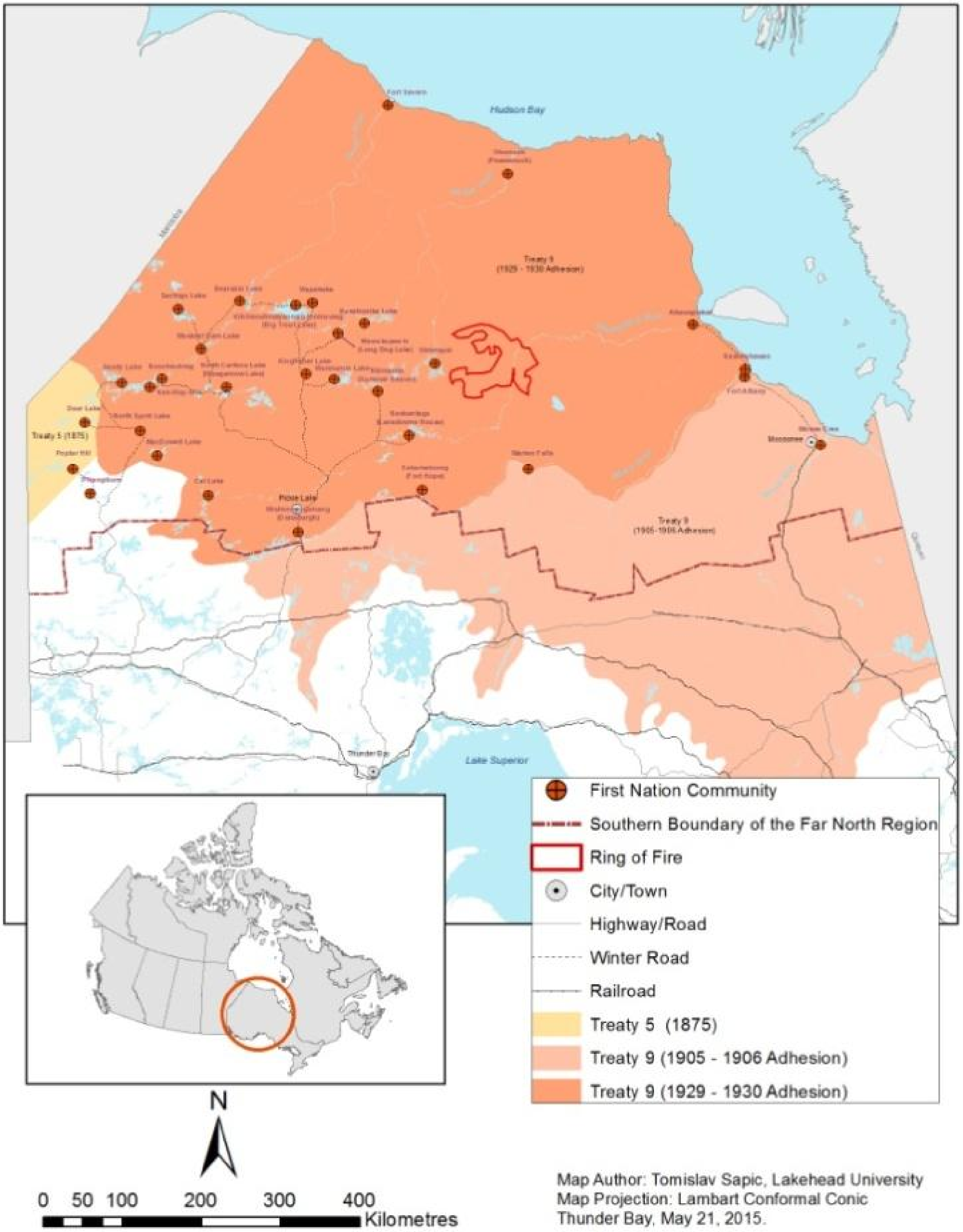
One Supreme Court of Canada decision that may directly relate to harvesting of Crown lands for the purpose of community heating is the case of R. v. Sappier; R. v. Gray in 2006. First Nation community members in New Brunswick were charged with unlawful possession of or cutting Crown timber from Crown lands under the New Brunswick Crown Lands and Forests Act (1980). The timber was cut from traditional lands and would be used in the construction of a new dwelling in the community, community fuel wood use, and by a fashion furniture maker local to the First Nations community (AANDC 2010). Because they possessed an Aboriginal and treaty right to harvest timber for personal use, and the community members had no intent of selling logs or products made from the harvested timber, they were acquitted at trial (AANDC 2010). The Supreme Court of Canada unanimously agreed that the community members were acting within their Aboriginal and treaty rights. In conjunction with a few other court cases, the Supreme Court of Canada also rules that, in the case of the Mi'kmaq and Maliseet communities in the eastern provinces, pre-contact practices have evolved over time that allows community members to harvest and use wood in the construction of modern shelters, or for transportation, tools and fuel wood (AANDC 2010). However, this right extends only within a community's traditional territory, and the goods harvested cannot be sold, traded or bartered to produce assets or raise money, even if it is intended to finance construction or other projects (AANDC 2010). The Supreme Court of Canada made it clear that there is no commercial dimension to this right. As a result of the Sappier and Gray decision, the governments of Manitoba and New Brunswick put in place guidelines for First Nations accessing timber on provincial Crown lands (AANDC 2010). There are no such guidelines in Ontario. Perhaps future policy development in Ontario will develop a system for First Nations to access timber on provincial Crown lands, such as an Aboriginal forest tenure model.

The Far North Act and the Crown Forest Sustainability Act

For the rural and remote communities that are being reviewed, there are two primary pieces of legislation that affect how the communities can access and utilize the forest resources on their traditional territories—The Far North Act (FNA) (2010), which affects the remote community, and the Crown Forest Sustainability Act (CFSA)(1994), affecting the rural community.

In 2010, to the dismay of many First Nation communities in the remote regions of Ontario, the Ontario government passed a piece of legislation entitled the“Far North Act. The Far North Act: An Act with Respect to Land Use Planning and Protection in the Far North”, also known as Bill 191, which came into effect in 2011, essentially limits development on Crown land in the province of Ontario in the lands located above the AOU unless a government-approved community-based land use plan (C-bLUP) is in place (Youden 2010; Smith 2014). The FNA (2010) outlines the process and procedures required for any development in the area north of approximately 50°-51° latitude in an area now referred to as the Far North (The Far North Science Advisory Panel 2010). The area is 452,000 km^2 in size, roughly 42% of the total area of Ontario (The Far North Science Advisory Panel 2010). As Figure 11 shows, the Far North region located above the AOU encompasses Treaty 5 and Treaty 9 areas; the Act is binding on the communities located in this area. While the FNA requires First Nation consent for large-scale development projects in an attempt to ensure First Nations' voices would be heard and acknowledged when planning for developments, the FNA (2010) also restricts First Nations from utilizing their traditional territories (off-reserve land) until a C-bLUP, including protected areas, is in place. While the FNA claims to acknowledge Aboriginal and Treaty rights, it does not provide communities with complete autonomy over their traditional lands (Youden 2010; Burlando 2012). A review of the regulations described under the FNA has found that the Ontario Ministry of Natural Resources and Forestry has the final say in approving C-bLUPs (Far North Act 2010). The communities living in the Far North are opposed to the FNA due to the lack of consultation in the development of the Act and, for the reasons noted above, and have called for action to alter the FNA (NAN 2010). Though the FNA in a way protects the region from unfettered large-scale industrial development by making the commitment to placing half the land base in an interconnected network of protected areas, it also proves to be a barrier to First Nation communities already struggling to assert their rights to manage and utilize their own traditional areas and resources (Youden 2010; Smith 2015).

The C-bLUP process involved both community-community interactions, as well as collaboration between governments, industrial partnerships, and community members



Map Author: Tomislav Sapic, Lakehead University
Map Projection: Lambart Conformal Conic
Thunder Bay, May 21, 2015.

Figure 11. The Far North region of Ontario including Treaty Areas (Sapic 2015).

themselves (Far North Act 2010). Some communities have completed C-bLUPs (Cat Lake-Slate Falls, Deer Lake and Pauingassi and Little Grand Rapids in Manitoba) and some were grandfathered (Pikanjikum for the Whitefeather Forest) (Far North Act 2010; OMNR 2015b), while others, such as Eabametoong and Mishkeegogamang, Marten Falls, Wawakapewin, Constance Lake and Webequie have completed Terms of Reference and are beginning to collect the information necessary to move forward with C-bLUP (OMNR 2015b).

While First Nations communities oppose the Far North Act, there are those that support the FNA and its intent. The FNA does provide an outline for the process and requirements to create a C-bLUP, and the OMNRF has created a branch to assist with development in the Far North, the Far North Branch, which is to provide technological services and guidance to communities undergoing the C-bLUP process (OMNR 2014b). The outline for the planning process and the Far North Branch ensures that plans are in place before development can occur (Far North Act 2010). Orton (1996) has stated that environmental concerns should take precedence over social and political goals, leaving Aboriginal and Treaty rights as a side note in the overall goals in sustainable development, conservation, or preservation. The FNA ensures that plans are outlined and approved by provincial Ministers who are informed and educated in western-styles of land management and should be acting in the best interest of First Nations while balancing interests of the broader society, as determined by the Supreme Court of Canada (Hurley and Wherret 2000; Smith 2015).

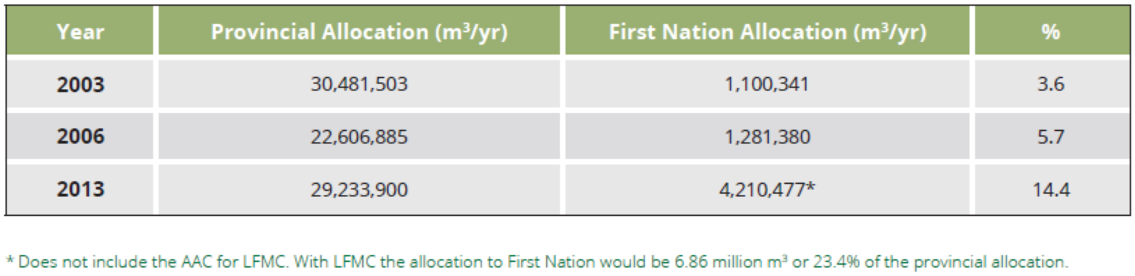
For the rural First Nation community within the AOU, the CFSA (1994) applies. The purpose of the CFSA is to ensure that forests are managed sustainably to meet social, economic and environmental needs by regulating the use of the forest (Crown Forest Sustainability Act 1994; OMNR 2009). The CFSA governs how forest licences are issued and encompasses numerous regulatory and revenue-sharing procedures, such as revenue collection, allocation of resources to trust funds, and forest resource agreements (Crown Forest Sustainability Act 1994). Additional regulations regarding forest operations, in particular the Forest Management Planning Manual, compliance with existing laws and plans, as well as remedies and enforcement mechanisms support the CFSA. The CFSA also regulates the licensing of wood scalers, and independent forest audits. Provisions within the CFSA (1994) state that the CFSA does not detract from or add to any Treaty rights that are recognised and affirmed by section 35 of the Constitution Act (1982).

Communities such as Lac Seul First Nation are able to apply and compete to get forest licenses which would give the community control over the forest resources subject to provincial laws. The National Aboriginal Forestry Association (NAFA) produced a series of reports which assess First Nation-held forest tenure over time which may serve as a viable indicator of market access (NAFA 2015:6). NAFA (2015) states:

> forest tenure information is already monitored by governments for non-First Nation entities to measure economic and political performance. The additional effort to identify First Nation-held tenure would be minimal and result in an expanded analysis of sustainability indicators. (NAFA 2015:6).

In 2011, Ontario underwent tenure modernization and the Ontario Forest Tenure Modernization Act (OFTMA) came into effect June 1, 2015 (NAFA 2015: 17) with amendments to the CFSA to support modernization objectives (NAFA 2015:17). One of the objectives was to develop economic development opportunities for Aboriginal people through forest tenure agreements (OFTMA 2011; NAFA 2015:18). Table 2 shows the increase in wood allocated for First Nations in the years 2003, 2006, and 2013. In 2003, only 3.6% of provincial wood was allocated to First Nations while 14.4% was allocated in 2013. In BC, the current estimate is that First Nations collectively hold 17% of the total provincial annual harvest, approximately 90 M m³ in 2005 (Puglaas and Raybould 2011). It can be seen that there is an increase in access to wood supply markets for Aboriginal communities under the new tenure modernization process (Canadian Biomass 2011; NAFA 2015:18).

Table 2. Provincial allocation of wood supply to Aboriginal tenure holders (NAFA 2015:19)



Year	Provincial Allocation (m^3/yr)	First Nation Allocation (m^3/yr)	%
2003	30,481,503	1,100,341	3.6
2006	22,606,885	1,281,380	5.7
2013	29,233,900	4,210,477*	14.4

* Does not include the AAC for LFMC. With LFMC the allocation to First Nation would be 6.86 million m³ or 23.4% of the provincial allocation.

In other areas of Canada, provincial governments are working to enable First Nation involvement in biomass operations. For example, in BC the Tsilhqot'in National Government (TNG) and Western Biomass have partnered in a 50/50 joint venture for a 34 MW biomass facility located next to a TNG sawmill (Run of River (ROR) Power and Western Biomass 2010). There are several aims for the development: to reduce open slash burning; to fit government policy initiatives; to accelerate reforestation; fire protection; create 130 permanent direct and indirect jobs; and to have a capital investment of $140M (ROR Power and Western Biomass 2010). The project will contribute annual revenue to the northern economy while addressing environmental issues such as flooding and damage to riparian areas around salmon rivers (ROR Power and Western Biomass 2010). Further, there were numerous presentations to local, regional, provincial, and federal governments as well as to community members (ROR Power and Western Biomass 2010). The sawmill produces 36,000 m^3 of residual fibre (15,126 oven dry tonnes [ODT]); the biomass power plant requires an additional 467,318 m^3 or 196,352 ODT to operate (ROR Power and Western Biomass 2010). The operation will source roadside residues and utilize waste from sawmills where feasible (ROR Power and Western Biomass 2010). This project was possible because policies were put in place, such as the BC Bio Energy Strategy, Clean Energy Plan, and Clean Energy Act, which promoted First Nation opportunities (BC First Nations Forestry Council 2008; ROR Power and Western Biomass 2010). Further, under the BC Bioenergy Network—an association created to develop the bioenergy sector in the province of BC—has received proposals for three projects in the north-central region of interior BC in which the applications have been composed of partnerships between energy companies and First Nations, and two other applications which involve First Nations (BC First Nations Forestry Council 2008). These projects highlight that the opportunities to participate in forest management and utilize the resources begins with securing access to fibre and continued work with partners, consultants, and governments (BC First Nations Forestry Council 2008; ROR Power and Western Biomass 2010).

Although such projects could benefit communities, the forest management companies must adhere to the rules and regulations and meet the harvest volume requirements delegated by the OMNRF (OMNR 2009). This means that community management organizations have the freedom to act within existing regulations; it is not complete freedom over resource management. Greenpeace was critical of the tenure modernization process, particularly about the involvement of local communities, Aboriginal and non-Aboriginal, in forest management planning (Greenpeace 2010). Their letter produced in response to the “Proposed Framework to Modernize Ontario’s Forest Tenure and Pricing System” states that the five-to-fifteen management corporations comprised of 9-12 board members that will manage all of Ontario’s allocated forest do “not have the flexibility required for the range of forests and diversity of needs and concerns in Ontario. It also does not provide for substantive representation of communities, Aboriginal or non-Aboriginal.” (Greenpeace 2010). The letter also highlights a need for tenures specifically designed for Aboriginal communities which would require a great deal of capacity-building and support from governments in order to effectively manage the local forests (Greenpeace 2010). Further, the system of forest tenure allocation should allow for First Nations’ management of traditional territories, especially when access is desired and sought after by the communities (Greenpeace 2010).

CHALLENGES OF INVENTORYING FOREST RESOURCES IN REMOTE AND RURAL FIRST NATIONS

In Ontario, forest resources are inventoried using Ontario’s Forest Resource Inventory (FRI) methodology created by the OMNRF. The FRI is carried out on all lands in the AOU where commercial forest operations take place, combining a series of aerial photo interpretation with on-the-ground measurements (Leckie and Gillis 1995). The purpose of the FRI is to have a complete inventory of forest resources (Penner et al. 1997) to gain an edge on potential new developments and identify areas with harvest potential or those to be conserved or protected (OMNR 2009). This helps forest managers determine the volume of standing timber, stocking, species composition, ecosite, regeneration techniques, AHA, and recommended harvest treatments for an area (Sims et al. n.d; Stupak et. al 2009; OMNR 2014a). The FRI is based on different stands delineated by ecosites, so if the same ecosite and site quality can be identified across a region, we can assume that it would have similar volumes, stocking, and species composition (Penner et al. 1997; Thompson et al. 2007). In the AOU, areas are broken down into FMUs, as depicted in Figure 12, where the forest resources are measured using the FRI methodology.

Figure 12. Forest management units in Ontario (OMNR 2014a).

In order to develop an FRI, one must first acquire digital imagery of the area. This is to assist in identifying features such as elevation, water, vegetation, roads, etc. (OMNR 2014a). Once digital imagery is obtained, the next step is to interpret the photos and delineate forest stands based on the imagery as can be seen in Figure 13. The second stage of this process is to conduct field sampling of the stands identified on the imagery. Sampling provides a way of collecting information about a forested stand that can assist in interpreting forest conditions seen in the aerial imagery (Thompson et al. 2007). When enough samples have been done in the stands, interpreters make reasonable and accurate estimates of the standing wood volumes for an area (OMNR 2014a). When FRI information is gathered over a long period of time, the data can also provide insights as to growth and yield conditions, historical fire data, soil and drainage information, and records of past silvicultural activities (Leckie and Gillis 1995).

Figure 13. Aerial photography showing forest stand delineation (GIM International 2011).

There are a few methods to inventory a forest to generate biomass volume estimates; this report will focus on two: one method to calculate biomass uses existing FRI stem wood volume estimates and applies a biomass factor which generates an estimate of the amount of biomass in relation to the stem wood volume; the other method involves an actual inventory designed to measure the amount of biomass available in a given stand (Leckie and Gillis 1995; Penner et al. 1997).

There are benefits and drawbacks of each of these approaches. Traditional FRI methods are aimed at capturing the amount of merchantable timber (sawlogs and pulp) from merchantable species in a stand, but are not very effective at measuring the amount of biomass remaining in the tops and branches, non-merchantable species, or the slabs and sawdust at the mills (Lowe et al. 1996; Ter-Milaelian and Korzukhin 1997). Although numerous studies have been done to quantify the volume of biomass in relation to the stem wood volume for various tree species across different ecoregions (Alemdag 1984; Gonzalez 1989; Singh 1982; Singh and Kostecky 1986; Ter-Milaelian and Korzukhin 1997), the biomass:stem wood ratio calculated provides a general guideline but is not necessarily accurate. This may result in an over- or under-estimate of available wood (Thompson et al. 2007).

This method was used when Canada conducted a national biomass inventory which was based on forest inventories conducted in each province and to which a biomass factor specific to species and ecoregion was applied (Penner et al. 1997). The purpose was to inventory biomass to model carbon budgets (Botkin and Simpson 1990; Kurz and Apps 1993; Penner et al. 1997), and to have the information to understand the biomass potential in each province and Canada in total (Lowe et al. 1996). This method of calculating biomass is based on site class, age class and species composition (Penner et al. 1997). The FRI was primarily developed and used to identify areas with high potential for sawlogs and pulpwood, neglecting minor species not of commercial value.

Because the FRI for Ontario only takes into consideration the dominant species or the species used for sawlogs and pulp, the biomass estimates do not accurately reflect the minor or non-merchantable species which would represent waste in forest harvesting operations and provide fuel for biomass heating operations (Penner et al. 1997). Further, the current inventory procedures in Ontario do not capture or reflect northern non-commercial forests (Leckie and Gillis 1995), which includes remote First Nation communities. Though this method is less expensive and less time-consuming compared to actual biomass inventories, it is also less accurate. Although heating with wood is not a new concept (Abbasi and Abbasi 2010), measuring and managing for biomass adds additional complexities to traditional forest resource inventories and management plans.

The second method for conducting biomass inventories is essentially a more detailed forest inventory whereby other parameters that would influence the amount of biomass available are taken into account (Xu 1999; Zheng 2007). Xu (1999) has developed a model for estimating biomass based on DBH, height of the tree, crown volume, crown size and crown length. Though these measurements can yield a more accurate estimation of biomass volume available, the methods are time consuming and costly, which would limit the use of these methods for large areas (Zheng 2007). As changes in management practices and priorities evolve, whether as a response to environmental concerns and multiple land uses, new technologies, or changing world markets, the methods of forest inventory are likely to evolve as well (Leckie and Gillis

1995). A combination of the above two methods can provide a reconnaissance inventory for biomass volumes in and around remote communities in northwestern Ontario. As biomass opportunities are realized and prioritized, perhaps forest inventory methods will evolve to capture biomass volumes in order to generate realistic estimates.

Overall, it is important to manage the forest resources to reduce the potential to affect forest users in a negative way in order to achieve sustainable development. This involves a balance of social, economic and environmental considerations (OFIA 2015). It is important to plan for a sustainable supply of biomass for energy projects (Abbasi and Abassi 2010) while managing for sustenance harvesting, trapping ,and fishing (OMNR 2009; OMNR 2015a), and for the protection of habitat, and traditional and contemporary lifestyles (OMNR 2009; OMNR 2015a). This may help alleviate conflicts between forest users and ensure a shared benefit from forest management.

CHAPTER 3: METHODS

To assess the thermal potential of the forest resources in northwestern Ontario selected wood properties of forest resources from remote and rural First Nation communities were compared as shown in Figure 14. For each community the forest resources on reserve lands and the surrounding Crown lands were assessed for forest type, species composition, volume, stand age, wood density and thermal potential. Data collected for this study was completed in tandem with Confederation College's "Biomass Heat as a Catalyst for Community Development" research project. The experimental design was simple and balanced, with an inference space limited to First Nations located in the Northwest Forest Region of Ontario as shown in Figure 15.

COMMUNITY SELECTION

As part of Confederation College's community selection process, remote First Nation communities located above the AOU and rural First Nations within the AOU were invited to express their interest to participate in the "Biomass Heat as a Catalyst for Community Development" research project. Once the College's selection process was completed, and one remote (no all-season road access) community that currently receives its electricity, heat, and hot water primarily through diesel generation, and one rural (all-season road access) community that does have access to the natural gas pipeline network and utilizes the existing electrical grid network to provide heat, hot water, and electricity to the community were selected to participate in the joint research, all partners were informed. This design allowed for a comparison between the two communities' forest resources thermal potential.

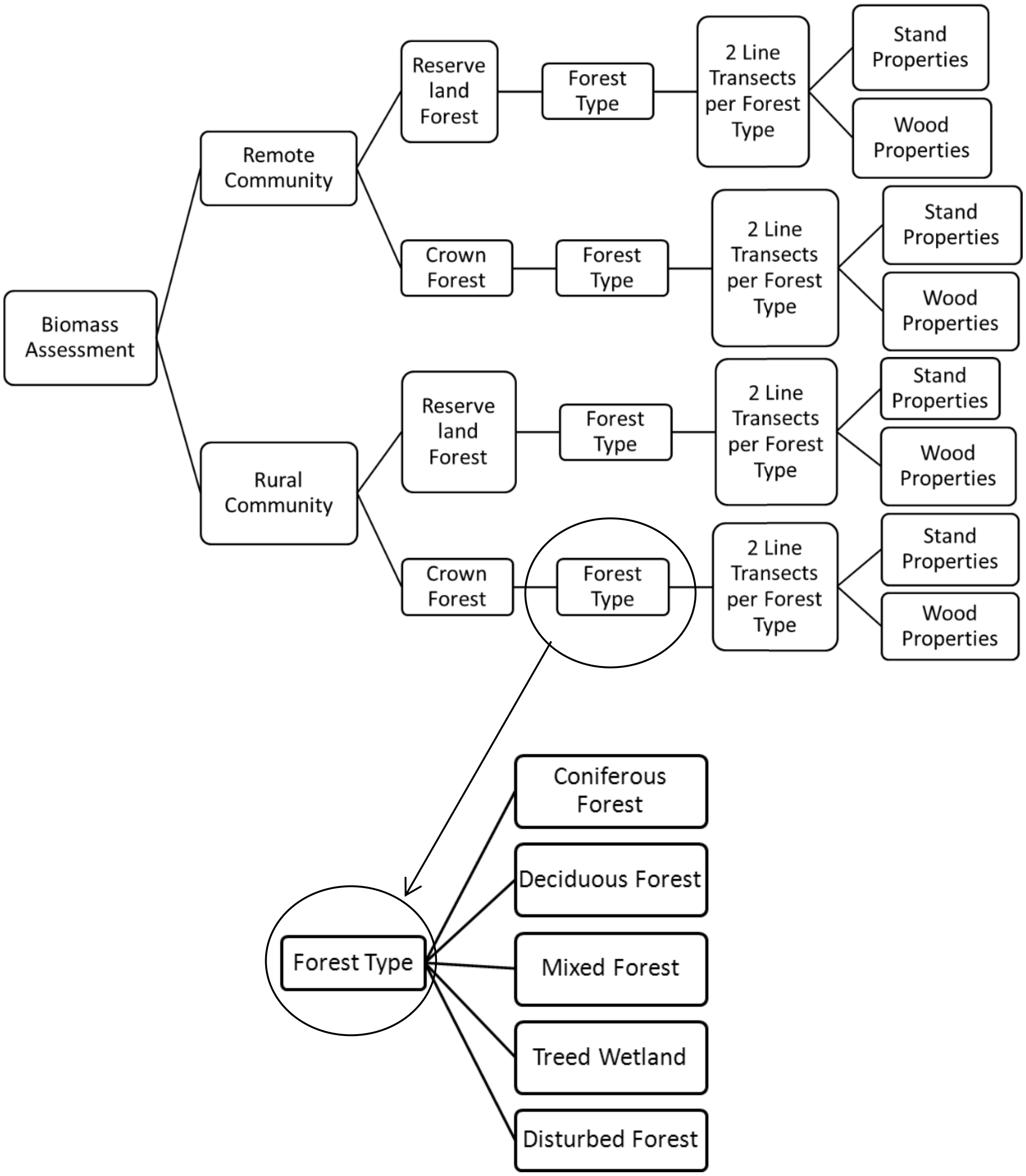


Figure 14. Experimental design for assessing forest biomass thermal potential.

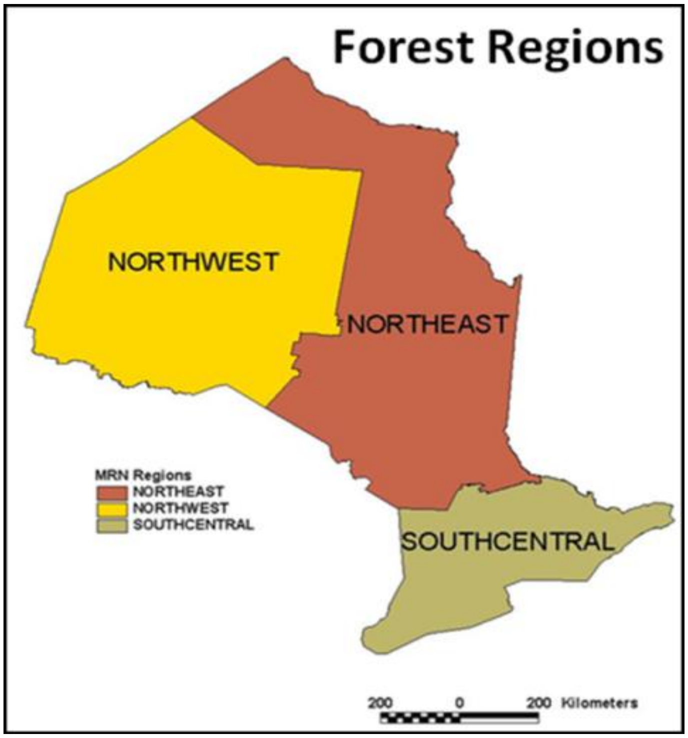


Figure 15. Forest regions of Ontario (OMNRF 2015a).

Using Statistics Canada and AANDC information, a brief description of each community was developed which included the community's geographic location and population. The study complied with Lakehead University and Confederation College research policy and ethical conduct, including the Tri-Council Policy Statement on the Ethical Conduct for Research Involving Humans, Chapter 9, Research Involving First Nations, Inuit, and Metis Peoples (Panel of Research Ethics 2010).

Sachigo Lake First Nation

The first community, Sachigo Lake First Nation (SLFN), is considered a remote First Nation community and is located approximately 425 km north of the town of Sioux Lookout (633 km northwest of Thunder Bay) in the unorganized Kenora District of northwestern Ontario (KNET First Nation Communities 2009; Windigo Education Authority n.d.). The First Nation is accessible via ice roads in the winter or air travel during the summer (Albert 2007; Southcott and Walker 2009). The on-reserve population is roughly 428 persons and 178 homes (AANDC 2013b). A satellite image of the community can be seen in Figure 16. Sachigo Lake First Nation is a signatory to Treaty 9 and a member of the Windigo First Nations Tribal Council, as well as the political territorial organization representing Treaty 9 First Nations, Nishnawbe Aski Nation (AANDC 2013b).

Figure 16. Sachigo Lake First Nation community (Google Earth n.d.).

The on-reserve area is divided into three parcels separated by provincial-owned Crown land that is subject to treaty terms. The total area of the parcels is 8 144.6 hectares (ha) with the main parcel where the community is located making up 3 588 ha of the total area. The community has established a campground on the second parcel of reserve land with a total area of 2 833 ha located on a high ridge with generally sandy soils. The surrounding forest in this area is composed primarily of jack pine; a portion of this area, which extends into Crown land burned by wildfire in 1986, is recovering naturally. The third parcel surrounds Ponask Lake which has few permanent settlements and totals 1 723.6 ha. Although the reserve parcels and surrounding provincial Crown land are primarily forested, the community is unable to access off-reserve resources until a C-bLUP is developed and approved under the Far North Act 2010, thus potentially limiting the resources available for immediate use for community heating needs.

On-reserve community buildings that have a greater heat energy demand than the 173 residential buildings include the band office, a small motel, the Northern store, healing centre and nursing station, arena, water treatment plant, churches, residences for teachers and nurses, TV/radio station, a small convenience store, the elementary school, the airport and associated buildings, the diesel generation site, a garage for heavy equipment, a small fire hall and a police station (KNET First Nation Communities 2009). In 2011, the community used 2 847 000 kWh or energy; a total of 788 069 L of fuel (HORCI 2012). A Wellness Centre is currently being constructed which will further add to the electrical load.

The electrical grid and natural gas pipeline do not extend this far north and the electrical and heating needs are provided to the community via diesel power generators (HORCI 2013). Some buildings have back-up generators in the event that power is lost in the winter when electrical loads are maximized and temperatures are low; however, these are not long-term solutions to reducing community diesel consumption.

With the exception of the Wellness Centre under construction, the community is unable to add additional buildings to the local grid as the capacity of the diesel generators has been reached. This means that stores and homes cannot be built thus limiting economic development opportunities and the growth capacity of the communities.

Lac Seul First Nation

The second community, Lac Seul First Nation (LSFN), is considered a rural First Nations community and is located approximately 25 km west of the town of Sioux Lookout (319 km NW of Thunder Bay) and receives its heating and electrical needs via an electrical transmission line (AANDC 2013a). The community is divided into one main community, Frenchman's Head, and two satellite communities—Whitefish Bay and Kejick Bay—which contain a combined total of 306 houses and an on-reserve population of 762 (AANDC 2013a). In total, the community covers 26 821.5 ha. Lac Seul First Nation is a signatory to Treaty 3, and a member of both the Independent First Nations Alliance (IFNA) and NAN (AANDC 2013a).

A non-First Nation settlement, the town of Hudson, is located nearby the reserve and can provide services to the communities. The reserve lands of LSFN are located within the AOU and within an existing FMU—the Lac Seul Forest—on which commercial forest operations under licence from the Ontario Ministry of Natural Resources and Forestry are conducted as shown in Figure 17. Figure 18 shows the location of each community in relation to the FMU and sawmill.

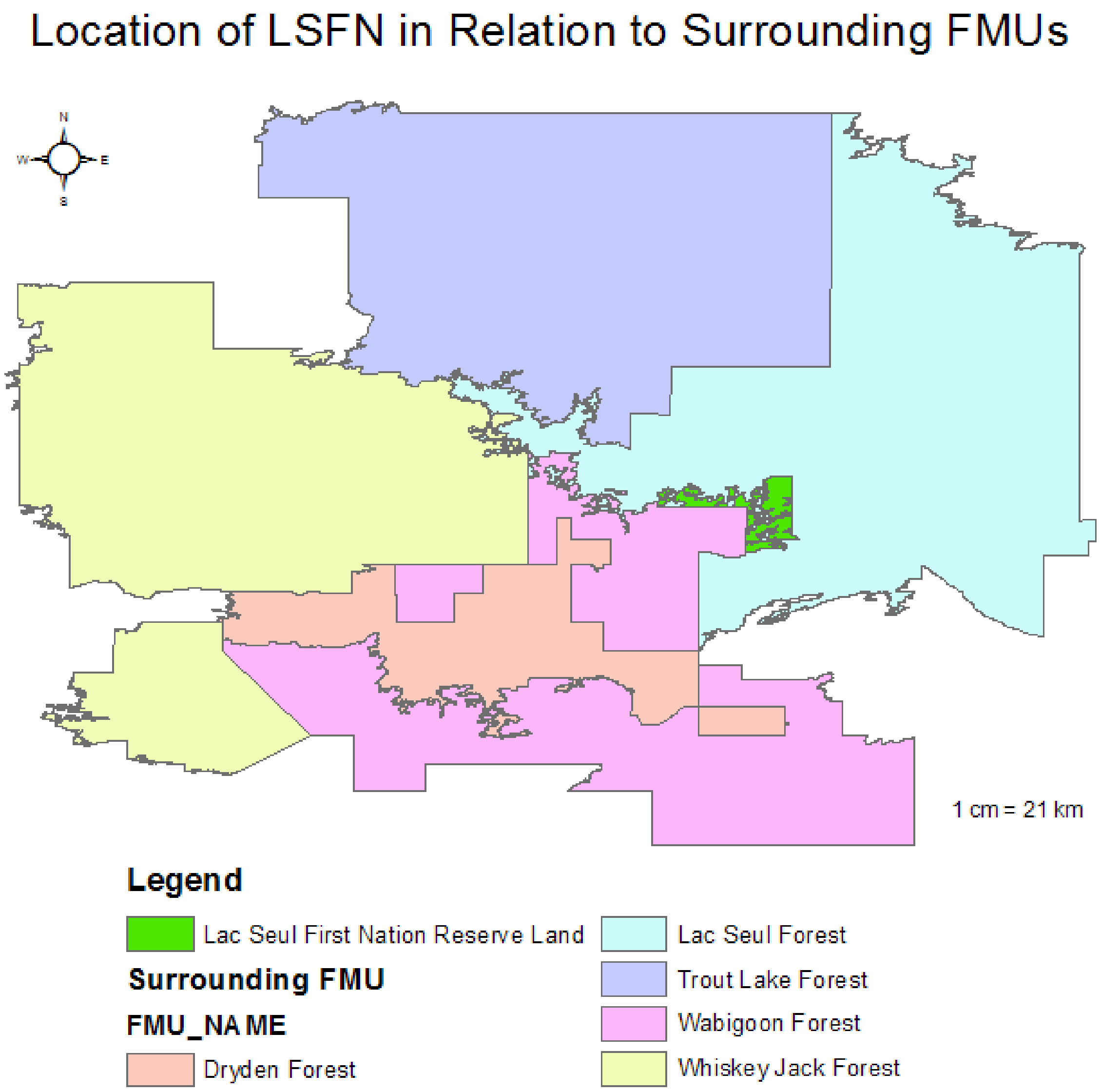


Figure 17. Location of LSFN in relation to surrounding FMUs.

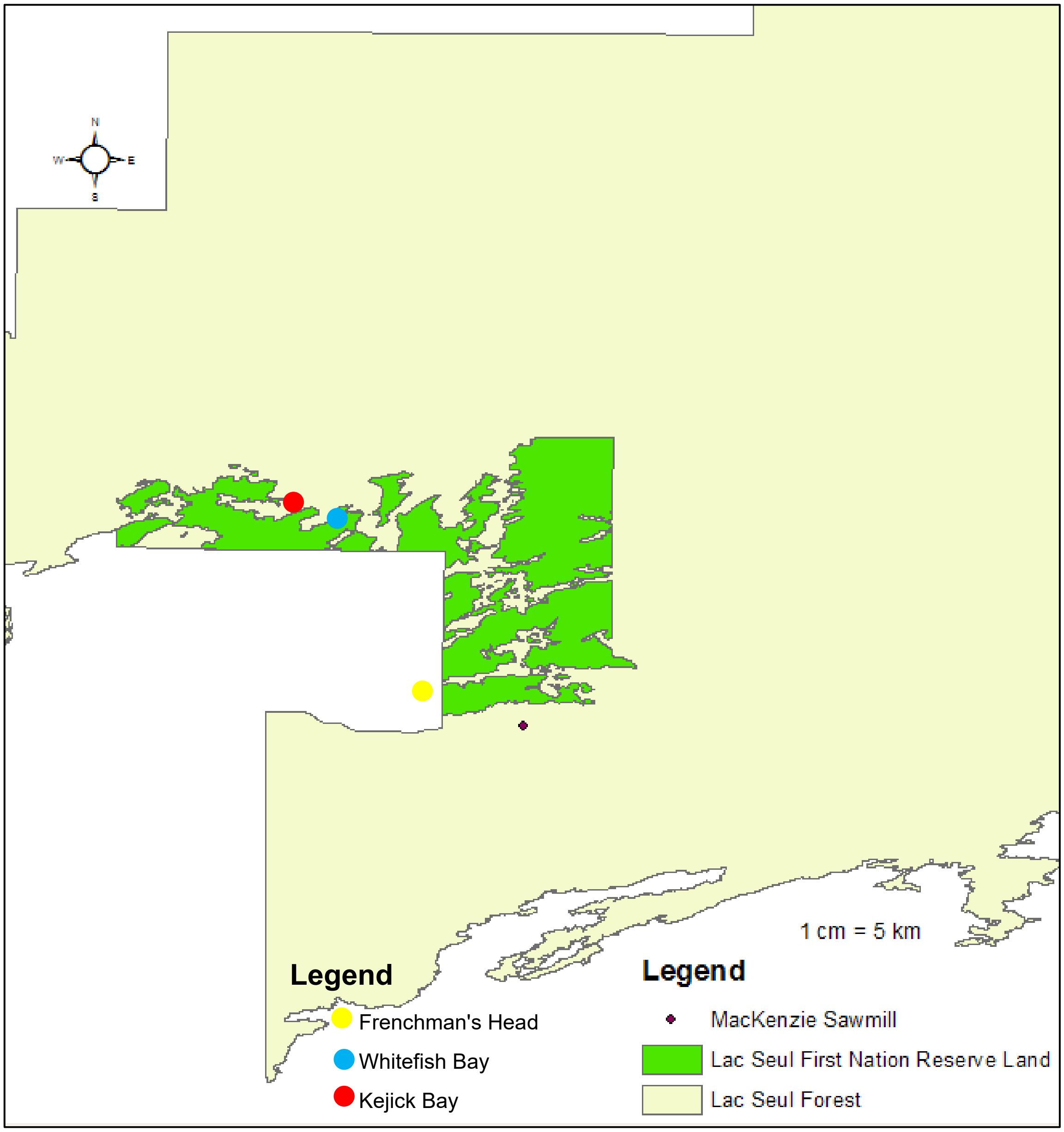


Figure 18. Location of Frenchman's Head, Whitefish Bay, and Kejick Bay in the Lac Seul First Nation Reserve land and Lac Seul Forest.

In 2012, a five-year Forest Resource License (FRL) was signed between the Government of Ontario and the Chief of Lac Seul First Nation “which provided the community 100% responsibility in managing the forest” (Shields 2014). Obishikokaang Resource Corporation (ORC) was formed to represent LSFN in managing the Lac Seul Forest and its commercial forest licence (Shields 2014). The office of ORC can be found in the town of Hudson.

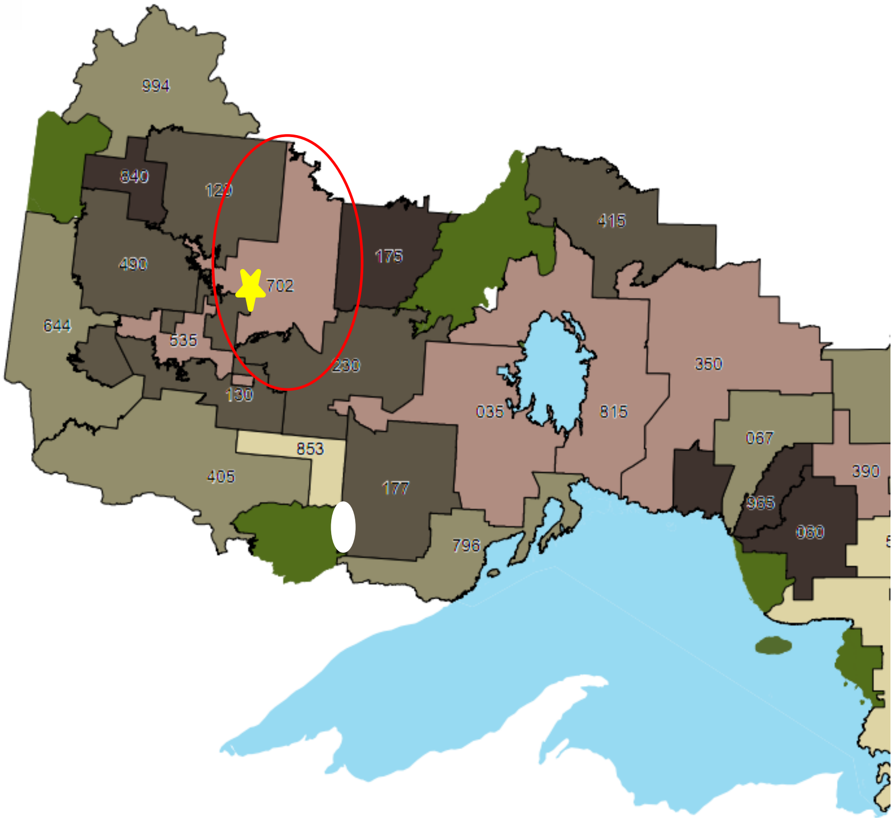


Figure 19. Map of FMUs in northwestern Ontario highlighting Lac Seul Forest and location of Lac Seul First Nation (OMNR 2015a).

Due to its location within an existing FMU, researchers were able to access the FRI, which had previously delineated the landscape by ecosite, forest cover type, age, and recommended harvest treatment, as well as past treatments and species composition. The geodatabase used for mapping purposes was provided by ORC through Greenmantle Forest Inc.; this is the same database used to develop the Lac Seul Forest 2011-2021 forest management plan (FMP) for the Lac Seul Forest. A greater amount of data is available in the FMP compared to the information available for LSFN and has provided researchers with the current AHA for the area as well as a series of five-year work plans that can help future planning for integration of woody biomass into the wood supply chain. Overall, there exists detailed information of the forest, which is beneficial to researchers and will in turn allow for greater detail when developing community recommendations.

A natural gas pipeline services various areas of Ontario but does not reach the communities of Lac Seul First Nation. Although the cost and risk of using diesel-generated power is not present in this community, high-energy prices are paid for heating and hot water needs as they are dependent on electrical heat. Hydro One and the Independent Electrical Systems Operators (IESO) are responsible for the production and delivery of energy to this location and charge a residential rate of $0.086 kW/h and a peak rate of $0.14 kW/h (Hosszu 2015).

Commercial buildings include an arena, band office, health building, schools, community centres, water treatment plant, police station, fire hall, elder and youth center, churches, and community stores.

PRE-FIELD WORK PLANNING – ACQUIRING FOREST INVENTORY DATA

In order to prepare for field data collection, it was important to first determine what information was available to the research team such as digital imagery, ArcGIS maps, forest inventory data, and road maps.

GIS Mapping and Lands and Resource Information in Rural and Remote Areas

Landcover of the remote regions of Ontario is obtained from the Scholars GeoPortal and the Lands and Information Ontario (LIO) database created and maintained by OMNRF, which was available at Lakehead University through their library system. One set of files entitled "Provincial Landcover 2000–27 Classes" (OMNR 2002) provided researchers with a basic outline of landcover in this region, including both Crown and reserve land. This provided information about the forest cover based on simple delineations (e.g. hardwood, softwood, mixedwood, treed swamp, bedrock, gravel pits, and lakes), but the landcover information lacked information about age, ecosite, and species composition. Supplemental layers also found in the LIO database were added to the maps to determine the location of roads, community buildings, water courses, and fire scars. With this information, researchers were able to determine the location of forested stands with potential for biomass harvesting, as well as the existing road networks that could be used to access these stands and information regarding ecologically sensitive sites that should be avoided during future harvests.

A sufficient GIS database exists for the community located within the AOU, which the OMNRF has created and updated with assistance from various other organizations including forest management companies. The information was provided by the forest management consulting firm that is responsible for developing the FMP, and includes both the FMP and the GIS database used. A Band Council Resolution (BCR) allowed for the sharing and use of the information in this project between team members and the community. Following completion of this project, the information will be given to each community. This database includes information regarding forest cover type, ecosite, tree species composition, age, merchantable volume, harvest history, and road layout for the Crown land surrounding the communities; this information is also available for the reserve lands. Once the landcover polygons and supplementary layers were obtained in ArcGIS through the LIO database for the federal reserve lands and surrounding provincial Crown lands, further information necessary for conducting a forest inventory was identified.

In order to calculate the wood volume available for remote areas, digital aerial imagery was acquired through the LIO database. The five potentially operable stands are described in the Provincial Landcover 2000–27 Classes Specifications V. 1.2 are as follows:

Coniferous Treed—In this forest type represented in Figure 20 one can expect to find tall treed vegetation (>10 m in height and >60% canopy closure) predominately composed (>75%) of upland conifer trees, though open (>25% canopy closure) and low treed (<10 m in height) areas are also included in this cover class. Common species include jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), and white spruce (*Picea glauca*). When interpreting the aerial imagery, there could be some confusion between Coniferous Treed sites and Coniferous Swamp sites, as they appear similar in the images. Ground verification of the sites or further development of Digital Elevation Models (DEM) could assist photo interpreters in more accurately identifying these sites.

Figure 20. Coniferous forest strata (Seymour 2015).

Deciduous Treed—These areas have a predominant forest cover of deciduous (leafy) trees on varying soils with dry, fresh or sometimes moist conditions. Upland deciduous tree species, such as trembling aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*) generally compose >75% of canopy closure as Figure 21 depicts.

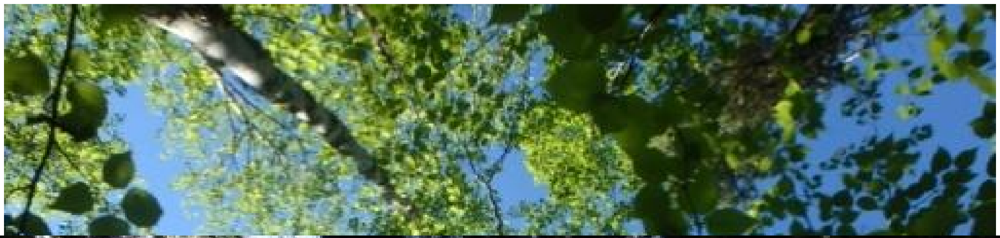


Figure 22. Canopy of a mixedwood forest strata (Seymour 2015).

Mixed Treed—These sites contain a mixture of deciduous and coniferous trees, as can be seen in Figure 22, which make up >75% of the canopy. Common species include jack pine, black spruce, white spruce, poplar and birch.

Disturbance–Treed and/or Shrub—These sites are the result of natural or anthropogenic disturbances which have occurred at some point over the last 20 years. In contrast to the above forest cover types, the Disturbance sites generally experience low treed vegetation (<10 m tall, >60% canopy closure) as can be seen in Figure 23.

Figure 23. Disturbed forest strata (Seymour 2015).

Treed Wetlands—These sites are an amalgamation of four Far North landcover classes: Treed Bog, Treed Fen, Coniferous Swamp, and Thicket Swamp. Generally, these sites have lower canopy closure, a greater abundance of shrub species, and are subject to seasonal flooding, high water tables, and standing water, as they are commonly found in depressions, low-lying areas, adjacent to streams, lakes, or bogs. Figure 24 shows a site representative of these wetland sites. It was determined that these sites had potential to:

a. Be confused with Coniferous Treed sites,
b. Represent low-lying areas common to the boreal forest, and
c. Contain some amount of standing timber that may be harvested during winter.

It is important to note that the identification and delineation of stands based on aerial imagery has a component of error to it. The specifications (OMNR 2002) state that “percentages of deciduous and coniferous forest estimated using satellite imagery may not align with field based estimates resulting in a source of field-remote mapping discrepancy”.

Figure 24. Representative treed wetland site (Seymour 2015).

The remaining landcover classes represent features such as bogs, fens, swamps, peatlands, marshes, bedrock/rock outcrop, community infrastructure, mine tailings and gravel pits. Though it is important to know where these are on the landscape, it is also important to note the reasoning behind delineating these sites as inoperable. These areas either have limited forest growth, community infrastructure, or are ecologically sensitive and susceptible to disturbances such as harvest activities. It is not recommended that harvesting take place in any of these sites.

Delineation of Strata based on Available Forest Inventories

Given that the remote community has limited information regarding forest cover, it was determined that the strata delineated in the Provincial Landcover 2000–27 classes could not be further stratified based on the information available. Of the 27 available landcover classes, it was determined that five could hold potential for harvesting based on the inferred species composition and cover; stands that indicated wet sites (e.g. swamps, fens, bogs, and marshes) were eliminated with the exception of the Treed Wetlands class. This is due to the potential error identified in the delineation of stands by the creators of the database as having potential to be confused with softwood cover types (OMNR 2002). Landcover classes that were also eliminated included lakes and rivers, exposed bedrock, community infrastructure, mines and mine tailings, sand/gravel, tundra heath, pasture, and cropland. The five cover types that were determined to have potential for biomass harvest in the remote area were as follows: Softwood, Hardwood, Mixedwood, Treed Wetland, and Disturbed Area (labeled “Regenerating Depletion” in (OMNR 2002)).

Further elimination of potential stands was based on physical limitations. Stands under eight hectares were eliminated from the selection of stands to sample, as an eight-ha minimum size requirement for FRI lines has been established by the OMNRF (OMNR 2009; OMNR 2011). These stands were not eliminated from the total volume;

rather they were eliminated from stands chosen for sampling in order to follow OMNR guidelines which have an eight-ha minimum size requirement to avoid sampling in stands affected by edge effect. Given that time and money were also limiting factors, stands >1 km from roadways and waterways were eliminated, as these stands would require a greater amount of travel time in between, and given the lack of forest harvesting in these areas, it was assumed that these stands would be representative of those outside the 1 km radius of roadways. Due to the limited road network, stands located far from roads were assumed to be inaccessible to harvest operations until a larger road network could be developed. This land may be accessible in the future should the community's need for biomass increase and their road network expand. This would allow harvest to be spread over a larger area to avoid overharvesting a smaller land base. In summary, stands were chosen based on three criteria: forest cover, size, and ease of access. After eliminating smaller stands and those difficult to access, researchers were able to randomly select stands for ground proofing once in the communities.

Given that the rural community has a detailed forest inventory database, a plethora of information existed that would have allowed researchers to sample a wide variety of forest cover types, ages, species composition, and ecosites. However, in order to compare the two sites, the forest cover in the rural community had to be delineated in the same manner as the remote community; that is, the stands must be categorized into five strata: Hardwood, Softwood, Mixedwood, Treed Wetlands, and Disturbed Areas.

Forest Resource Inventory

The researchers prepared a modified FRI similar to the OMNRF FRI guidelines that work in conjunction with the LUWSTF and their new Wood Science App (WSApp).

A crew of four field researchers spent ten days in each community sampling the forests and collecting information about community infrastructure. The purpose of this was to determine:

a. How much energy is the communities using (results in Hosszu 2015)?
b. How much woody biomass volume is present on Crown and reserve lands?
c. How much energy is available in the forest resources to be used in a BDHP (determined through laboratory work)?

Forest resource information gathered in the field was entered into LUWSTF WSApp (See Table 3). The WSApp allows raw forest resource data to be entered and calculations on wood volume, species composition, site condition, and other information carried out as needed. It contains embedded formulas consistent with the OMNRF's Strategic Forest Management Model (SFMM), an aspatial modelling program used by the province of Ontario for forest management planning (Kloss 2002). For the purpose of this study, additional wood thermal properties were added that allow the WSApp to calculate the amount of energy per unit of wood and further the amount of energy per unit area. Once stands were delineated into strata and stands that did not meet selection criteria were eliminated, stands within the strata were selected at random to be sampled.

Table 3. Description of field data collected.

Forest Collected in Field	Frequency	Purpose
Count and species of BAF 2 "in" trees	# trees/species/plot; 10 plots per line	Basal area calculations; species composition
Diameter at breast height (DBH) of "in" trees	All trees in all plots in a line	Size distribution; volume estimates; stand health;
Defect classification + location	All trees in all plots in a line	Amount of standing dead biomass Successional stage?
Crown class	All trees in all plots in a line	Canopy layers
Vegetation site	Once per line	Ecosite classification; growth factor
Other site information: fire sign; soil type + depth;	Once per line	Ecosite classification; stand origin; growth factors
Height	All 'Measure Trees'	Volume calculations
Age	All 'Measure Trees'	Stand age
Crown width Base-to-live-crown ratio	All 'Measure Trees'	Crown shape and size

Inventory for Biomass Estimates

Similar to FRIs conducted by the OMNRF, the inventory methods involved establishing a straight line, 200 meters long on a set azimuth and creating ten sample plots along the line each 20 meters between plots. The line must be at least 10 m from the stand edge and must be in a stand >8 ha (Thompson et al. 2007) in order for the line to fit, to not cross into other stands, and to ensure plots are far enough from the stand edge where oddities in species composition may occur due to the edge effect. This prevented overlap between plots to ensure that the same tree was not counted within both plots. At the beginning of each line, soil and site information was recorded which is similar to what the OMNRF would record when conducting FRIs.

Soil Type and Ecosite Identification

At the beginning of each line, a soil auger and the field manual for describing soils in Ontario (Denholm et al. 1993) were used to determine the underlying soil composition up to 1.6 m beneath the surface layer. A visual representation of how this was conducted in the field is presented in Figure 25. This information was recorded in the WSApp and was used to assist in identifying ecosites. A visual inspection of the surrounding tree and shrub species, in conjunction with the soil type and the Field Guide to the Forest Ecosystem Classification for Northwestern Ontario (Sims et al. 1997), allowed researchers to determine the ecosite. It was further noted if any fire scars or charcoal in soils were found, this would give an indication as to how the stand was created/regenerated naturally. Further, it was recorded whether the stand was a natural stand, or if it was a planted stand as this would give an indication to the expected volumes to be found on site. If, along the line, the ecosite changed, this was noted in the WSApp.

Figure 25. Example of soil profile assessment in field (Seymour 2015).

Plot Creation and Labelling Methods

In order to establish sample plots and maintain a labelling system, the following method was established. For the lines containing ten plots spaced 20 m apart beginning 10 m from the edge of the stand, these plots were numbered 1-10 sequentially along the line. Once a 20 m distance between plots had been reached, flagging tape with the label information recorded on it was tied to a branch in the centre of the plot and photographs were taken facing each cardinal direction (i.e. North, South, East, West), upwards showing the canopy, and toward the ground showing ground cover. Trees selected for additional measuring and non-destructive sampling were also numbered; a further description of this process can be found in subsequent sections. A labelling system was established and can be described as:

$$L_x - AA - BB - D - P_y - (T_z)$$

Where L_x = line number (lines were labelled beginning at one and following in subsequent order); AA = study location (SL represents the remote community and LS represents the rural community); BB = strata type– (a two-letter label was applied to each strata: SW for softwood (coniferous) strata, HW for hardwood (deciduous) strata, MW for mixedwood strata, DI for disturbed areas strata, and WL for treed wetlands; D = jurisdiction of the land: C represents Crown land and R represents reserve land); P_y = plot number (labelled 1-10 sequentially); and T_z = tree number.

The labels were used both in the recording of information in the WSApp and also in the labelling of samples for laboratory procedures.

BAF counts

At the establishment of each plot after applying flag tape with a label to the central point and photographing the location, a prism sweep was conducted using a relascope prism with a Basal Area Factor of 2 (BAF2) to get an accurate estimate of basal area. The method for determining which tree to measure, or “count”, is demonstrated in Figure 26. To ensure consistency between plots, the sweep was always done by the same crew member. The prism sweep starts at a bearing of 0º or due north and proceeds clockwise to 360º determining if trees were in the BAF2 plot or out of the plot. When it was unclear if a tree was in or out of the BAF2 plot, referred to as a borderline tree, limiting distance calculation was employed (OMNR 2014).

$$LD\ \ m\ \ = DHB\ \ cm\ \ \times \sqrt{(0.25 \div BAF)} \qquad \text{Equation (1)}$$

Where *LD (m)* = limiting distance in meters, *DBH(cm)* = diameter at breast height in cm, and *BAF* (m^2) = Basal Area Factor.

For a BAF2 plot, a simpler formula may be used:

$$LD\ \ m\ \ = DBH\ \ cm\ \ \times 0.3535 \qquad \text{Equation (2)}$$

Where *LD (m)* = limiting distance in meters and *DBH (cm)* = diameter at breast height in cm.

Each “in” tree was spray-painted with a number beginning at one and sequentially until a complete 360º sweep was accomplished. The field crew of four persons was divided into groups of two; the first group would orienteer to the next plot, flag and photograph the location, conduct a BAF sweep and label the trees before moving on to repeat the process at the next plot location. The second crew would follow behind and record the stem analysis information.

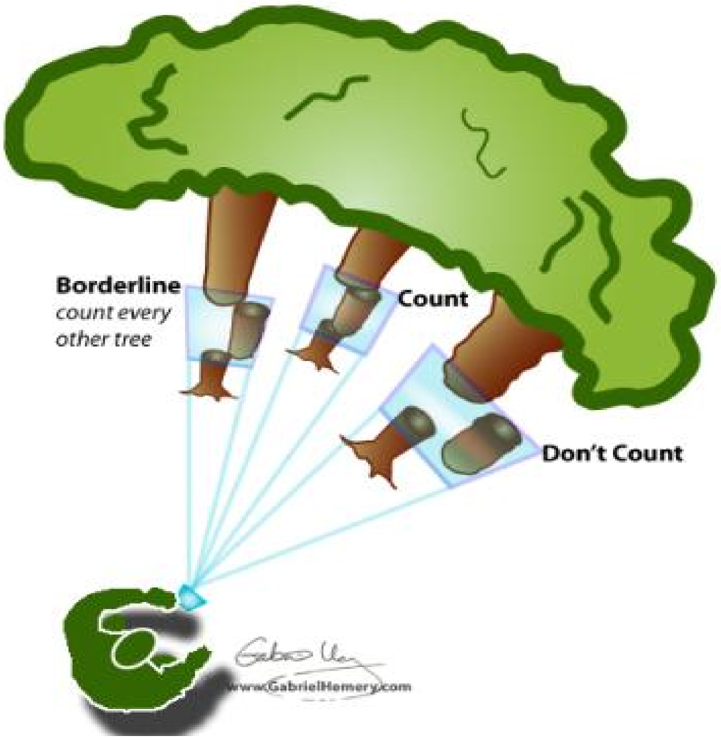


Figure 26. Examples of In (“Count”) vs. Out (“Don’t Count”) trees (Hemery 2011).

<u>Stem Analysis</u>

After the “in” or “count” trees had been determined, the second crew would arrive at the plot and begin to classify each labelled tree. The species of each tree was recorded and the DBH was measured using a diameter tape and recorded to the nearest 0.1cm increment as seen in Figure 27. A visual inspection of the tree allowed

Figure 27. Example of DBH measurement (Seymour 2015).

Figure 28. Examples of tree defects (University of Minnesota 2011).

researchers to determine if the tree was alive, and whether or not the tree had defects. Examples of tree defects can be seen in Figure 28 and include external and internal defects, trunk or crown defects; suppressed (flat-topped) trees; scars; leans >20º; hollow trunk; dead or dying top; forked (U or V) top; and presence of fungi or disease (OMNR 2004). This gives an indication as to the health of the stand and the quality of wood that can be found on the site. One difference between the study sampling methods and OMNRF methods is the recording of dead trees. This can help determine the successional stage of the stand. Further, a recorded visual inspection of the crown helped researchers determine the canopy position of the tree relative to surrounding trees.

Figure 29 gives a visualization of these canopy positions with D representing dominant; C – co-dominant; I – intermediate; and S – supressed. Dominant or emergent trees are those which rise above the co-dominant canopy layer and are likely to have survived the last stand-replacing disturbance. Co-dominant trees share the highest full layer of the forest canopy with others roughly the same height; intermediate trees are those shorter than co-dominant, but not quite in the understory; and understory/ overtopped/ suppressed trees are often the shrub layer and generally represent a tree not of the same age as those in the co-dominant layer that has grown under the full canopy (OMNR 2004). This assisted researchers in inferring the successional stage and the potential secondary growth of the forest. All this information was recorded and entered into the WSApp.

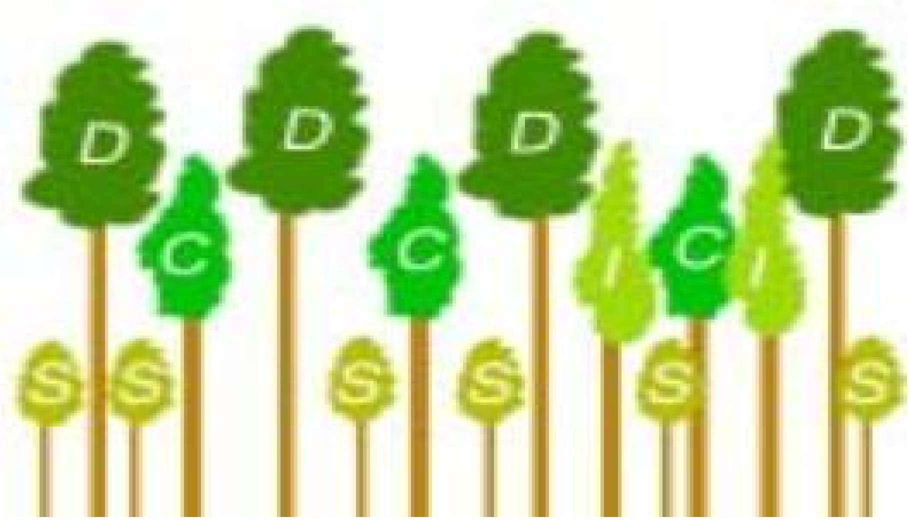


Figure 29. Crown canopy positions (OMNR 2004).

Measure Trees for Wood Quality and Biomass Estimates

Once the measurements for a line and all its plots were complete, researchers selected representative trees for additional measurements. These trees were selected by determining the dominant species present in the line and, targeting for measurement, the defect-free trees that had the largest, smallest and average DBH for the line. In addition to selecting three trees from the dominant species, the largest, defect-free tree of each of the other species present on the line was selected for additional measurements. These additional measures included the height of the selected trees, crown canopy measurements (i.e. base-to-live-crown, crown width) and measurements indicating stem wood quality or potential biomass quantity (i.e., height to first whorl, height to first branch, large branch diameter). Heights were measured using a Suunto Clinometer, seen in Figure 30, and measuring tapes. Again, to ensure consistency, these measurements were taken by the same crew member each time.

Figure 30. Use of Suunto clinometer (Seymour 2015).

The age of each selected tree was also measured using a 5 mm increment borer. Increment bores drilled at DBH, as seen in Figure 31, allowed researchers to count tree rings and, using age correction factors, determine the age of the trees. In summary, these additional measures would generally not be completed to the same level of detail in OMNRF sampling methods, but provided researchers a greater amount of information from which to infer conditions about the forest, which would influence the amount of biomass available in a stand.

Figure 31. Use of increment borer to determine age (Seymour 2015).

Non-Destructive Sampling

Non-destructive sampling took place on each selected measure tree. The purpose of this non-destructive sampling was to provide bole, branch, and bark samples for laboratory analysis of thermal properties, density, moisture content, and ash content. The increment bores used to determine age provide a sample of the heartwood and sapwood of the tree, while branch and bark samples provide samples of biomass that exist on a tree other than the heartwood and sapwood. An example of this can be seen in Figure 32. These samples were stored in Ziplock bags and given labels using a common format. When the samples were returned to the lab, they were further processed to test various properties relating to thermal energy stored in the samples.

Figure 33. Bark sample (Seymour 2015).

Regeneration Surveys

The LUWSTF sampling methods allowed researchers to collect a variety of information about forested stands. However, it was noted that these methods would not be appropriate in disturbed stands where the vegetation has not yet reached a merchantable size (<2.5m in height; < 10 cm DBH), and conducting a BAF sweep in these stands would not give an accurate representation of basal area and volume

(Chaundhry 1981). In order to avoid this, researchers had determined that it would be appropriate to conduct a variation of a regeneration survey: a technique used to assess regenerating stands that have not yet reached a free-to-grow stage (Chaundhry 1981). Similar to the LUWSTF methods, lines on a specific azimuth 200 m long with plots 20 m apart beginning 10 m from the stand edge were established. Rather than conducting a BAF prism sweep at each plot center, four 1 m x 1 m plots (representing 0.0002 ha) were established at plot centre, and the species and DBH class (i.e. 0-2 cm; 2-4 cm; 4-6 cm; 6-8 cm; 10+ cm) were recorded for each tree. Figure 33 shows a simple diagram of regeneration survey plot organization. The tallest tree of each species was selected for non-destructive sampling and the average height was recorded. Because the origin of these stands is believed to be fire, it is assumed that the trees are all relatively the same height and age and the selected trees for sampling are representative of the strata.

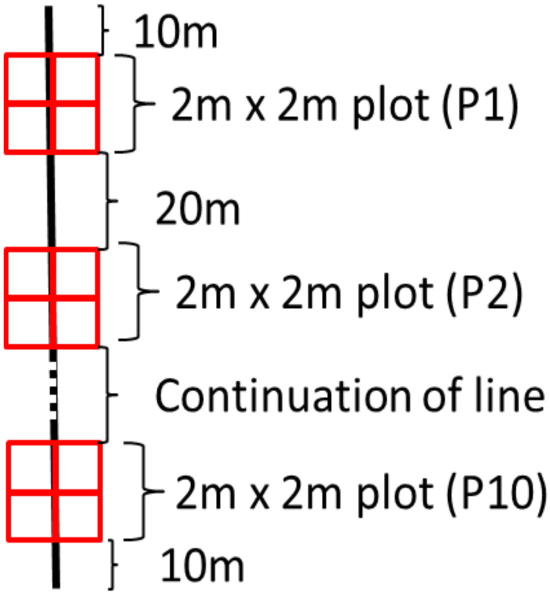


Figure 34. Example of regeneration survey setup.

IDENTIFYING AVAILABLE BIOMASS ON A SUSTAINABLE HARVEST LEVEL

Field data collected was entered into LUWSTF's WSApp via tablet in order to generate volume, species composition and thermal potential outputs.

Standing and Harvest Volumes

Standing wood volume and potential harvest volumes were calculated using the embedded formulas in the WSApp which are concurrent with the formulas and constraints embedded in SFMM, the provincial modelling program. Honer's volume equation (Equation 4) was used to calculate the volumes for standing trees:

$$V_{tot\,(m)} = [a_2\ d_{1.3}\ ^2] \div [a_0 + (a_1 \div H_m\ ] \qquad \text{Equation (3)}$$

Where $V_{tot\,(m)}$ = total volume in m^3; $d_{1.3}$ = DBH in centimeters; $H_{(m)}$ = total height of the tree; and a_1, a_2, and a_0 are species-specific regression coefficients (Honer 1967; Honer et al.1983).

The WSApp works in conjunction with the Geographical Resource Management (GEREMA) software program, a spatial modelling program, which utilizes the principles of SFMM in that it removes the wood volumes found in buffer zones and protected areas, providing an estimate of standing volumes (Kloss 2002) and a map demonstrating where these volumes are located.

Species Composition

Species composition is expressed as a percentage of total volume in the forest for each species. When the OMNRF calculates species composition for a forest, any species that makes up <10% of the total volume is not recorded, neither is the volume of shrub species or undesirable (non-merchantable) species. The species composition calculated from this research included species that make up any percentage of volumes regardless of how small the percentage, whether they were tree or shrub species, and whether or not they are merchantable. Species composition was calculated for each species using the following formula:

$$Sp.Comp \ \ \% \ = (V_{Sp} \div V_{tot}) \times 100 \qquad \text{Equation (4)}$$

Where *Sp.Comp* (%) = species composition expressed as a percent of total volume; V_{sp} = total volume of a given species in the stand; and V_{tot} = total volume of the stand (Ford-Robertson 1971: 52). By applying this calculation to all species present in a stand, it was possible to get a more accurate estimate of available biomass.

LABORATORY ANALYSIS OF WOOD PROPERTIES

Further analysis was done in the LUWSTF to determine a number of additional wood properties that would affect how much biomass is needed on an annual basis to offset heat and hot water usage within the community. Once the researchers returned from field data collection, the bark, branches and bole wood specimens were classified by species, aged, weighed and recorded as the green weight, then placed in a Hotpack oven to dry at 70° Celsius for 48 hours. After this time, the specimens were removed and weighed again, then placed in the oven for a further four hours to ensure the weight did not change anymore; once the weight did not change anymore this was recorded as the dry weight. After these steps, further preparations were done as per the standards of various testing procedures, described below. Figure 34 demonstrates the various steps in preparing the samples for testing. These tests assisted in determining the amount of heartwood and sapwood, the age of sampled trees, the moisture content of green wood, the amount of energy stored per unit of wood for each species, and the amount of ash

A. Establish mass of specimens.
B. Press probe into earlywood of specimen.
C. Dunk specimen into a breaker filled with distilled water and record displacement (volume).

Wood density = Mass/Volume

Figure 35. Example of wood properties testing procedures and equipment. Figure 34a. shows the removal of wood from an increment borer. Figure 34b shows the weighing and dunking of wood samples to determine density, and Figure 34c shows the bomb calorimeter where thermal potential is measured.

remaining after the sample had been burned. The age of the trees assisted researchers in determining the age of the stand and in determining when the stand is available for harvest. Moisture content, thermal energy value of the wood, and the residual ash content assisted researchers in determining the ideal species mix for the BDHP; choosing a species with a high density which can equate to a high thermal energy value, and a low residual ash content, is ideal for the boilers to reduce ash buildup and maximize energy production per unit of woody biomass.

Moisture Content

In order to determine the moisture content of the wood, the American Society of

Testing Materials (ASTM) standards and methods were used. In particular, ASTM Standard E 871-82 was used; Method A – Primary Oven Drying Method, was used as "it is structured for research purposes where the highest accuracy or degree of precision is needed" (ASTM 2013). The test determined the total moisture in a solid sample of wood as a percentage of total volume (ASTM 2013). This was done by determining the loss in weight of a given sample "when heated under rigidly controlled conditions of temperature, time and atmosphere, sample weight and equipment specifications" (ASTM 2013). The materials required for this testing include a drying oven capable of temperature regulation of 103 ±1ºC and allowing natural air circulation via openings in the oven, a desiccator which contains the open containers, and open containers which are nonporous ceramic and hold the test sample (ASTM 2013). The MC analysis is carried out by the TGA-601 Thermogravimentric Analyser seen in Figure 35.

Figure 37. TGA-601 used for analyses (LECO Corporation 2001).

The procedures for calculating initial and oven-dry moisture content after previous preparations are completed involved recording the initial weight of the sample container then the sample container containing the material to be tested (Equation 5). The sample was again placed in an oven to dry; with the dry weight recorded to the nearest 0.02g. The sample, after being stored in a desiccator, was then transferred into open containers or crucibles, which had been weighed in the TGA-601 to determine the initial weight, and then weighed again to determine the weight of the sample to the nearest 0.01 g. The analysis was conducted over a three-hour period or until the "total weight changes varies less than 0.2%" and then the final weight was recorded. The following formula was used to calculate moisture content:

$$MC\ \% = \frac{Wi - Wf}{Wi - Wc} \times 100 \qquad \text{Equation (5).}$$

Where *MC (%)* = moisture content of the wood sample expressed as a percent; *Wi* = initial weight of sample in grams' *Wf* = final weight of sample after drying in grams; and *Wc* = weight of the open container (crucible) in grams (ASTM 2014).

Wood Density

In order to calculate the density of wood samples, ASTM Standard D2395 - 14 - Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials – was used. For the purpose of this study, density serves as an indicator of the amount of wood fuel that can be produced (ASTM 2014) and information regarding the amount of fuel that can be transported in a specific volume container such as a log or chip hauling truck can be inferred.

Increment Core Sample Preparation

Test Method E – Increment Core was used for this test given that there was no destructive sampling; only increment cores and bark and branch samples were taken. To prepare the samples, the core samples taken in the field were removed from their protective casings, the sample divided roughly in half, and the growth rings counted beginning at the pith. After the samples were processed in this manner, they were then placed in aluminum trays labelled following a common labelling format. The samples were then cut into segments of five annual growth rings, placed in test tubes, subsequently labelled as described above, and placed into a conditioning chamber set at 65% humidity and 20ºC to acclimatize to 12% moisture content. After 14 days in the conditioning chamber, a moisture content of 12% was achieved.

Density at 12% Moisture Content

Due to the size and condition of core samples, the traditional method of calculating wood volume by the water displacement method was not possible. As such, the volume was calculated by measuring the width and length of each core sample using a calliper capable of measuring to the nearest 0.01 cm. The formula for calculating volume of a cylinder was applied (Equation 6):

$$V = \pi r^2 h \qquad \text{Equation (6)}$$

Where V = volume; r = radius of increment core (diameter ÷ 2); and h = length of increment core (ASTM 2014).

The initial mass of each length of core sample was recorded using a scale capable of measuring to four decimal places that had been calibrated prior to the commencement of this test. This was done for all wood samples that were then returned to their respective test tubes and placed into a drying oven in preparation for the next analysis.

Thermal Properties (MJ/kg Calculations)

In order to test the thermal properties of the wood, the ASTM D5467-02 Standard Test Method for Gross Calorific and Ash Values of Waste Materials was used. This test determines the calorific value using a bomb calorimeter equipped with electronic temperature sensors and automatic calorimeter controllers. In summary, this method allows for the determination of calorific values by burning a sample of a given weight under controlled conditions in a calibrated calorimeter using oxygen. The calorific value of the test sample was determined via temperature measurements made before, during, and after combustion. The gross calorific value is defined by the ASTM Standard D5467-02 as “the heat produced by combustion of a unit quantity of a solid or liquid fuel when burned at a constant volume in an oxygen bomb calorimeter under specified conditions with the resulting water condensed into a liquid”; the calorific value is expressed in mega joules per kilogram (MJ/kg).

The accuracy of the bomb calorimeter was tested using benzoic acid tablets as described in the ASTM standards (ASTM 2007b).

The procedure for assessing gross calorific values has several steps. First, the mass of the pellet was recorded to the nearest 0.0001g in the sample holder in which it was burned. The bomb must then be rinsed with water in order to lubricate dry surfaces and internal seals, which must be done prior to assembly. The next step was to connect the fuse to the ignition terminals as per the manufacturer’s guidelines and to place this into the bomb, place the lid on and charge it with oxygen to a consistent pressure of 3

MPa. If this pressure is not attained, the result will be incomplete combustion and may be visually determined by the presence of carbon residues or by the formation of carbon monoxide (CO) rather than CO_2. Then, the bomb, bucket, and calorimeter water must be transferred to the jacket via the water handling system and the calorimeter started. It is important that the initial water temperature be the same ±0.5° C for each sample.

In order to conduct this test, a number of calculations are used and described below:

$$t = t_c - t_a + C_r \qquad \text{Equation (7)}$$

Where t = corrected temperature rise in Celsius; t_c = final temperature reading; t_a = initial temperature reading at time of firing; and C_r = radiation correction[4] (ASTM 2007b).

$$E = \quad H_c m \ + e_1 + e_2 \ \div t \qquad \text{Equation (8)}$$

Where E = calorimeter heat capacity; H_c = heat of combustion of benzoic acid (J/kg in air); m = mass (weight in air) in grams of benzoic acid; e_1 = correction for the heat of formation of HNO_3 (4.2 J or 1 cal (considered a constant value); e_2 = correction for heat of combustion of ignition fuse OR 5.9 J/kg (1.13 J/mm) for No. 34 B and S gauge iron wire (considered a constant value); and t = corrected temperature rise in Celsius (ASTM 2007b).

$$Q_g \ gross \ = \ tE \ - e_1 - e_2 - e_3 - e_4 \ m \qquad \text{Equation (9)}$$

Where $Q_g(gross)$ = gross calorific value expressed in J/kg; t = corrected temperature rise; E = heat capacity; e_1 = titration correction (correction for the heat of

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[4] It is important to note that there is an error associated with the use of correction factors. Generally, there is a 96% confidence interval or a range of ±5% on all correction factors (Tarasov 2014).

formation of HNO_3 (4.2 J or 1 cal.; considered a constant value)); e_2 = fuse correction (correction for heat of combustion of ignition fuse OR 5.9 J/kg (1.13 J/mm) for No. 34 B and S gauge iron wire (considered a constant value)), e_3 = correction for difference between heat of formation of H_2SO_4 and the heat of formation of HNO_3 expressed in joules or 55.2 J/g multiplied by the percentage of sulfur in the sample multiplied by the sample mass; e_4 = a correction for use of tape (or gelatin capsule, mineral oil, ethylene glycol, spiking material); $e_4 = m\ (g)\ x\ H_c\ (J/g)$ where H_c is as described in the above formula for thermochemical corrections, and m = mass in grams (ASTM 2007b).

$$Q_n\ net\ = Q_g - 0.2122H \qquad \text{Equation (10)}$$

Where Q_n *(net)* = the net calorific value,;Q_g*(gross)* = gross calorific value expressed in J/kg calculated in section 3.5.3.3; and H = total hydrogen expressed as a percentage of mass (ASTM 2007b).

Additional calculations are required for the re-standardization of testing materials. Further information about these calculations can be found in ASTM Standard D5467-02.

Ash Content

To determine the ash content of the wood, ASTM Standard D1102-84 (2013) was used as this allows researchers to determine "an approximate measure of the mineral content and other inorganic matter in [the] wood." The test allowed researchers to determine the amount of ash expressed as a percentage of remaining residues after dry oxidation (580ºC-600ºC) of the wood sample. This represents an approximate measure of the amount of minerals or other inorganic matter in the wood sample (ASTM 2013). Specimens were prepared by grinding samples into coarse material and then into fine material (able to pass through a No.40, 425µm sieve) (LECO Corporation 2001) using a Wiley No. 2 Mill and weighing no less than 2 g to ensure accuracy. Prepared samples were sent to the Forest Resources and Soils Testing (FoReST) Laboratory at Lakehead University where the tests were conducted. The necessary testing equipment includes crucibles with lids to hold the samples, along with a muffle furnace with a pyrometer, which is used for igniting wood samples and maintaining desired temperatures, an analytical balance that can record weights to the nearest 0.1 mg and a drying oven which can be controlled to remain between 100°C and 105°C (ASTM 2013). The procedure takes place after moisture content is calculated using the TGA-601. After MC (%) is determined, the crucible and its contents were placed in the muffle furnace and ignited until all the carbon was eliminated leaving only the inorganic matter and other mineral content from the wood sample. The sample was then removed and placed in a desiccator with the covers loosely removed to allow for cooling and an accurate weighing recorded to the nearest 0.1 mg. The formula to calculate ash content was as follows:

$$Ash\ \% = \frac{W1}{W2} \times 100 \qquad \text{Equation (11)}$$

Where *Ash (%)* = the amount of ash remaining after dry oxidation expressed as a percentage of the sample's initial weight; *W1* = the weight of ash remaining in the crucible; and *W2* = the weight of the oven dry sample of wood (ASTM 2007a; ASTM 2013).

Statistical Analysis

The four stated null hypotheses where grouped into two statistical analyses: forest inventory and wood properties. The forest inventory null hypothesis states:

H_0: There is no difference between the outcomes of forest inventory methods, among sites, between field methods and the interaction between sites and field methods.

The wood properties null hypothesis states:

H_0: There is no difference among wood properties, between sites, between field methods and the interaction between sites and field methods.

The statistical model used for the analysis was as follows:

$$Y_{ijk} = u + S_i + M_j + SM_{ij} + \varepsilon_{ij\ k} \qquad \text{Equation (12)}$$

Where: Y_{ijk} = measured response; u = overall mean; S_i = random effect of the two sites; M_j = fixed effect of the two field methods; and $\varepsilon_{ij\ k}$ = random effect.

The forest inventory and wood properties test results were compiled and then analyzed using 'R' Statistical software. An analysis of variance (ANOVA) was carried out using a general linear model and a Tukey's HSD post hoc test at 95% probability. For forest inventory, variance was determined using averages of each FRI line. For wood properties variance was determined using species grand means for each site and published values. During the statistical analysis, interactions were pooled when no significance was found.

CHAPTER 4: RESULTS

In order to promote sustainable development in rural and remote communities, it is important to identify potential forest development opportunities to utilize their natural resources for community heating needs. This was done by assessing one rural and one remote First Nation community's natural resources to determine whether or not sufficient woody biomass is present on the surrounding land base to determine the AHA which can be sustained in perpetuity to provide fuel for a BDHP.

COMPARING PROVINCIAL DATA WITH DATA COLLECTED DURING STUDY

Landcover with Potential for Biomass Harvest in Remote Areas: SLFN

In the case of SLFN, it was found that the LUWSTF inventory provided a more detailed description of the forest cover compared to the "Provincial Landcover 2000–27 Classes". This included information about ecosite, age, species composition, volume, and thermal properties.

Table 4 summarizes the land base by total area and area of usable forest land in SLFN. This takes into account the areas removed for buffers around lakes and water courses, as well as inoperable areas such as swamps, fens, wetlands, community settlements, rocky outcrops and roads. Table 5 shows a comparison between the species composition calculated from the Provincial Landcover 2000–27 classes and the LUWSTF FRI.

Table 4. Summary of forested areas by parcel and authority for SLFN.

Parcel	*Total Area (ha)*	*Forested Land (ha)*
Parcel 1: Community Reserve Land	3,588	2, 266
Parcel 2: Reserve Land	2, 833	1, 898
Parcel 3: Ponask Lake Reserve Land	1, 723.6	867
Reserve Land (total)	8, 144.6	5, 031

Crown Land: (excluding Reserve land)		69, 677

Table 5. Comparison of species composition using the Provincial Landcover 2000–27 classes and the LUWSTF FRI at SLFN.

Data Source	Strata	Authority	Species Composition	Volume (m^3)
Provincial Landcover 2000–27 classes	Coniferous	Crown Reserve	Conifer species (Pj, Sb, Sw) ≥ 75% of Canopy Closure	N/A
	Deciduous	Crown Reserve	Deciduous species (Pt, Bw) ≥ 75% of Canopy Closure	N/A
	Mixedwood	Crown Reserve	Deciduous + Coniferous species (Pj, Sb, Sw, Pt, Bw) ≥ 75% of Canopy Closure	N/A
	Disturbed	Crown Reserve	No species description	N/A
	Treed Wetland	Crown Reserve	Primarily bog species; shrubs	N/A
	TOTAL			N/A
LUWSTF FRI	Coniferous	Crown	Pj 955 Sb 045	2,315,071.0
		Reserve	Sb 805 Bf 078 Sw 043 Bw 028 Wil 013 Ald 012 Pt 010 Pb 008 Pj 003	138,904.8
	Deciduous	Crown	Bw 550 Pt 306 Pj 135 Sb 009	2,202,537.2
		Reserve	Pt 470 Sb 287 Bw 156 Pj 087	293,202.0
	Mixedwood	Crown	Pj 386 Sb 313 Pt 157 Bw 144	785,573.1
		Reserve	Sb 531 Pt 177 Pj 116 Bf 092 Bw 078 Wil 003 La 003	121,892.9
	Disturbed	Crown	Pj 963 Ald 021 Pt 007 Bw 004 Sb 003 Wil 002	0
		Reserve	N/A (no Disturbed sites on Reserve Land were sampled)	0
	Treed Wetland	Crown	N/A (no Treed Wetland sites on Crown Land were sampled)	0
		Reserve	Sb 566 Pj 385 Pt 037 Bw 008 Bf 004	211,697.4
	TOTAL			6,068,878.3

Pj – Jack pine; Pw – White pine; Pr – Red pine; Sb – Black spruce; Sw – White spruce; Pt – Trembling aspen; Pb – Balsam poplar; Bw – White birch; Bf – Balsam fir; La – Larch; Wil – *Salix* sp.; Ald – *Alnus* sp.; Map – *Acer* sp.; AmS – *Amelanchier* sp.

Comparison between Species Composition and Volumes Calculated for SLFN

We found a greater variety of species, as well as additional volumes from the inclusion of these species, when compared to the OMNRF data provided. Figures 34 and 35 demonstrate the species composition calculated using the LUWSTF methods and OMNRF data, respectively.

Using the LUWSTF methods, it was found that SLFN Crown land is primarily composed of jack pine (87.9%), while the remaining 12.1% of the 11,391,614 m^3 present on Crown land is composed of white birch (5.5%), trembling aspen (3.6%), and alder, white spruce and willow composing <3% combined. Comparatively, using the OMNRF methods for calculating species composition, it was determined that jack pine dominates the landscape, making up 90.9% of the 11,391,614 m^3 present on Crown land, while white birch (5.5%), trembling aspen (3.0%), and black spruce (0.6%) compose the remainder. It can be seen that using the OMNRF methods of calculating species composition would result in an overestimation of volumes for the dominant species and an underestimation of volumes for minor species. Figures 36 and 37 demonstrate the difference in species composition calculated using the OMNRF and LUWSTF methods.

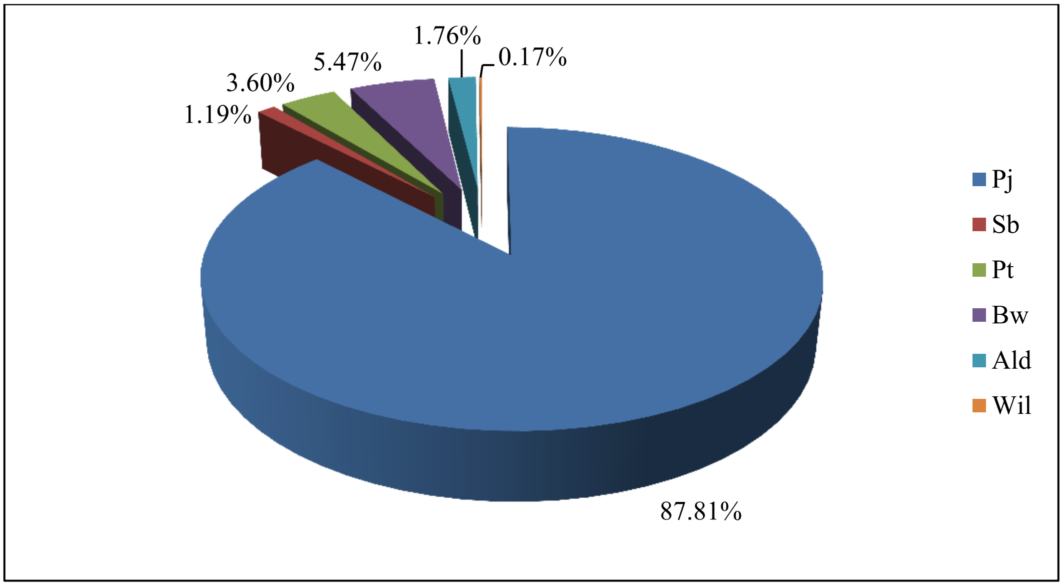

Figure 38. Species composition and percentage of 11,391,614 m³ total volume for SLFN Crown land using LUWSTF methods.

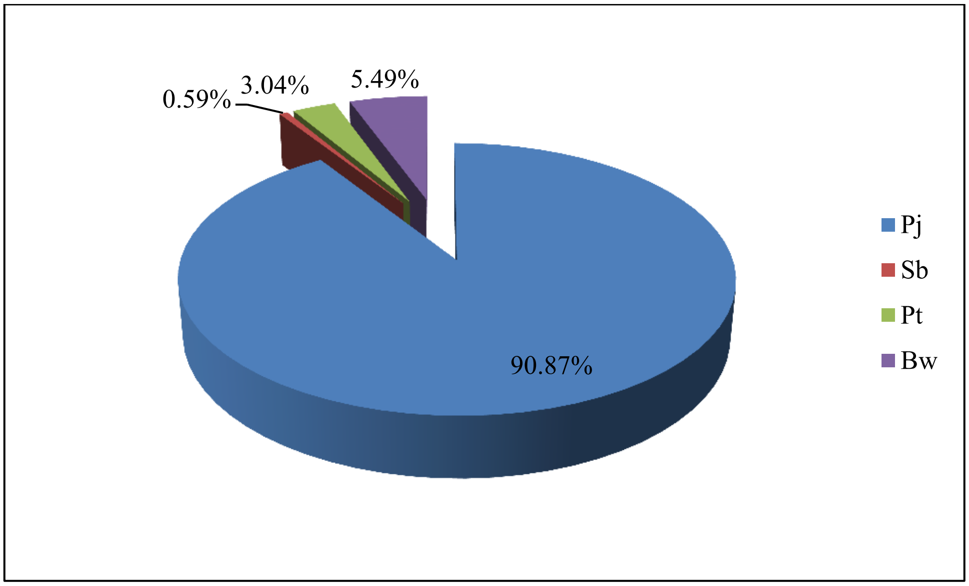

Figure 39. Species composition of SLFN Crown land as calculated using OMNRF methods.

The total volume of wood on the land base remained the same (11,391,614 m³) regardless of the method of calculating species composition. The major difference is the addition of minor or under-reported species that make up a portion of the landscape. When these species are not taken into account, there is an overestimation of volume in the dominant species. Figure 38 demonstrates the difference in wood volumes calculated using the two methods. Figure 39 shows the difference in overall species composition and volume calculated using the two methods. It can be seen that there are more species present when using the LUWSTF methodology and the OMNRF methodology yields more volume of the dominant species, which can lead to an overestimation of available wood for that species. In addition, the volume of underutilized species is low in the OMNRF methodology.

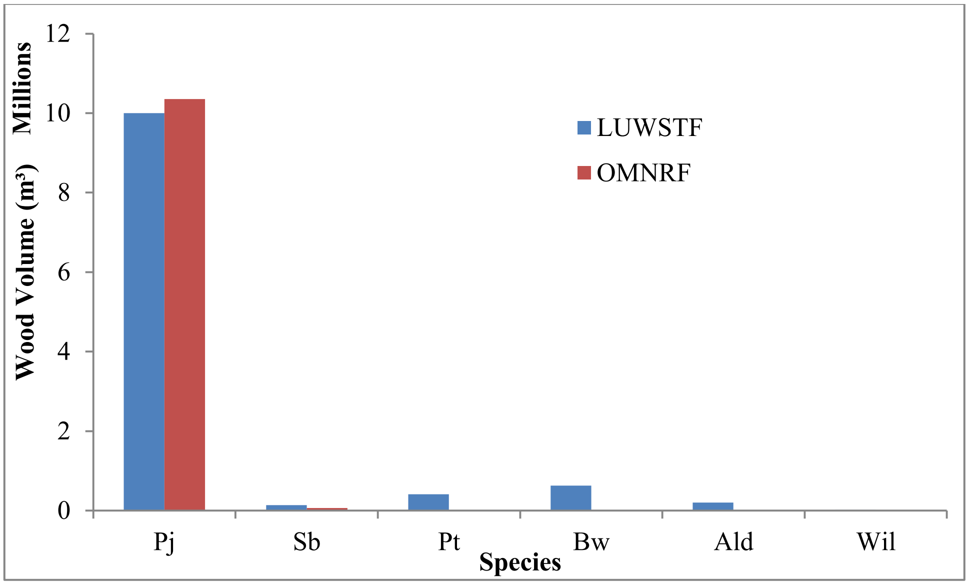

Figure 40. Summary of volumes on SLFN Crown land calculated using two methods.

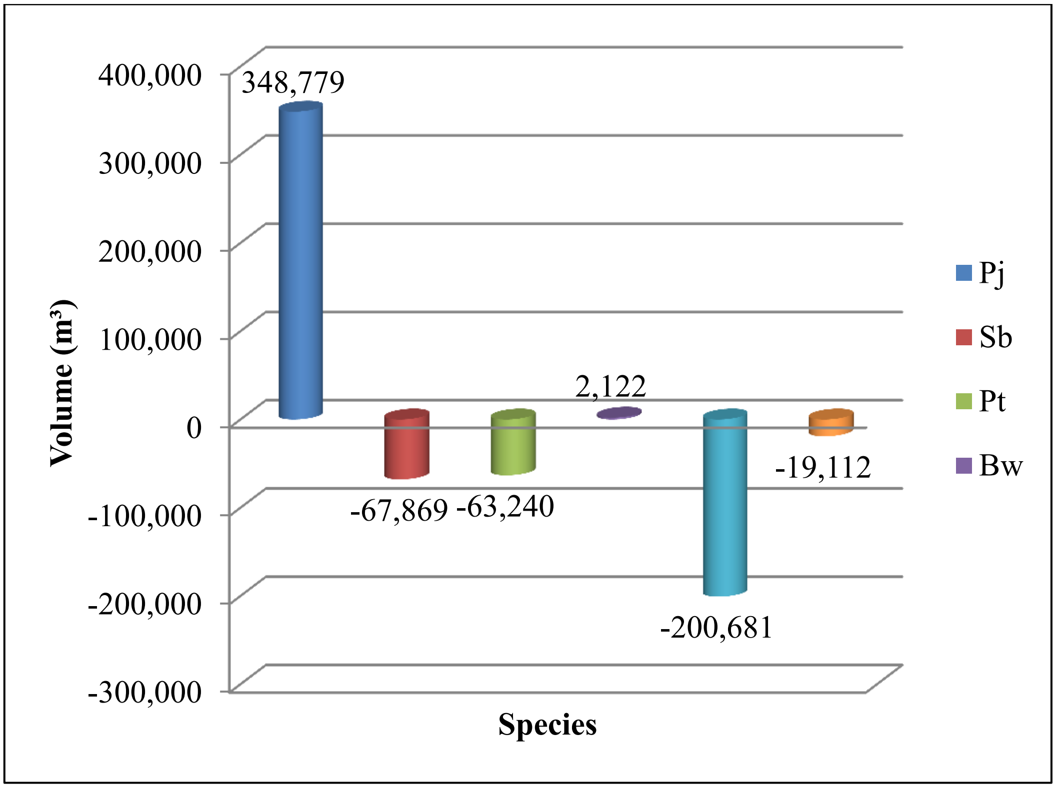

Figure 41. Over and underestimation of volumes on SLFN Crown land. This graph was developed by using the volumes determined by the OMNRF methods as the baseline (0), and the LUWSTF methods and resulting volumes as the differences (positive and negative).

For the reserve land, a total of 8,144.6 ha, the presence and percentage of total volume of each species on the land base was vastly different than that of Crown land. Once again, it was noted that there was a difference in overall species composition as a percentage of total volume on the land base. The volume present on reserve land was significantly less (1,516,236 m^3) compared to Crown land, though this is likely a result of a smaller area of reserve land. Comparing the OMNRF results for species composition, it was found that the results differed from those calculated using the LUWSTF methods (See Figures 40 and 41). Black spruce was found to be the dominant species making up 49.4% of the total volume using OMNRF methods and 37.3% using the LUWSTF methods, jack pine made up 32.6% and 12.0%, respectively, and white birch made up 15.1% and 12.3%, respectively. Other species present on the land base include balsam fir 1.7% and 0.8%, respectively and trembling aspen 0.8% and 36.8%, respectively. There is a notable difference in the percent composition of trembling aspen calculated using the different methods which resulted in a volume of 12,129.9 m³ using OMNRF methods and 557,823.2 m³ using the LUWSTF methods, a difference of 545,693.3 m³.

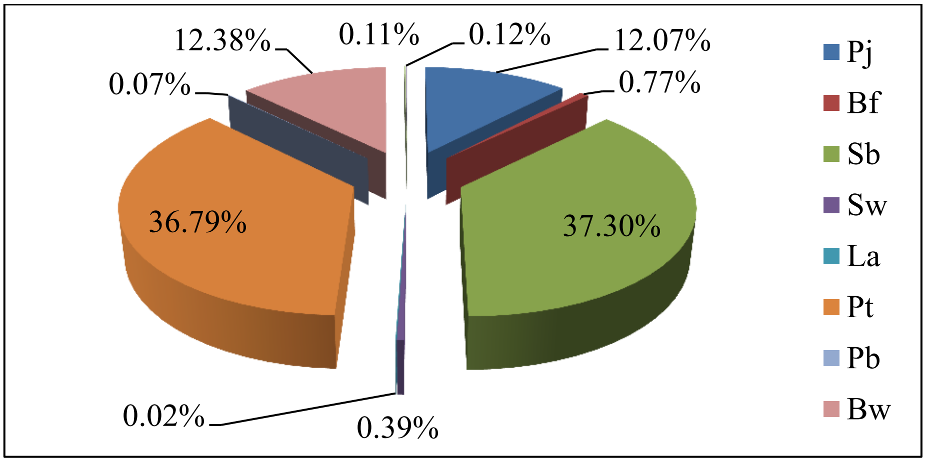

Figure 42. Species composition of SLFN reserve land calculated using LUWSTF methods.

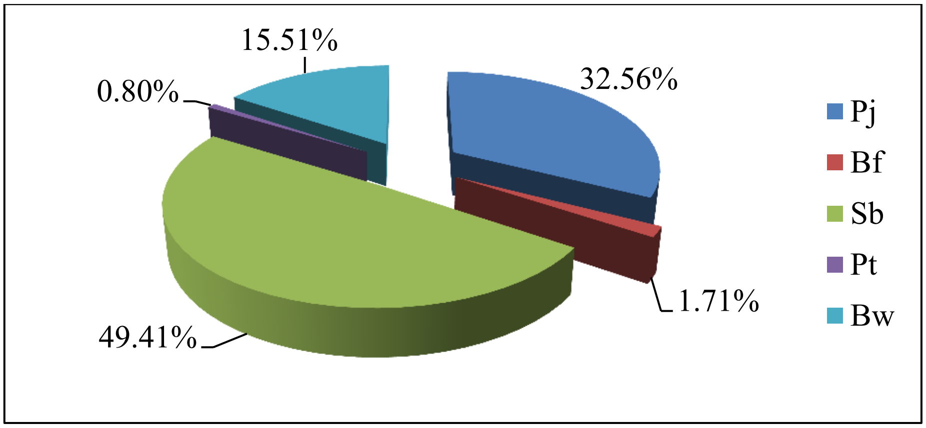

Figure 43. Species composition of SLFN reserve land calculated using OMNRF methods.

Figure 42 demonstrates the difference in volumes for each species calculated using the two methods. The notable differences in volumes are seen in the dominant species—jack pine, black spruce, white birch, and trembling aspen. Figure 43 shows the difference in volumes using the two methods.

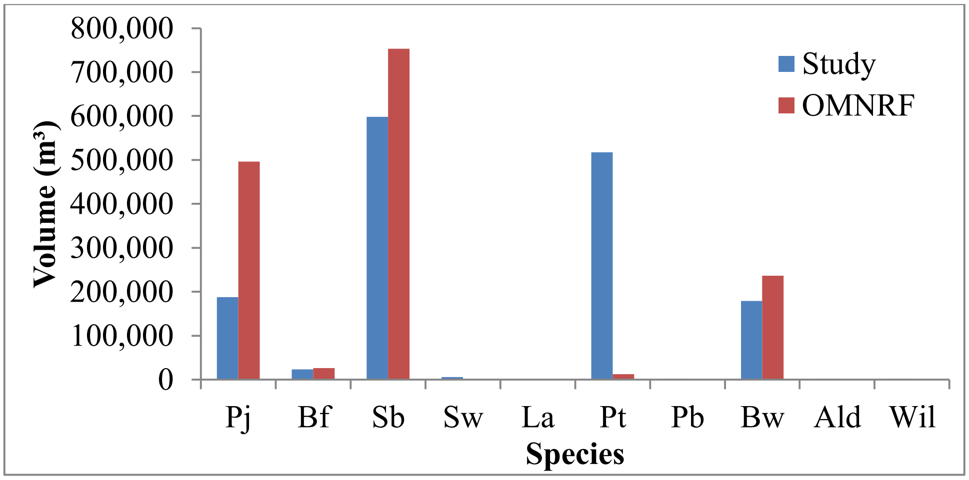

Figure 44. Summary of volumes calculated for SLFN reserve land using OMNRF and LUWSTF methods.

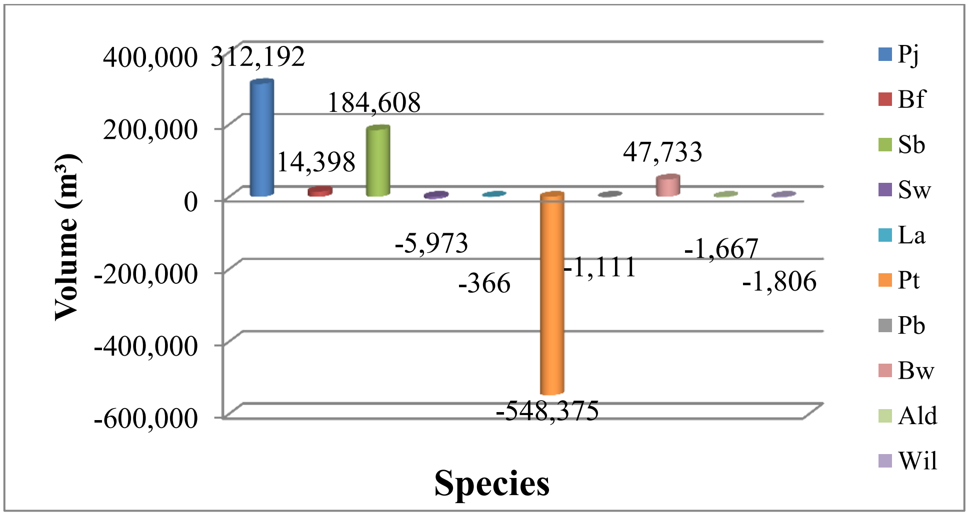

Figure 45. Demonstration of over or underestimates (difference between outcomes of two methods for calculating species composition on SLFN reserve land). This graph was developed by using the volumes determined by the OMNRF methods as the baseline (0), and the LUWSTF methods and resulting volumes as the differences (positive and negative).

In summary, the comparison between the provincial forest cover data in the case of SLFN is the recording and reporting of all species present on the land base. For SLFN, the LUWSTF FRI methodology was able to provide actual volumes and species composition and provide some information about ecosite, age, and soil type.

Landcover with Potential for Biomass Harvest in Rural Areas: Lac Seul First Nation

In order to study and inventory the rural forest in the same manner as the remote location, the forest/landcover classes were divided into the same five land classes that were determined to be operable—Coniferous Treed, Deciduous Treed, Mixedwood, Treed Wetlands, and Disturbance–Treed and/or Shrub. There are 11 different forest units on the Lac Seul Forest. A summary can be found in Figure 44 showing finer distinctions of the five land classes. Four landcover classes can be found under *Coniferous Treed*, including:

Conifer Mixedwood 1 (COMX1)—This forest cover type consists of a mix of primarily conifer species, such as red pine (*Pinus resinosa*), white pine (*Pinus strobus*), black and white spruce, jack pine, and balsam fir, making up roughly 70% of forest cover while poplar and white birch compose the remainder. In 2011, this forest type made up approximately 105 018 ha or 15% of the available forests units in the Lac Seul Forest at that time.

Jack Pine Dominated (PJPUR—This forest unit is dominated by jack pine which means that ≥70% of the forest is composed of jack pine, with ≤20% poplar and white birch composing the remainder of cover.

Red and White Pine Mixed (PWRMX)—This stand type is identified by the percent composition of red and white pine on the landscape (≥40%). Less than 1% of the Lac Seul Forest is available in this stand type. The majority of this landcover class can be found in parks, protected areas, or around water bodies which contributes to the lack of availability on the forest landscape.

Spruce Upland (SPUP)—This common forest unit consists primarily of upland spruce stands containing ≥70% black or white spruce, and a combined poplar and white birch composition making up the remainder. Overall, this forest cover type represents 23% of available forest in the Lac Seul Forest.

Additional conifer-dominated forest/landcover classes were identified (ex. BFDOM, OCL [Other Conifer]), but the percent cover on the landscape was very low and was not within reasonable haul distance for the community.

Two landcover classes were identified for *Deciduous Treed:*

Poplar Dominated (POPUR)—This forest cover type contains stands that contain ≥70% poplar. In the past, poplar was not fully utilized as there was a lack of steady markets to send wood, and thus there remains quite a bit of POPUR forest in an older age category (81-100 years). Although this forest cover type makes up a small portion of the landscape (3% of available forest in 2011), there is potential for these sites to provide an opportunity to create Short Rotation Woody Crops (SRWC) to be managed as a biomass plantation.

HWDMX—This forest cover type indicates a stand composed of ≥50% poplar, white birch, and black ash (*Fraxinus nigra*). During the year 2011, approximately 6% of available forest cover was composed of HWDMX. Historic records show this forest cover was in greater abundance, but passive regeneration has led to an increase in balsam fir and conifer-mixedwood stands. Current forest management objectives may result in a further decline of this cover type.

Within the *Mixed Treed* designation, one landcover class was identified:

Conifer Mixedwood 2 (COMX2)—This forest type contains ~50% conifer species (red and white pine, black and white spruce, jack pine, balsam fir, cedar (*Thuja occidentalis*) and larch (*Larix laricina*) while the remainder is composed of deciduous species (poplar, birch). Past passive regeneration practices during the 1970's has led to an increase in this forest type across the landscape. In the year 2011, this forest/landcover type composed 10% of Lac Seul's available forest at that time.

The *Disturbance–Treed and/or Shrub* stands were chosen based on three different criteria: age, recent history of fire activity, and recent harvest treatments. Within the FRI geodatabase for the Lac Seul Forest, stands less than 20 years of age were identified as "Disturbed" as it was inferred that these sites would have been depleted either naturally through disease or fire or artificially through harvest. An additional column of information available through the FRI geodatabase described the current status of the stands as determined by their most recent harvest treatments. It was determined that stands classified as "Depleted – Harvest" would have been harvested during the last period before the FRI geodatabase was updated, while stands classified as either "Depleted – Natural" or "Depleted – Fire" were also classified as disturbed areas.

Within the *Treed wetlands* designation, two landcover classes were identified:

Lowland Black Spruce (SBLOW)—These sites are composed primary of lowland spruce (≥70% spruce or a black spruce–larch mixture) forests on organic soils. There is a significant amount of this forest cover type on the landscape (19% of available forest in 2011), particularly in mature age classes (81-100 years).

Mixed Conifer Lowland (MCL)—Similar to SBLOW, these sites are dominated by conifers, including spruce, balsam fir, larch, and cedar, and contain a small portion of hardwood species such as birch and poplar.

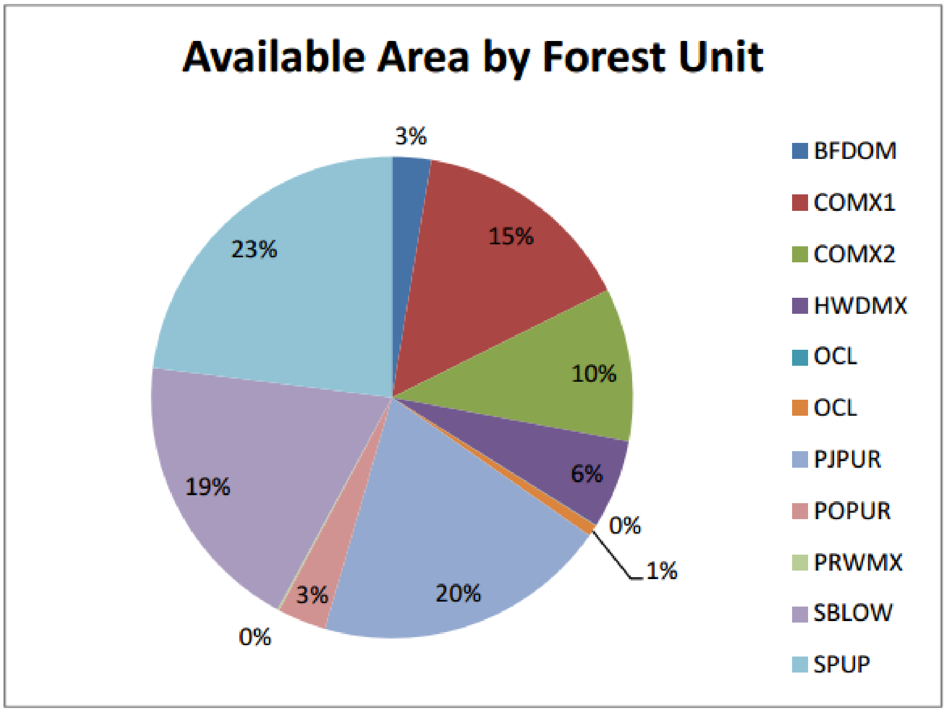

Figure 46. Area of forest cover type expressed as a percentage of total area of the Lac Seul Forest (Brailsford 2011).

Table 6 compares the species composition and volume of the Lac Seul Forest calculated from the provincial FRI and the LUWSTF FRI. It can be noted that the provincial FRI takes into account two dominant species and does not contain minor species, shrubs, or those that make up less than 10% of the total volume. This results in an over-estimation of volumes of certain species and an under-estimation of 'waste' created from the presence of minor or under-reported species.

Table 6. Volume summary for the Lac Seul Forest comparing provincial FRI with LUWSTF FRI.

Data Source	Strata	Authority	Species Composition	Volume (m^3)
MNRF FRI	Coniferous	Crown	Pj 50 Sb 40 Bf 10	14,156,544.9
		Reserve		2,593,190.4
	Deciduous	Crown	Bf 50 Bw 20 Pt 20 Sb 10	1,106,756.1
		Reserve		131,859.0
	Mixedwood	Crown	Pt 40 Bf 30 Sb 20 Bw 10	3,959,720.9
		Reserve		89,826.3
	Disturbed	Crown	N/A	N/A
		Reserve		43,447.7
	Treed Wetland	Crown	N/A (sites contained in buffers; eliminated from available volume calculations)	N/A
		Reserve		40,592.6
	TOTAL			22,121,937.9
LUWS TF FRI	Coniferous	Crown	Pj 539 Sb 397 Bf 043 Bw 021	14,156,544.9
		Reserve	Pj 899 Bw 041 Bf 026 Sb 018 Pt 014 Sw 002	2,593,190.4
	Deciduous	Crown	Bf 464 Bw 250 Pt 214 Sb 072	1,106,756.1
		Reserve	Pt 439 Bf 230 Bw 138 Ald 069 Sb 050 Pb 042 Sw 021 Pw 003 Wil 003 Pr 003 Pj 002	131,859.0
	Mixedwood	Crown	Pt 357 Bf 310 Sb 178 Bw 071 Ald 048 Ce 036	3,959,720.9
		Reserve	Bf 372 Ce 210 Bw 181 Map 064 Sb 061 Pt 056 A ld 022 Pb 017 Wil 007 Pj 007 Sw 003	89,826.3
	Disturbed	Crown	N/A (no Disturbed sites on Crown Land were sampled)	N/A
		Reserve	Pj 246 Pt 229 Map189 Ald 103 Ch 097 AmS 080 Bf 034 Bw 017 Sb 005	43,447.7
	Treed Wetland	Crown	N/A (no Treed Wetland sites on Crown Land were sampled)	N/A
		Reserve	Sb 657 Bf 165 Bw 056 La 053 Pb 036 Pt 030 Ald 003	40,592.6
	TOTAL			22,121,937.9

Comparison between Species Composition and Volumes Calculated for LSFN

Similar to what was found for SLFN, there was a difference in the outcomes of the LUWSTF inventory procedures and the OMNRF inventory procedures. Again, this was likely a result of the different inventory procedures conducted in the field and how the information was analyzed.

The LUWSTF FRI showed a greater variety of species, as well as additional volumes from the inclusion of these species, when compared to the OMNRF data. Figures 36 and 37 demonstrate the species composition calculated using the OMNRF and the LUWSTF methods.

The total volume of wood on the land base remained the same (1,516,236 m^3) regardless of the method of calculating species composition. The major difference is the addition of minor or underreported species that make up a portion on the landscape. Figures 45 and 46 represent the difference in overall species composition calculated using the two methods. Figure 47 demonstrates the difference in wood volumes calculated using the two methods. When minor or underreported species are not taken into account, there is an overestimation of volume in the dominant species and an underestimation of volume in the unreported species, as can be seen in Figure 48. It can be seen that there are more species present when using the LUWSTF methodology and the OMNRF methodology yields more volume of the dominant species, which can lead to an overestimation of available wood for that species.

A comparison between Figure 45 and 46 shows that there are only five species present on LSFN Crown land using the OMNRF methods of calculating species composition, whereas the LUWSTF methods yields seven species. The percent composition of the dominant species—jack pine, black spruce and balsam fir—is similar using both methods; however balsam fir using OMNRF methods is over estimated by roughly 5%, which yields a difference in volumes of over 1 M m³. Similar to what was seen in SLFN, the underreported and minor species—eastern white cedar and alder—account for approximately 1.1% of the total volume which yields 100,284 m³ and 133,714 m³ respectively, a total of 233,996 m³. Figure 47 shows the differences in volumes calculated using both OMNRF and LUWSTF methods. Using OMNRF methods, the volume of jack pine, white birch, alder and cedar are underestimated, while balsam fir, trembling aspen, and black spruce are overestimated. Figure 48 shows the volume that is over- or underestimated for each species.

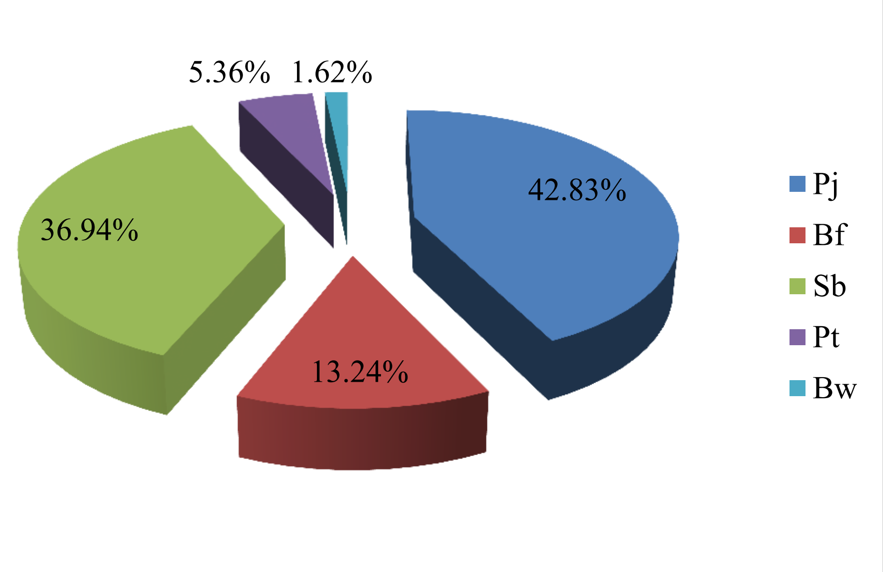

Figure 47. Summary of species composition as a percentage of total volume (19,223,022 m³) for LSFN Crown land using OMNRF methods.

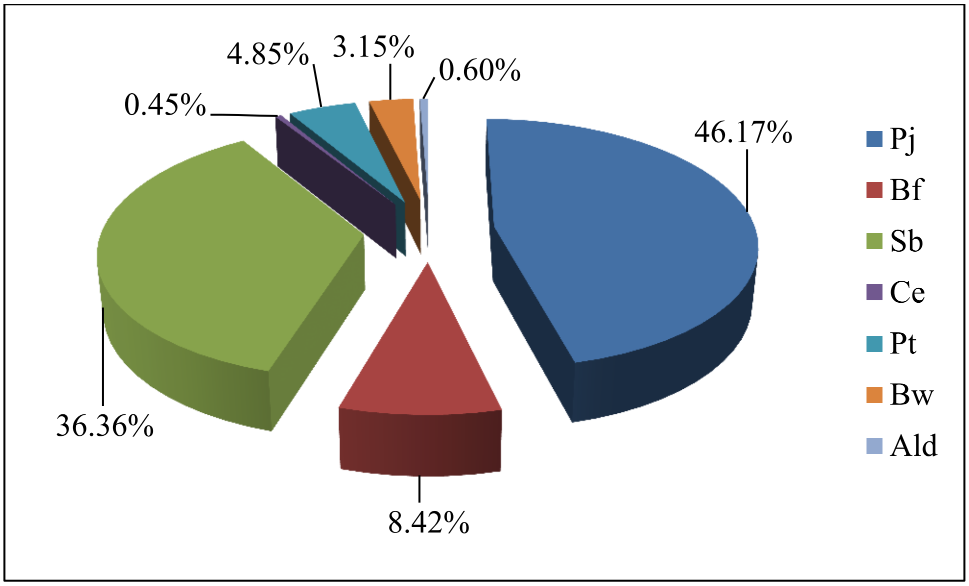

Figure 48. Summary of species composition as a percentage of total volume for LSFN Crown land using LUWSTF methods.

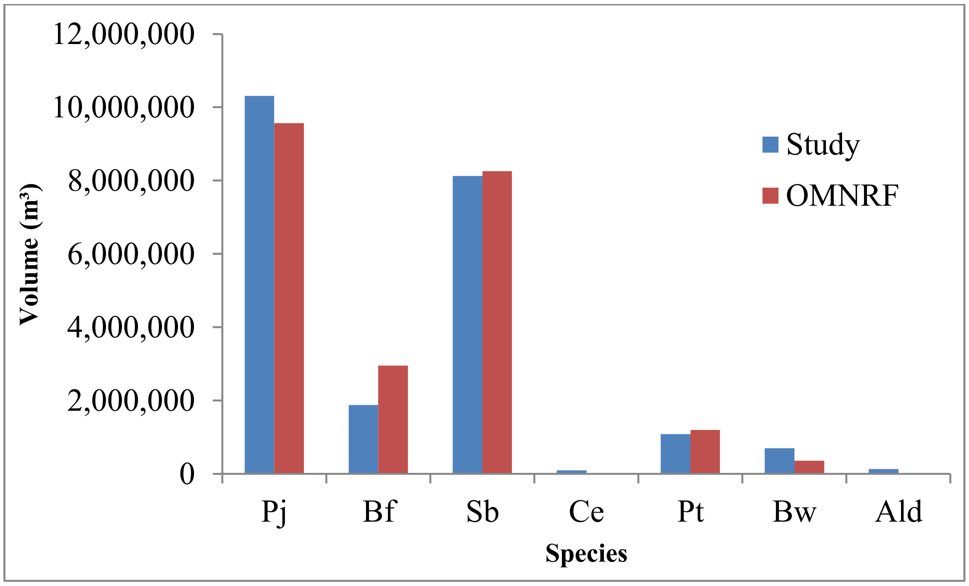

Figure 49. Summary of volumes calculated for LSFN Crown land using OMNRF and LUWSTF methods.

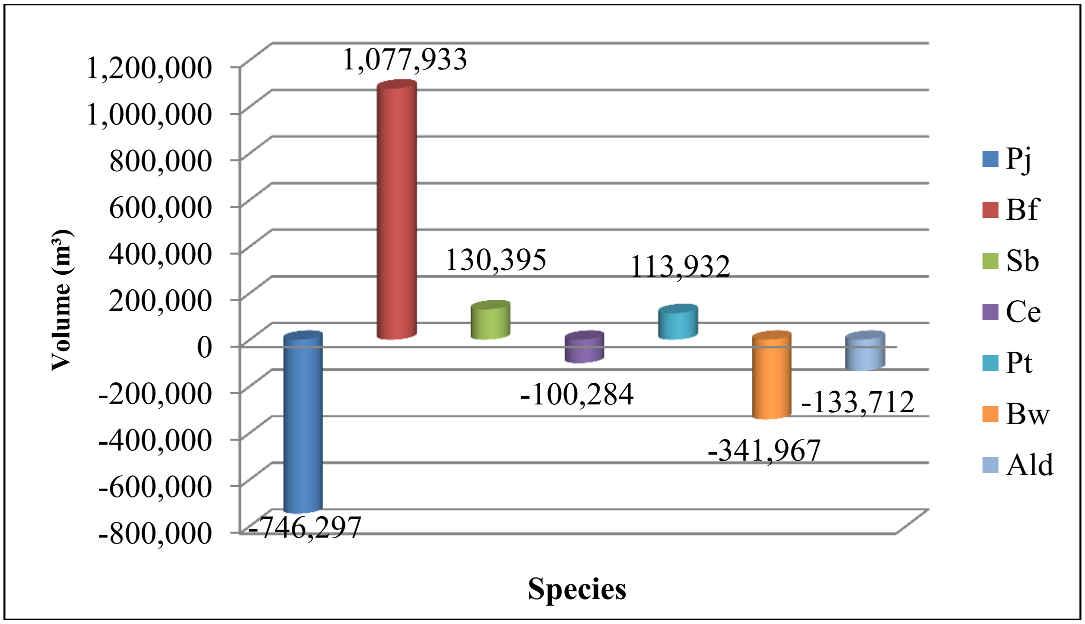

Figure 50. Demonstration of over/underestimates of volumes for LSFN Crown land. This graph was developed by using the volumes determined by the OMNRF methods as the baseline (0), and the LUWSTF methods and resulting volumes as the differences (positive and negative).

Using the LUWSTF methods, a greater presence of the minor or under reported species present on the land base was found, which may provide an opportunity for biomass. Further, the over reporting of dominant species may lead to an assumption of greater volumes to be harvested as determined by the management plan, but that are not actually present on the land base.

When reviewing the species composition for LSFN reserve land, a total of 26,821.5 ha, we see a similar trend in species reporting and associated volumes. The OMNRF methods yield a higher volume and percent composition for the major commercial species and some minor specie (i.e. jack pine, larch, alder and cherry) and an underestimate of the other species present (i.e. balsam fir, black spruce, cedar, trembling aspen, white birch, and maple). This can be seen in Figures 49 and 50. The largest difference is noted in jack pine, which yields 88.2% using OMNRF methods and

79.4% using the LUWSTF method, a difference of 308 835 m^3. Figure 51 gives a summary of volumes calculated for LSFN reserve land using OMNRF and LUWSTF methods. The major differences can be seen in the volumes calculated for black spruce, balsam fir, white birch and trembling aspen. These species are under reported on the land base which, if accounted for, would contribute 76,500 m^3 of black spruce, 65,682 m^3 of balsam fir, 110,311 m^3 of white birch, and 27,778 m^3 of trembling aspen to the total volume present on the land base. Figure 52 demonstrates the over- or under-estimation of volumes using the OMNRF methods compared to the LUWSTF methods. By accounting for these species, a total of 280,271 m^3, the volume and species composition could be more representative of what is present on the land base. In summary, for LSFN we see a difference in the volumes of minor or under reported species and an over estimation of volumes for major commercial species in general. By accounting for all species, more realistic estimates of volumes across the land base are provided.

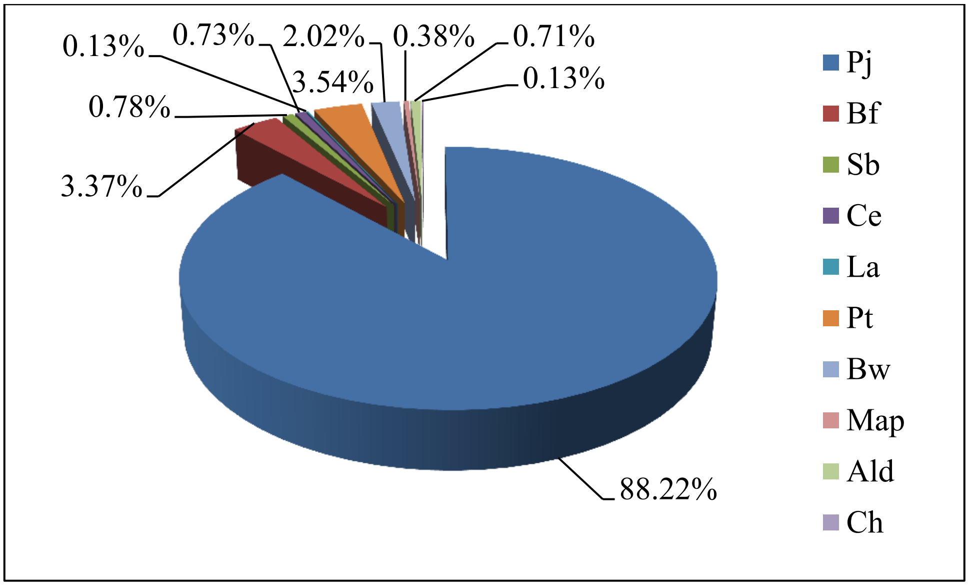

Figure 51. Summary of species composition as a percentage of total volume (2,898,916 m³) for LSFN reserve land using OMNRF methods.

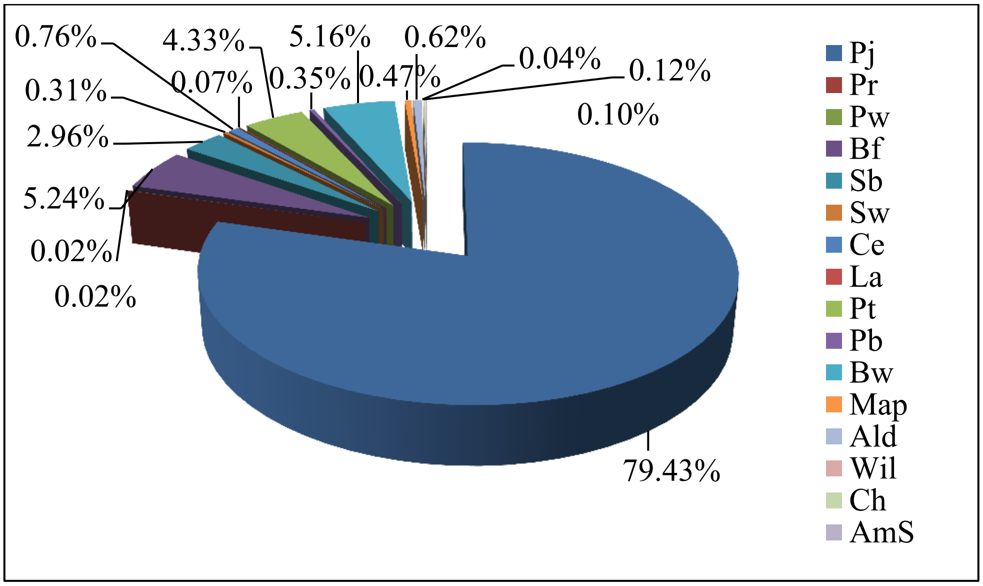

Figure 52. Summary of species composition as a percentage of total volume (2,898,916 m³) for LSFN reserve land using LUWSTF methods.

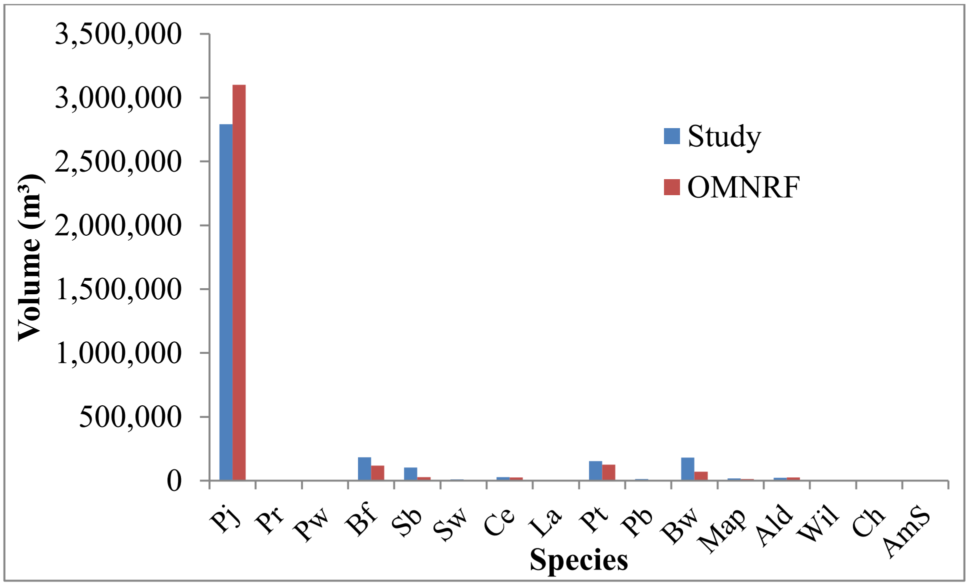

Figure 53. Summary of volumes calculated for LSFN reserve land using OMNRF and LUWSTF methods.

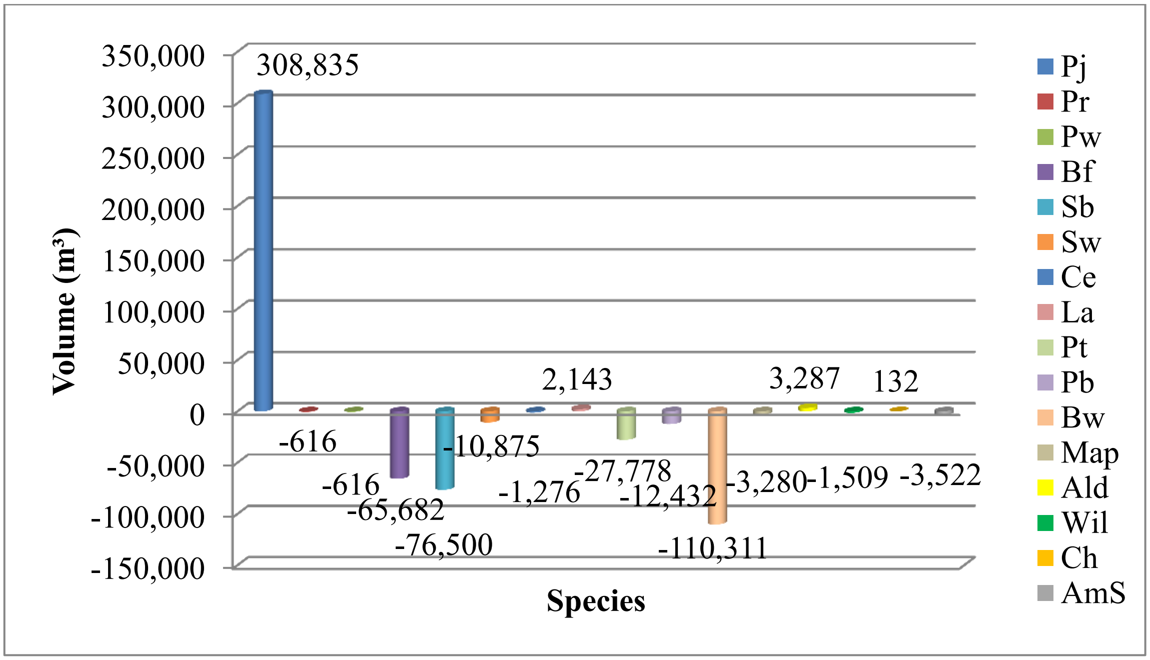

Figure 54. Demonstration of over- and under estimations of volumes on LSFN reserve land. This graph was developed by using the volumes determined by the OMNRF methods as the baseline (0), and the LUWSTF methods and resulting volumes as the differences (positive and negative).

COMPARING THE RESOURCES OF THE RURAL (LSFN) AND REMOTE (SLFN) FIRST NATIONS

The results show that there is a difference between the forest resources available to the remote community compared to the rural community noted in two ways: species composition and wood volume. Figures 53 and 54, respectively, demonstrate these differences. Lac Seul First Nation has a more detailed FRI as they are part of an active forest license in the AOU, which contains information such as species composition, ages, and seral stages. However, because the FRI methodology includes only species that make up at least 10% of the total volume, the research provided an opportunity to include a variety of other species that could be captured in biomass harvest operations. Although stand types were grouped together to create the same strata as was used in SLFN, there is more variation in stand types within the delineated strata in the Lac Seul Forest; however, it was not feasible to sample all stand types at the same intensity as was done in the remote community because of the size of area.

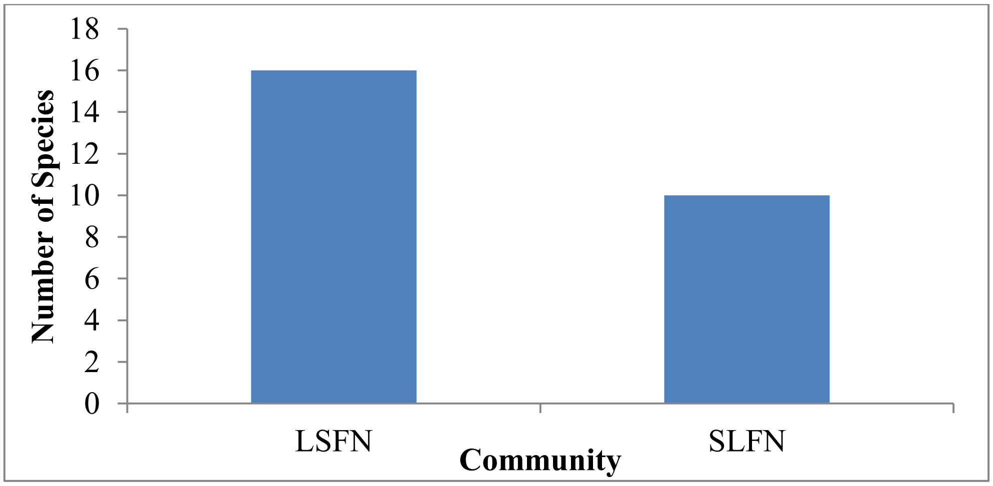

Figure 55. Comparison between number of species present in each community.

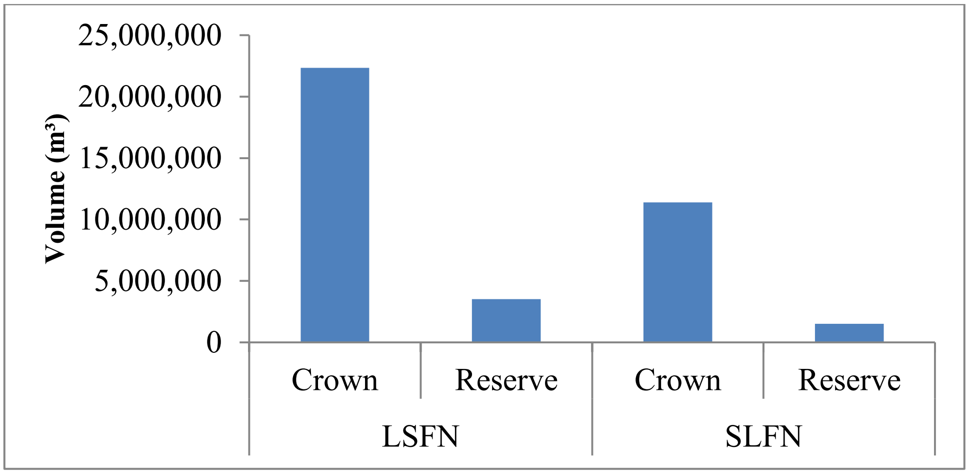

Figure 56. Difference in volumes present in each community.

Another way the forest resources in LSFN and SLFN differ is the growth rate of the forest. We see a faster growth rate in LSFN compared to SLFN which may be attributed to the difference in latitude, the variation in climate, and the different lengths of growing season. With a faster growth rate, the forests of LSFN are able to grow back quicker which decreases the length of time between harvests, meaning that the forests can be harvested on a shorter rotation in LSFN compared to SLFN. Figure 55 demonstrates the difference in growth rates between LSFN and SLFN with a growth rate of 3 m^3/ha/year and 1.75 m^3/ha/year, respectively.

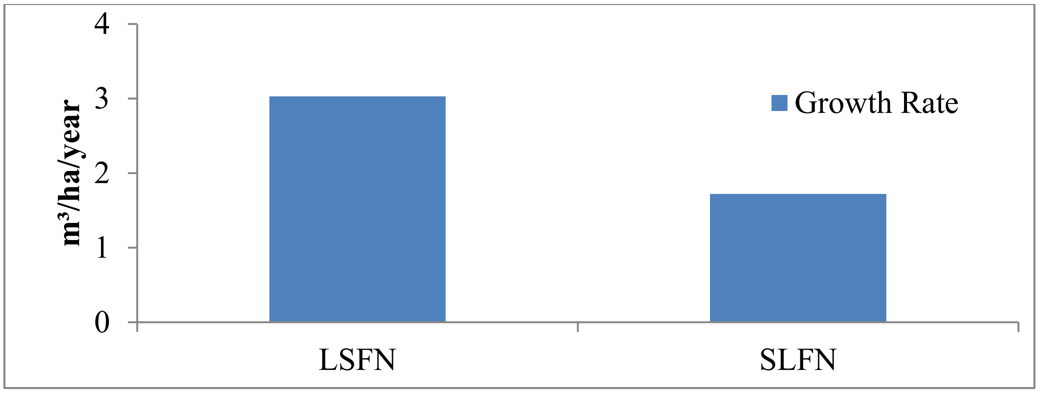

Figure 57. Growth rate of forests in SLFN and LSFN.

One significant difference in forest resources available in LSFN compared to SLFN is the presence of commercial forest operations in LSFN. Figures 56 and 57 show the potential sources of biomass on LSFN reserve and Crown land. These numbers are approximate, with further studies required to determine the forest harvesting activities that are taking place that have not been accounted for in the FMP for the area. For example, the forested reserve lands on LSFN do not have a proper FMP, and the forest is currently supporting a log home building company which may be competition when determining wood supply. These opportunities are not present or are not determined for SLFN as no commercial operations are taking place, and there is no existing FMP or C-bLUP that would provide researchers with an insight as to the management activities of the community.

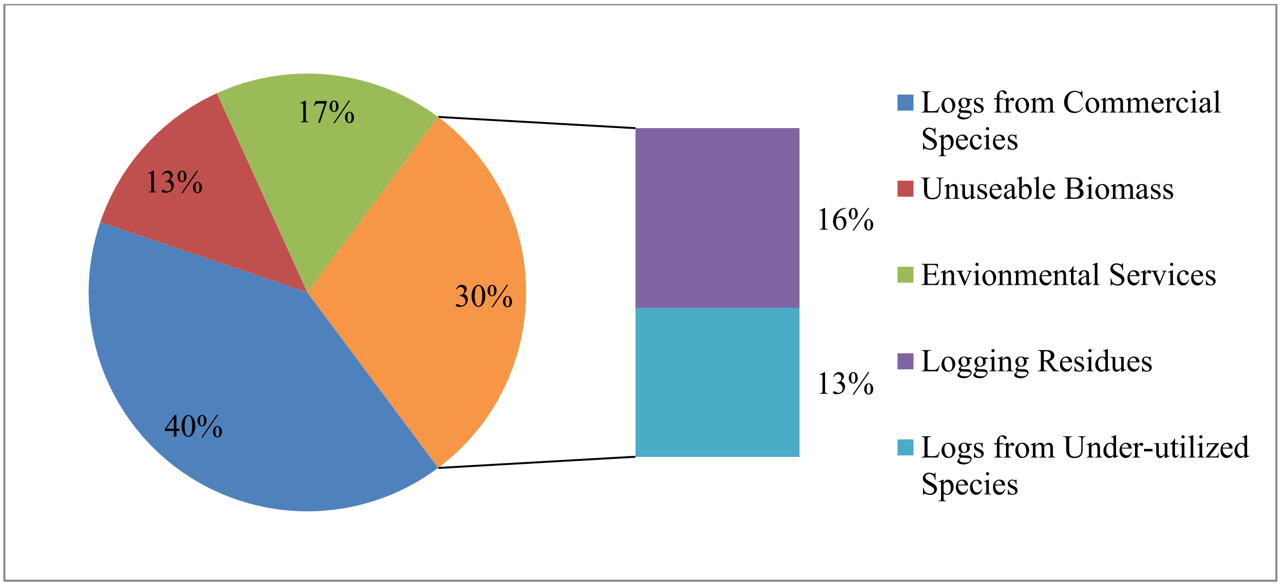

Figure 58. Potential sources of biomass in LSFN reserve land.

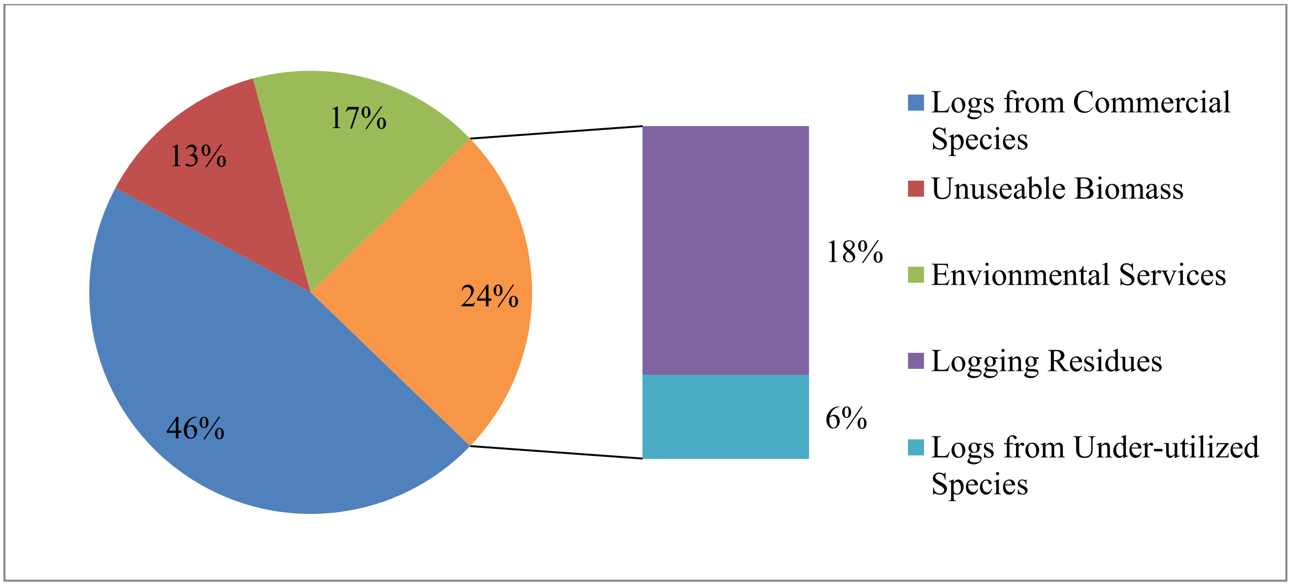

Figure 59. Potential sources of biomass in LSFN Crown land.

Figure 58 serves as a visual comparison between the areas on and off reserve land for each community. Both communities had lower volumes of on-reserve wood resources compared to the volumes found on Crown land, though the volume on LSFN reserve land was reduced because some wood, mainly pine species, was directed towards local business ventures and removed from the total volume (Brailsford 2011).

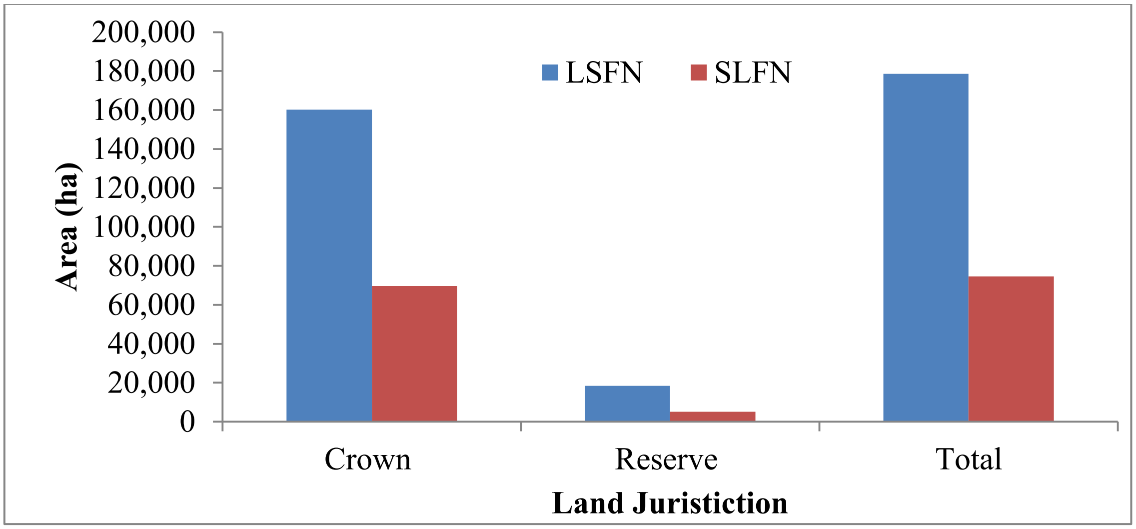

Figure 60. Difference in area available to the rural and remote communities.

However, it is noted that LSFN has slightly more volume on its land base than SLFN as is seen in Figure 59.

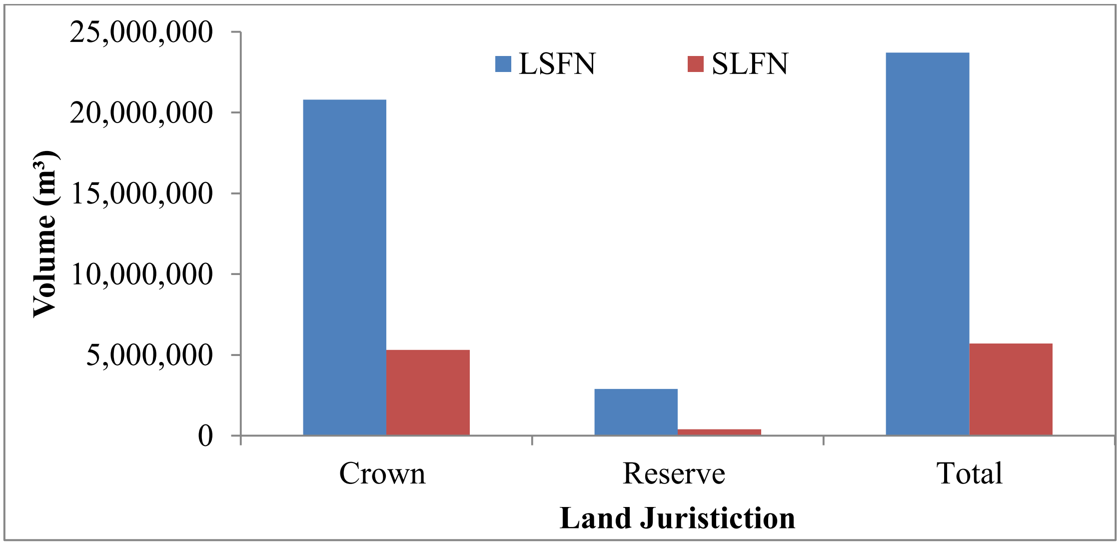

Figure 61. Differences in volumes present on LSFN and SLFN land bases sorted by on and off reserve land.

Statistical Analysis of the Forest Inventory

The ANOVA results of the forest inventory compared the field methods and sites with regards to volume and species composition. The data was tested for normality and homogeneity using the Shapiro-Wilk normality test and the Bartlett test of homogeneity of variances. This confirmed the assumptions used when analyzing parametric data: independence, normally distributed and homogeneity. The ANOVA indicated that for volume there was a significant difference between site and method but there was no significant difference between interaction of site and methods. For site and method, the null hypothesis is rejected in favor of the alternative (F1,47 = 5.38, p < .001) (F15,47 = 19.72, p < .001). The Tukey's HSD post hoc test showed that there were two homogenous subsets for site and method, rural and remote for site, and OMNRF species volume and LUWSTF species volume for method, although the was no difference in total volume for each site regardless of which method was employed.

The ANOVA indicated that for species composition there was a significant difference between site and method but there was no significant difference between interaction of site and methods. For site and method, the null hypothesis is rejected in favor of the alternative (F1,71 = 32.28, p < .001) (F1,71 = 31.65, p < .001). A post hoc test was not required for species composition as there were only two elements for each factor: site had rural and remote while method had LUWSTF and OMNRF.

Wood properties

A series of laboratory tests on wood properties were conducted according to ASTM Standards, including ash content, recoverable heat value, and wood density. This included ASTM E711-87 Standard test method for moisture analysis of particulate wood fuels, ASTM D1002-84 Standard test method for ash in wood, ASTM D5467-02 Standard test method for gross calorific and ash values of waste materials, and ASTM D2395-14 Standard test methods for density and specific gravity (relative density) of wood and wood-based materials.

Comparison between Wood Properties in LSFN and SLFN

When comparing the recoverable heat value of the solid wood (thermal potential), it was found that there is a difference between the thermal potential of tree species in SLFN and LSFN (Figure 60). Alder (15.3 MJ/kg and 13.1 MJ/kg, respectively), balsam poplar (14.18 MJ/kg and 12.8 MJ/kg, respectively), trembling aspen (13.98 MJ/kg and 13.1 MJ/kg, respectively), white birch (14.38 MJ/kg and 13.8 MJ/kg, respectively) and willow (15.3 MJ/kg and 14.4 MJ/kg, respectively) have a higher thermal value in SLFN compared to LSFN, while black spruce (13.83 MJ/kg and 15.9 MJ/kg, respectively) has a lower thermal value in SLFN compared to LSFN. Larch, white spruce and jack pine have roughly the same thermal value in both communities. Again, because cherry (Ch), eastern white cedar (Ce), white pine (Pw), mountain maple (Map), and red pine (Pr) were not sampled in SLFN, thermal properties for these species were not determined due to lack of time and resources. Table 7 offers the numerical values for recoverable heat value of solid wood (green) for SLFN, LSFN, and the published values used for comparison.

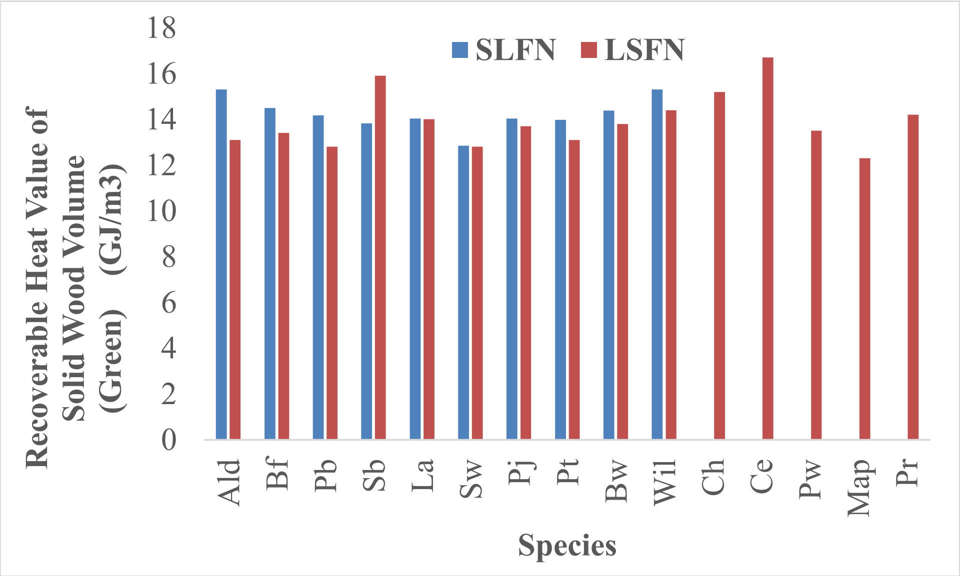

Figure 62. Comparison of thermal values between tree species in LSFN and SLFN.

Table 7. Comparison of thermal values.

Species	SLFN Results (Green) (GJ/m³)	LSFN Results (Green) (GJ/m³)	Published Results (Green) (GJ/m³)
Ald	15.3	13.1	13.1
Bf	14.5	13.4	13.3
Pb	14.18	12.8	13.5
Sb	13.83	15.9	12.4
La	14.04	14	14
Sb	12.85	12.8	12.6
Pj	14.04	13.7	12.8
Pt	13.98	13.1	12.9
Bw	14.38	13.8	12.6
Wil	15.3	14.4	14.4
Ch	N/A	15.2	15.2
Ce	N/A	16.7	14.6
Pw	N/A	13.5	14.9
Map	N/A	12.3	12.3
Pr	N/A	14.2	14.1

Figure 61 shows a comparison of ash content in tree species between LSFN and SLFN. Table 8 summarizes the ash values found in the study. Due to the absence of certain species on the land base in SLFN, ash content was not able to be determined for cherry (Ch), eastern white cedar (Ce), white pine (Pw), mountain maple (Map), and red pine (Pr) due to lack of time and resources. Overall, it was found that LSFN tree species had lower ash content when compared to SLFN.

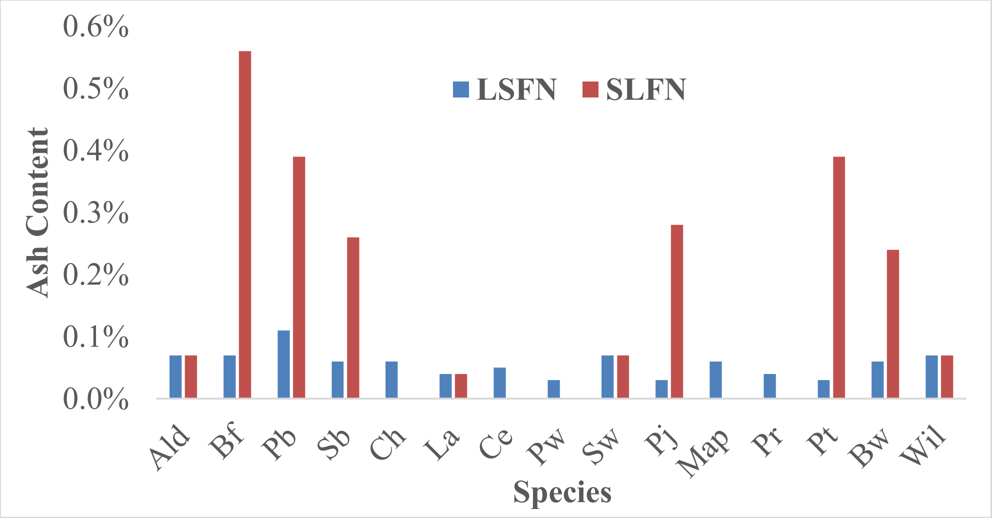

Figure 63. Comparison of ash content between tree species in LSFN and SLFN.

Table 8. Summary of ash content (%).

Species	*SLFN Results (%)*	*LSFN Results (%)*
Ald	0.07	0.07
Bf	0.56	0.07
Pb	0.39	0.11
Sb	0.26	0.06
La	0.04	0.04
Sw	0.07	0.07
Pj	0.28	0.03
Pt	0.39	0.03
Bw	0.24	0.06
Wil	0.07	0.07
Ch	N/A	0.06
Ce	N/A	0.05
Pw	N/A	0.03
Map	N/A	0.06
Pr	N/A	0.04

When comparing wood density, it was found that densities were roughly the same in both communities with some minor differences. The biggest differences were noted in white birch and trembling aspen. White birch had a higher density in LSFN compared to SLFN (775 kg/m³ and 653 kg/m³, respectively) as did black spruce (557 kg/m³ and 541 kg/m³, respectively). Trembling aspen had a lower density in LSFN compared to SLFN with a density of 685 kg/m³ and 596 kg/m³, respectively. Figure 62 demonstrates the comparison between the wood densities in LSFN and SLFN. Table 9 summarizes the actual values.

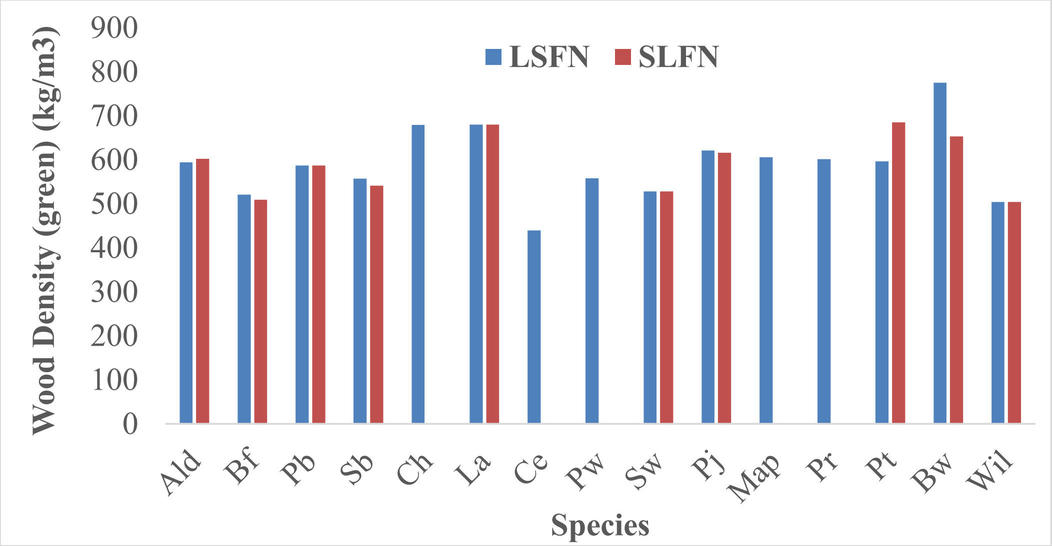

Figure 64. Comparison of wood densities between tree species in LSFN and SLFN.

Table 9. Summary of green wood density comparison for SLFN and LSFN.

Species	SLFN Results Green Density (kg/m³)	LSFN Results Green Density (kg/m³)
Ald	602	594
Bf	509	521
Pb	587	587
Sb	541	557
La	680	680
Sw	528	528
Pj	616	621
Pt	685	596
Bw	653	775
Wil	504	504
Ch	N/A	679
Ce	N/A	439
Pw	N/A	558
Map	N/A	606
Pr	N/A	601

Overall, it was found that the percentage of ash content in SLFN was higher compared to that of LSFN, while the thermal potential of SLFN was higher than LSFN with the exception of black spruce. Further, wood density was higher in SLFN compared to LSFN with the exception of trembling aspen. Species that were not found in each community were not able to be compared.

COMPARISON BETWEEN PUBLISHED VALUES AND LUWSTF RESULTS FOR WOOD PROPERTIES

Figure 62 compared the published (Jessome 2000) range of green wood density for the species present on the LSFN land base to those found in the study. Species that fall within the range of published densities include black and white spruce, cherry, larch, maple and willow. As a result of this study, alder, balsam fir, balsam poplar, cedar, white pine, red pine, jack pine, trembling aspen and white birch were found to be above the published range of green wood density for LSFN (see Figure 63). Table 10 summarizes the LUWSTF results compared to the published values.

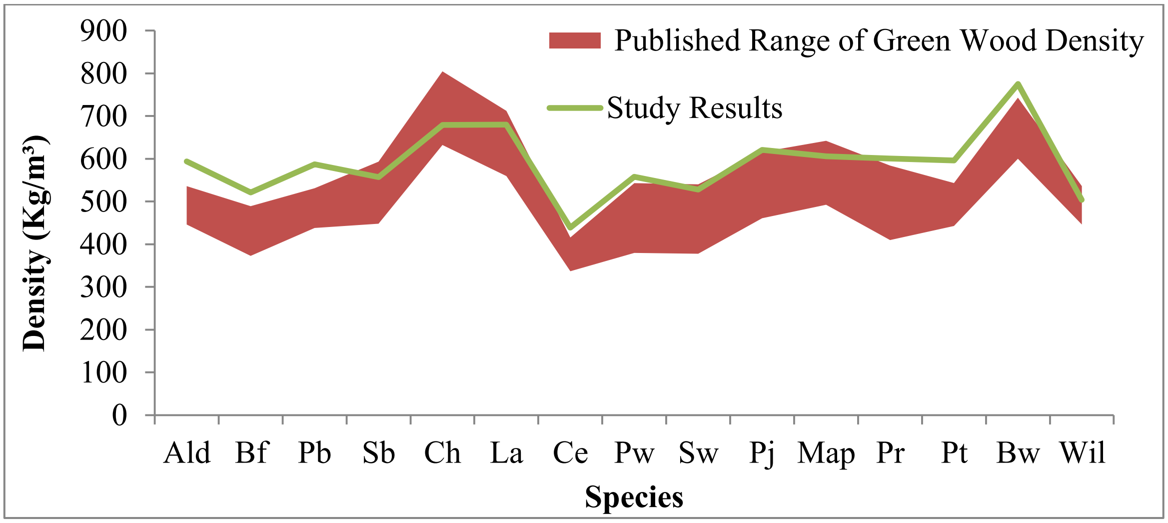

Figure 65. LSFN wood density comparison to published values.

Table 10. Comparison of LUWSTF results and published values for LSFN.

Species	Range of Wood Density (green) (kg/m³)		LSFN Results Green Density (kg/m³)
Ald	446	536	594
Bf	373	489	521
Pb	438	531	587
Sb	448	593	557
La	560	712	680
Sw	378	540	528
Pj	461	616	621
Pt	443	543	596
Bw	600	743	775
Wil	446	536	504
Ch	632	805	679
Ce	337	416	439
Pw	380	543	558
Map	492	642	606
Pr	410	584	601

Figure 60 shows the results of wood density tests for species found in SLFN compared to published values (Jessome 2000). Once again, white and black spruce, cherry, willow, white birch, and larch are within the range of published values (Jessome 2000). In the case of white birch, it falls within the published range of green density for SLFN but not LSFN. Species that were found to have a higher density than published values include alder, balsam fir, balsam poplar, trembling aspen, and jack pine (see Figure 60). Table 10 gives a summary of these values.

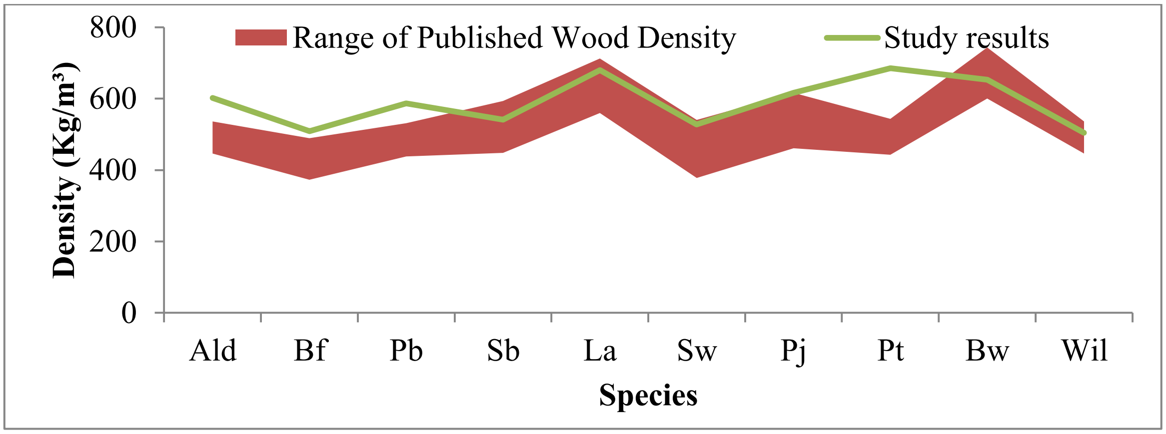

Figure 66. SLFN wood density comparison to published values.

Table 11. Summary of green wood density comparison between LUWSTF results and published values for SLFN.

Species	Range of Wood Density (green) (kg/m³)		SLFN Results Green Density (kg/m³)
Ald	446	536	602
Bf	373	489	509
Pb	438	531	587
Sb	448	593	541
La	560	712	680
Sw	378	540	528
Pj	461	616	616
Pt	443	543	685
Bw	600	743	653
Wil	446	536	504

In order to compare thermal potential for the species in the study compared to published values, Figures 65 and 66 were developed. Figure 65 demonstrates the difference between published gross heat for green wood (thermal potential) expressed as MJ/kg for the tree species sampled in SLFN. It can be seen that all species in SLFN have a higher thermal potential than published values (Singh 1982; Singh and Kostecky 1986; Hosegood 2011). Table 12 shows the actual values for this comparison.

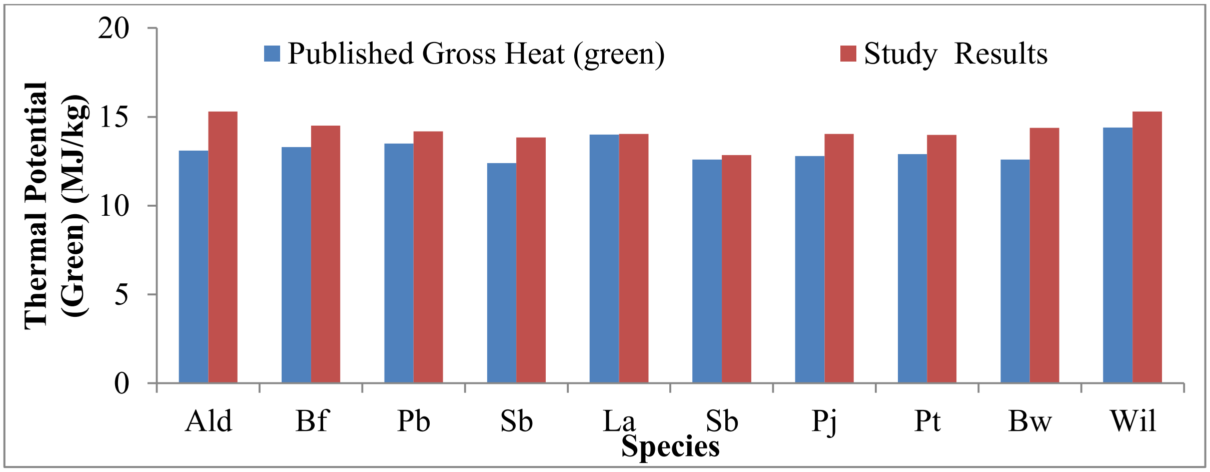

Figure 67. SLFN comparison between green published thermal values and LUWSTF results.

Table 12. Summary of published values and LUWSTF results used for comparison for SLFN.

Species	SLFN Results(Green)(MJ/kg)	Published Results(Green)(MJ/kg)
Ald	15.3	13.1
Bf	14.5	13.3
Pb	14.18	13.5
Sb	13.83	12.4
La	14.04	14
Sb	12.85	12.6
Pj	14.04	12.8
Pt	13.98	12.9
Bw	14.38	12.6
Wil	15.3	14.4

Figure 66 compares the thermal potential of tree species in LSFN to published values. Table 13 summarizes this information. Willow, cherry, alder, larch and maple were found to have the same thermal potential in both published values and study results. Black spruce, white birch, jack pine and cedar were found to have a higher thermal potential compared to published values, while balsam poplar and white pine were found to have a lower thermal value compared to published values. Balsam fir, red pine, white spruce, and trembling aspen differed slightly from published values, but were found to be quite close to published values.

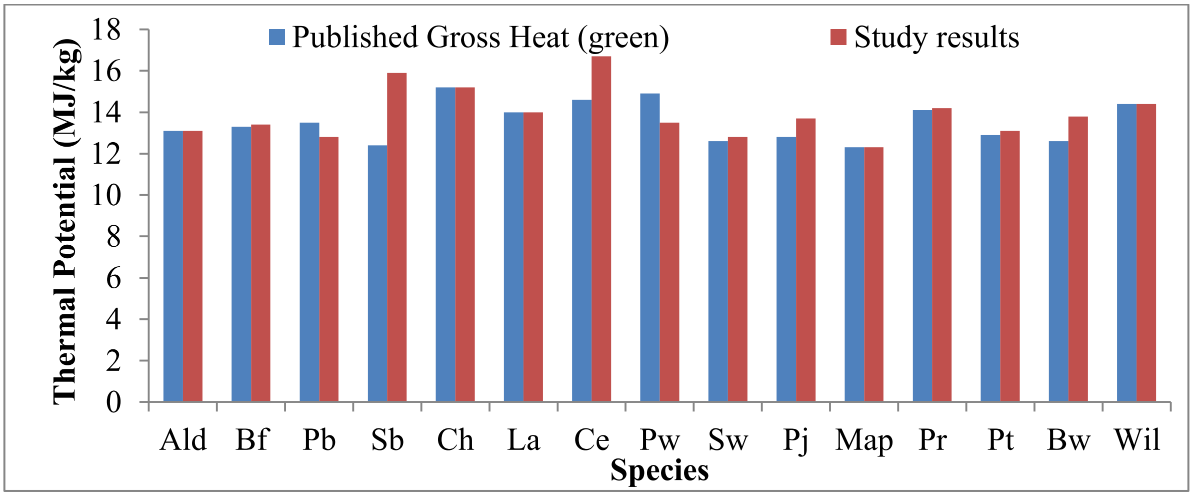

Figure 68. LSFN comparison between published thermal values and LUWSTF results.

Table 13. Summary of LUWSTF results and published values for LSFN.

Species	LSFN Results(Green) (MJ/kg)	Published Results (Green) (MJ/kg)
Ald	13.1	13.1
Bf	13.4	13.3
Pb	12.8	13.5
Sb	15.9	12.4
La	14	14
Sb	12.8	12.6
Pj	13.7	12.8
Pt	13.1	12.9
Bw	13.8	12.6
Wil	14.4	14.4

A separate comparison was done between published ash content for particular tree species and the ash content of the same tree species found in SLFN and LSFN. Figures 67 and 69 demonstrate this comparison. It is important to note that there are very few published ash values for these species in this particular region.

In Figure 67 we see the SLFN ash content in wood as determined by this study compared to published values. Table 14 gives a summary of published values and results. It can be noticed that alder, white spruce and willow do not have published ash values for this region. Balsam fir, larch, black spruce and white birch yield lower ash content than was previously published (Zhurinsh 1997; Hosegood 2010; Avelin 2014), while jack pine, trembling aspen, and balsam poplar yield a higher ash content from this study compared to published values (Hosegood 2011).

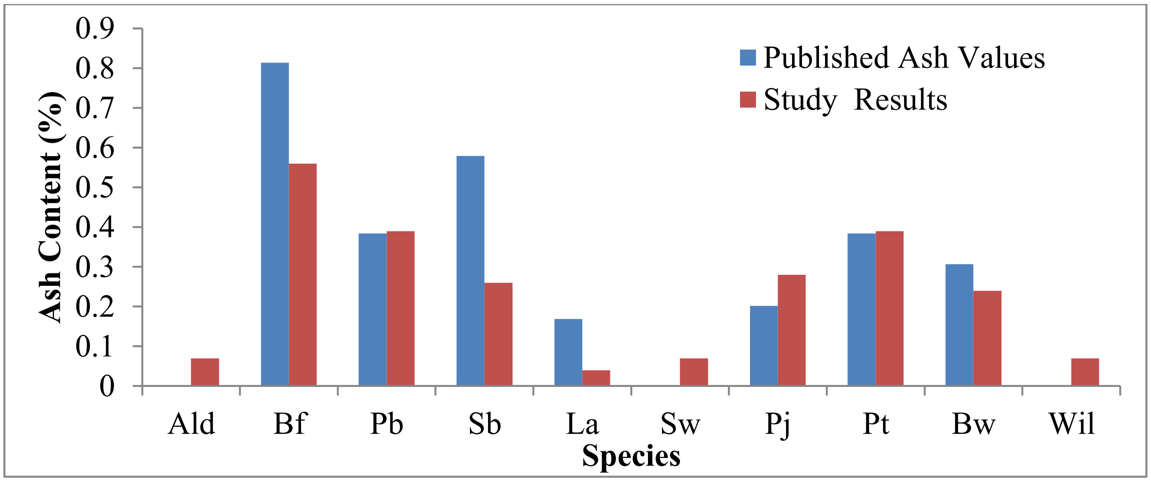

Figure 69. SLFN ash content in wood compared to published values.

Table 14. Summary of LUWSTF results and published values for SLFN.

Species	Published Ash Values (%)	SLFN Results (%)	LSFN Results (%)
Ald	0.680	0.07	0.07
Bf	0.814	0.56	0.07
Pb	0.384	0.39	0.11
Sb	0.579	0.26	0.06
La	0.169	0.04	0.04
Sw	0.220	0.07	0.07
Pj	0.202	0.28	0.03
Pt	0.384	0.39	0.03
Bw	0.307	0.24	0.06
Wil	0.680	0.07	0.07
Ch	0.680	N/A	0.06
Ce	0.260	N/A	0.05
Pw	0.300	N/A	0.03
Map	0.680	N/A	0.06
Pr	0.300	N/A	0.04

Figure 68 demonstrates the ash content in tree species found in LSFN compared to published values (Zhurinsh 1997; Hosegood 2010; Avelin 2014). Table 15 summarizes the published values and results. All species that underwent laboratory tests to determined ash content as a percentage of solid wood yielded less ash than previously published.

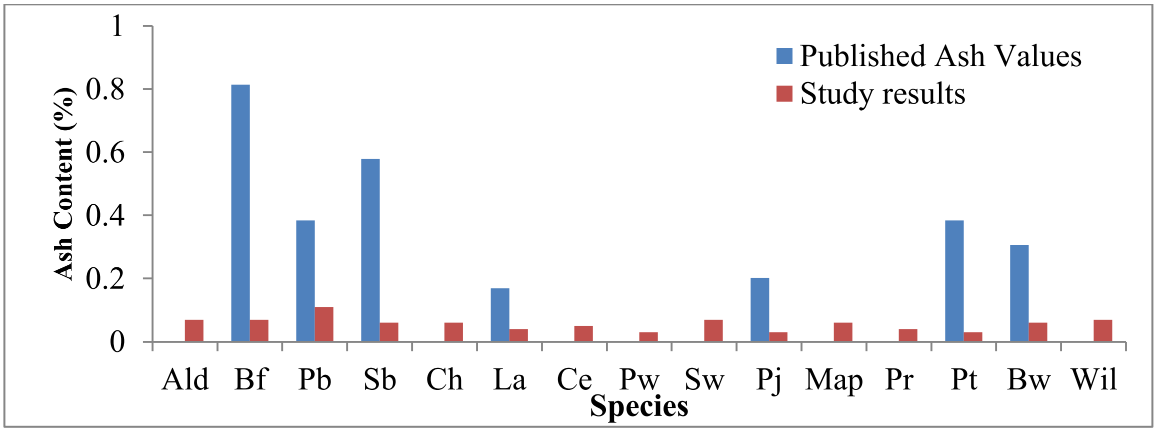

Figure 70. LSFN ash content in wood compared to published values (Hosegood 2011).

Table 15. Summary of LUWSTF results and published values for LSFN.

Species	Published Ash Values (%)	LSFN Results (%)
Ald	0.680	0.07
Bf	0.814	0.07
Pb	0.384	0.11
Sb	0.579	0.06
La	0.169	0.04
Sw	0.220	0.07
Pj	0.202	0.03
Pt	0.384	0.03
Bw	0.307	0.06
Wil	0.680	0.07
Ch	0.680	0.06
Ce	0.260	0.05
Pw	0.300	0.03
Map	0.680	0.06
Pr	0.300	0.04

Statistical Analysis of the Wood Properties

The ANOVA results of the wood properties compared the published data and sites with regards to wood density, thermal values and ash content. The data was tested for normality and homogeneity using the Shapiro-Wilk normality test and the Bartlett test of homogeneity of variances. This confirmed the assumptions used when analyzing parametric data: independence, normally distributed and homogeneity. The ANOVA indicated that for wood density and thermal potential there was no significant difference between site and published values with interactions pooled. For site and published, the null hypothesis is accepted ($F2, 37 = 2.288$, $p < .116$) ($F2, 37 = 1.569$, $p < .222$) respectively. The ANOVA for ash indicated there was a significant difference between site and published values with interactions pooled. For site and published values, the null hypothesis is rejected in favor of the alternative ($F2, 37 = 21.85$, $p < .001$). A Tukeys HSD was completed on the ANOVA results and nine homogeneous subsets were identified as shown in Table 16.

Table 16. Post hoc subsets and species.

Post Hoc Subset	Species
Remote and rural significantly different to published	alder, larch, white spruce and willow
Remote and published significantly different to rural	balsam fir, white birch, balsam poplar, Jack pine, trembling aspen, black spruce
Rural and published significantly different to remote	None
Published and rural not significantly different	red pine, white pine
Published and rural significantly different	alder, balsam fir, white birch, cedar, cherry, larch, maple, balsam poplar, Jack pine, trembling aspen, black spruce, white spruce and willow
Published and remote not significantly different	balsam poplar, Jack pine, trembling aspen
Published and remote significantly different	cedar, cherry, maple
Remote and rural not significantly different	alder, larch, white spruce, and willow
Remote and rural significantly different	balsam fir, white birch, balsam poplar, trembling aspen, Jack pine, and black spruce

CHAPTER 5: DISCUSSION

This section will focus on discussing the results of the study, give potential reasons for why the results differ, and how the results may affect future studies or demonstration projects using biomass for BDHP operations.

FOREST INVENTORY RESULTS (HYPOTHESIS 1)

The major difference between the inventory outcomes using LUWSTF methods and OMNRF is the species composition of the forest. In both LSFN and SLFN Crown and reserve land, the volume calculated was the same using both methods in SFMM, but the percentage of the total volume occupied by each species was different. There was an overestimation of the dominant species as determined in the OMNRF methods, and an underestimation of the minor species that are often not recorded. These differences may be a result of the OMNRF methods targeting the dominant species because these are the species that would often generate sawlogs or pulpwood, while ignoring those species that make up <10% as they would not contribute a large amount to the overall volume and are often not used for traditional forest products (OMNR 2009). Given that forest management in the past has targeted these species in order to maximize production, it is understandable that the methods of calculating species composition favour the reporting of target species.

However, problems arise when the volumes of dominant species are overestimated, harvesters/management companies are harvesting less of the desirable species, and there is increased waste due to the presence of undesirable species that were not recorded in the inventory (Penner et al. 1997, Zheng et al. 2007). By recording the percent composition of all species on the land base, it is possible to get a more accurate picture of the forest on the land base and therefore be able to better manage for waste from harvest operations. Knowing the complete species composition allows better planning, particularly for the allocation of wood resources for biomass operations, which could utilize those species not allocated to sawmills or pulp mills, and the tops, branches, undesirable tree forms, and shrub species (Zheng et al. 2007, Alam et al. 2008). For example, Alam et al. (2012) stated “woody biomass may also be collected from underutilized wood (UW) species, which are not commercially important for lumber and pulpwood production.”

One factor, which may contribute to discrepancies between the FRI and the Provincial Land Cover 2000-27 Classes and the study results may be the timing of the different inventories. As Thompson et al. (2007) noted in their report, it is important to conduct inventories as close as possible in time to when the aerial photos are taken in order to have correct verification of forest conditions. Both the FRI and Provincial Land Cover 2000÷27 Classes were conducted more than a decade before the current study. This may lead to discrepancies between the study data and the inventory and stand delineation data (Thompson et al. 2007). For example, the GIS data used in this study was produced in 2002 (OMNR 2002) and our sampling was completed in 2014. The data specifications state that: the “percentages of deciduous and coniferous forest estimated using satellite imagery may not align with field based estimates resulting in a source of field-remote mapping discrepancy” (OMNR 2002), and lands labelled as treed wetlands could be confused with coniferous sites. Thompson et al. (2007) found that of the 129 stands sampled, 83 were classified incorrectly by species composition, and approximately 30% were incorrectly classified by dominant forest group such as conifer, mixedwood, and deciduous. Further, Thompson et al. (2007) found that 10-20% less softwood fibre was available on the land base for harvest than originally predicted from the FRI. The study also found that there was more poplar than predicted in the original FRI in the 30-50 year age class. The study did not quantify the economic impacts of this miscalculation.

Overall, the data from this study rejects the first null hypothesis that states that the outcomes of the provincial methods and this study will not be different, and supports the hypothesis. The difference between the outcomes is not in the total volume, but in reporting the volumes of all species present on the land base, not simply the dominant species.

WOOD RESOURCES AVAILABLE TO RURAL AND REMOTE COMMUNITIES

There appear to be five major differences between the wood resources available to the rural community compared to the remote community: i) the number of species present; ii) the area of the reserve land and surrounding Crown land; iii) the total volume present on the land base; iv) the growth rate; and v) access to commercial forest operations.

In LSFN, there are more species found on the land base with a total of 16 species compared to 10 species found in SLFN. This may be a result of longer growing seasons experienced at a more southern latitude or a result of the different soils found in the LSFN area compared to those in SLFN which may favour the growth of different species (Botkin and Simpson 1990, Krawchuk et al. 2012). Species not found in SLFN that were found in LSFN include cherry species, maple species, white and red pine, and eastern white cedar. This may be due to the location of LSFN and the environmental conditions it experiences. For example, the soil type is found to different than those found in SLFN, being more fertile and rich. The area experiences a longer growing season and less harsh winters compared to SLFN (Kemp 1991) and may be influenced from warm fronts moving across the prairie provinces or northern prairie states (Botkin and Simpson 1990; Krawchuk et al. 2012). Further, it is located closer to the GLSL forest region and may be in the transition zone, which means that one would see some more southern species in the forest composition.

The second major difference between the communities is the amount of area on and off reserve land (shown in Figure 69) that the community may access providing proper arrangements are made with federal or provincial ministries. LSFN has a total on-reserve area covering 18 438 ha; volume estimates were calculated for the off-reserve land in the Lac Seul Forest within a 150 km haul distance of the major community center of Frenchman's Head. The off reserve area provided an additional 160 192 ha for a total of 178 630 ha. This number was determined by the principle investigator who wanted to demonstrate the amount of volume present on the land base which could theoretically support a BDHP. Comparatively, SLFN has a total on-reserve area of 5 031 ha, with the area surrounding the community totaling 69 611 ha for a grand total of 74 642 ha. The available area was restricted by the limited roads to access the various areas of off-reserve land. The difference in area that each community could access has influenced the volumes available on each community's land base.

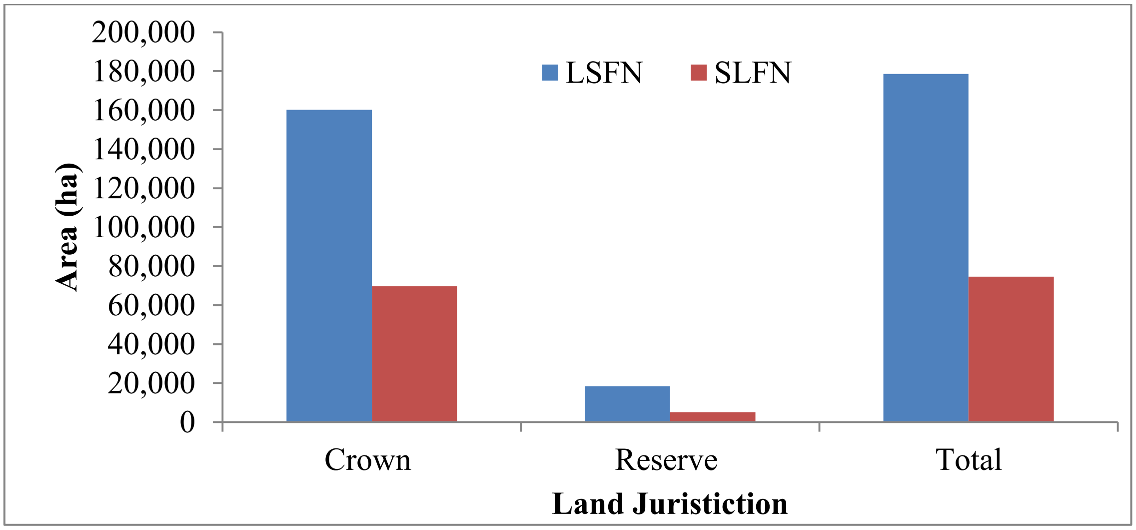

Figure 71. Difference in area available to the rural and remote communities.

The third difference between the rural and remote community is the amount of volume present on the land base. Once again, the pine species present on the LSFN reserve land were allocated to the local mills and log home ventures and were removed from the study volume (Brailsford 2011). Further, there are three communities on the LSFN land base, which further reduces the forested area on reserve.

The fourth difference in the forest resources in each community is the growth rate of the forests. LSFN was found to have a faster growth rate at 3m^3/ha/year compared to 1.75m^3/ha/year in SLFN. This again may be a result of shorter growing seasons in SLFN compared to LSFN (Hirsikko et al. 2005) or the different growing conditions in the southern rural community of LSFN compared to the northern remote community of SLFN (Bonan and Shugart 1989; Krawchuk et al. 2012).

In regards to the fifth difference noted between the two communities—access to commercial forest operations—a greater amount of forest resources was found to be available to the rural community compared to the remote community (see Figures 56 and

57). Sachigo Lake First Nation has greater restrictions on the amount of forest resources available, including limitations set by provincial policies such as Ontario's Far North Act (2010) and the Indian Act (1987). These areas have restrictions on growth due to the increased pressure to protect the boreal forest which has limited how communities living in the Far North region can utilize their resources. Though the Far North Act does not apply to reserve land, the Indian Act does. However, the Indian Act is not a perfect system, is outdated, and the governing body AANDC focuses more on water and waste issues than timber harvesting on reserve land. Despite there being a surplus of wood resources in the Crown forests surrounding the community, there exist limitations in the Far North Act and the Indian Act which may prohibit the use of resources in the immediate future (Smith 2015).

Lac Seul First Nation experiences fewer limitations to access forest resources than Sachigo Lake First Nation as opportunities in forest management are already in place. This includes holding the license for forest operations on the surrounding forest (Brailsford 2011). Given that harvest operations are taking place on the surrounding land base, biomass may be captured as harvest waste from existing forest operations, and the presence of a sawmill in nearby Hudson can provide additional biomass through wood scraps and waste (McKendry 2002; Puddister et al. 2011). Additionally, within the Lac Seul FMU, LSFN has been given an area to manage for community usage (Brailsford 2011) by the province. If sufficient biomass cannot be captured from harvest or mill byproducts, the reserve lands or lands set aside for LSFN can be managed to produce biomass. One area that is set out in the FMP (Brailsford 2011) is to eliminate the balsam fir content which could provide a resource of biomass during other management activities. The amount of balsam fir on the land base is higher than the historic average due to fire suppression and lack of replanting during the 1970’s. The community and the FMP have identified that they would like to reduce the amount of balsam fir on the land base to a historic average. Another area that can provide biomass is managing to improve forest health. In this area, roads and infrastructure are not limiting.

The terms “available” and “accessible” used in this report do not imply that communities are legally able to access these resources. It simply means that the resources are present on the land base and can be accessed providing the requirements of the provincial and federal legislation are met. For LSFN, amendments can be made to the FMP which would allow for wood flow to biomass facilities and may include further agreements with nearby mills. Historically, the softwood from the LSF has been destined for: MacKenzie Forest Products Inc. in Hudson, Ontario; Abitibi Consolidated Company of Canada in Fort Frances (shut down at the time of writing); Domtar Inc. in Dryden, Ontario; Bowater Canadian Forest Products Inc. in Thunder Bay; Atikokan Forest Products Ltd. in Sapawe, and Terrace Bay Pulp Inc. Hardwood species were sent to Weyerhaeauser Company Ltd. in Dryden, Ontario; Domtar Inc. in Dryden Ontario; Northern Sawmills Inc. in Thunder Bay; for commercial energy production at the AbitibiBowater mill in Fort Frances (shut down at time of writing); Bowater Canadian Forest Products Inc. in Thunder Bay, and Buchanan Northern Hardwoods Inc. in Thunder Bay (Brailsford 2011). According to the 2011-2021 Lac Seul Forest FMP, the wood is destined for MacKenzie Forest Products Inc. in Hudson to be manufactured into lumber and to Domtar Inc. in Dryden. There were other mills open at that time that are now closed, such as the AbitibiBowater mill in Fort Frances, and mills that were closed at the time which are now open, such as MacKenzie Forest Products Inc. in Hudson, Ontario. In the current management plan, biomass for the purpose of supplying a BDHP is not addressed (Brailsford 2011). On reserve land, the areas surrounding the community are generally used for hunting, hiking, fuelwood and as a buffer between homes and communities while some logs are used in the construction of log homes. This volume has yet to be quantified. The Indian Act essentially limits harvesting on reserve land until an approved plan is in place, but is not strongly adhered to by the governing body AANDC or the community itself.

In summary, the research conducted in this study supports the rejection of the null hypothesis and accepts the hypothesis that there is a difference between the wood resources available to the remote community compared to the rural community. These differences can be seen in the total volume and area for each community, the species present, the growth rate of the forest, and the access to commercial forest operations.

WOOD PROPERTIES

Several differences can be seen in wood properties between the rural and remote communities. These include ash content, recoverable heat value of solid green wood also referred to as thermal potential, and wood density. The first property compared was ash content. As was noted in the previous section, there were some species that were not present in both communities (i.e. cherry species, eastern white cedar, white and red pine, and mountain maple) and thus these species were not able to be compared between communities. The statistical analysis showed the ash content to be quite variable, with significant differences between the two sites and between sites and published values. As Bioenarea (2012) points out “the ash content may originate from the biomass itself, e.g.

materials that the plant absorbed from the water or the soil during its growth, or from the supply chain, e.g. soil collected along with biomass." However, both published and tested values for these species showed their ash content to be below 1%; thus the variability of the ash content is not an issue. According to Thek and Obernberg (2010) ash content should be 0.7% or less to meet European Union standards for wood pellets, while the Pellet Fuel Institute (2010) defines acceptable ash content to be equal to or less than 1%.

Ash content is not a limiting factor for the use of biomass in either community; the ash content falls below the threshold of 3% for commercial ventures and 1% for domestic heating (Tarasov 2014). Öhman et al. (2002) recommend that ash-rich fuels, such as logging residues and bark, should not be used in residential pellet boilers. Ash must be managed in order to maintain proper function of the BDHP and prevent slagging/residue buildup by regularly cleaning the wood boiler system (Bioenarea 2012). Öhman et al. (2004) also notes that the strength of ash deposits (sintering/slagging) was greatly affected by the fuel composition, which highlights a need for careful planning of biomass fuel sources to the BDHP. Additional planning must be done to ensure that waste disposal areas can support the increased amount of ash entering landfills (James et al. 2012). James et al. (2012) noted that when there is an increase in the use of biomass for energy, so too do the volumes of ash and residue entering landfills. Bark and foliage have higher ash content than pure wood (Baxter 1993). For example, Hakkila (1989) points out that average ash content of bark is 2.97%, while stem wood generally contains 0.3±0.1% ash content for softwoods and 0.5±0.3% for hardwoods. If the intent is to use harvest residues in the case of LSFN, then ash may be an issue. Further, James et al.

(2012) highlight the major concern of an increased use of wood fuel, which is the need to create storage, disposal, and use of the ash (James et al. 2012). In areas where landfill expansion can be limited, there is an issue of increased ash volume leading to a decrease in space available in landfills for storage of waste (James et al. 2012). Some studies have been done which look at the effects of spreading ash in the forest or for other industrial purposes (Campbell 1990; Demeyer et al. 2001; Pitman 2005; Abdullahi 2006 James et al. 2012). It is unsure at this time what the most cost-effective method at disposing of ash waste is in these communities, though simple disposal in landfills may be the ideal option until another usage becomes operationally and economically feasible. In some areas, ash may be used as a liming agent for roads, as a replacement for cement in concrete (Abdullahi 2006) or in gardens as a fertilizer (Naylor and Schmidt 1986; Pitman 2005). Care must be taken when using ash in gardens as it produces lye and salt when wet which, in small quantities, does not damage plants; in large amounts it may burn plants (Naylor and Schmidt 1986). Further studies are needed to determine the proper use for ash in these communities.

Both communities are below the threshold for ash. However, if either decides to use diseased wood, or primarily tops and branches, moisture content and ash content must be monitored. Further, with an increase in ash content, there exists potential to lead to an increased amount of waste in a landfill or to buildup of residues in boilers which cause them to be inefficient. However, there are alternate uses for ash. This includes as a liming agent for roads, an additive for concrete/cement/asphalt, fertilizer for gardens, and potentially respreads in forests. Further exploration regarding the most cost-effective methods for utilizing ash waste is required. MC must be monitored and maintained to ensure thermal potential. This can be done by planning for storage and drying methods. Roadside drying of slash piles or a storage bunker for chip drying are two options. When planning for a BDHP operation, forest inventories and management plans can include calculations of wood volume required based on thermal potential, rather than simple wood volume.

The second wood property compared was the recoverable heat value of solid wood, also referred to as thermal potential. The statistical analysis showed no significant differences in thermal potential between sites and published values relative to species. Larch, white spruce, and jack pine had roughly the same thermal values in SLFN and LSFN, while alder, balsam poplar, trembling aspen, white birch, and willow had a higher thermal potential in SLFN compared to LSFN. This may be a result of higher density wood in SLFN that would yield a greater recoverable heat value. Tarasov (2014) states, “heating value depends on the particular wood’s density, in other words how much mass is contained in each unit volume.” Black spruce was the only species with a lower recoverable heat value in SLFN compared to LSFN. The difference in thermal values relative to published values may be due to the lack of studies conducted in northern areas of the province.

The third wood property compared was the wood density of the available tree species in both communities. The statistical analysis showed no significant differences in wood density between sites and published values relative to species. There was some variability in density observed in white birch, which had a higher density in LSFN compared to SLFN, while black spruce and trembling aspen exhibited lower densities. The differences in densities may be attributed to different growing seasons and growth rates, or differences in site conditions. Miller (2010) points out that site factors leading to phenotypic variation within a tree species can account for substantial variation in wood density.

With regards to thermal properties and the recoverable heat values of wood from the selected tree species, the SLFN samples appear to have a greater recoverable heat value compared to the published values. Because recoverable heat values are closely linked to density, and wood densities were found to be higher in SLFN compared to the published values, these higher densities may help explain the differences in recoverable heat values. For LSFN, we see some species—balsam fir, black spruce, cedar, jack pine, red pine, trembling aspen and white birch—with a higher recoverable heat value than the published values. This again may be closely linked to a higher density wood in the area which in turn generates a higher recoverable heat value. In some cases, particularly for balsam poplar and white pine, it can be seen that the published results have a lower recoverable heat value than the published values. Overall, the recoverable heat values for the species in LSFN were closer to published values than SLFN. This may be a result of prior research being conducted on these species in similar latitudes or growing conditions.

The density and thermal potential of wood will not limit the use of biomass for district heating purposes in either community. Higher wood density leads to a greater thermal potential per unit of wood, and results in a lesser amount of wood needed to create the same amount of energy compared to wood with a lower density (Ragland et al. 1991). For example, Miller (2015) found that since SLFN was found to have a higher thermal potential, they will need to harvest less wood to produce the same amount of energy compared to LSFN. Calculating harvest volumes required for BDHP operations includes wood properties such as wood density, moisture content and thermal thermal potential calculations as opposed to simple volume estimates (Sandström et al. 2007; Alam et al. 2012). This may lead to a more accurate figure of how much wood volume is needed to produce the required amount of heat.

One wood property that is important to monitor is the moisture content of wood. The greater the moisture content, the lower the density and thermal potential (Guatam et al. 2010). If moisture content is greater, then the amount of space per unit of wood is filled with moisture, and if there exists a greater ratio of airspace to wood, the density is lower and the moisture can be higher as it is filling the empty spaces in wood cells. If density is low and moisture content is high, the thermal potential will be lower thus it is important to maintain proper moisture content for the wood boiler units else they will decrease efficiency and ultimately break down. Disease and rot can lead to a decrease in density (Sandström et al. 2007). If the community plans to improve forest health and remove the dead, dying and diseased for biomass, further studies could be done to determine density, thermal potential, and ash content of diseased trees.

The results of this study suggest that the wood properties of the forest resources included in this study differ from published properties. Some species exhibit the same or similar properties while some are vastly different. In terms of density, it was noted that some species in LSFN—alder, balsam fir, balsam poplar, cedar, white pine, red pine, jack pine, trembling aspen and white birch—were found to be above the published range of green wood density. Similarly, in SLFN, alder, balsam fir, balsam poplar, trembling aspen and jack pine were found to have higher density than the existing published values. This may be because the literature lacks published wood density for the further north areas in Ontario.

In summary, the data suggests that we accept the null hypothesis and offers support for the hypothesis that there is a no difference between wood properties measured in the rural community compared to the remote community. Although it was observed that the percentage of ash content found in SLFN was higher compared to that of LSFN, both were under 1% and within standard’s thresholds. Similarly, while the thermal potential of SLFN was higher than LSFN with the exception of black spruce, the values were not significantly different. Further, wood density was higher in SLFN compared to LSFN with the exception of trembling aspen; however, not significantly different.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF ARGUMENTS

Several conclusions can be inferred from this research. To address the hypotheses of the study: There is a difference between government-generated forest inventory methods and outcomes and the study methods and outcomes; there is a difference between the forest resources present in a rural community compared to a remote community; there is no difference between the published wood properties and the properties sampled in this study; and there is no difference between the wood properties in the remote community compared to the rural. The inference for this study is limited to LSFN and SLFN and the Crown land surrounding the two communities.

The difference between the two forest inventory methods outcomes can be attributed to the inclusion of all species when determining species composition (LUWSTF methods), not simply the lead species (OMNRF methods). This gives a more accurate representation of the species present on the land base, which may allow for better forest management planning, particularly for biomass which is currently not considered in management plans. The difference in forest resources present in each community may be attributed to the locations at different latitudes, which present different growing conditions that would accommodate a greater or lesser variety of species.

Although there is no significant difference between published wood properties and those determined by this study, the variability observed between communities and published values may be attributed to the lack of published wood properties from northern locations, specifically, northwestern Ontario. There exist some published values from the Atikokan area in northwestern Ontario, but none from the Far North region. Further, and this is reiterated when explaining the fourth hypothesis, the variability in densities can be attributed to the slower growing forests found in the northern boreal. The variability between wood properties in the rural and remote communities can be explained somewhat by the different growing conditions experienced in the two communities. The community located further north overall had higher ash content, density, and recoverable heat value compared to the community located further south. Conversely, Hosegood (2011) found no statistical differences in thermal potential and ash content when comparing these values from tree species found near Thunder Bay, Ontario and Atikokan, Ontario. These communities are located roughly at the same latitude about 200 km apart from each other longitudinally. Although the study is similar, the communities are not separated by the same geographical space, particularly in the latitudinal aspect. This summarizes the overall findings of this study.

Although the studies which attempt to quantify and qualify the amount and quality of the wood resources present in each community for the purpose of supplying biomass to a district heating operation, the issue of how to acquire the resource remains. There are processes, procedures, and mechanisms through which communities are able to access the resources through the governing federal and provincial departments, yet they are not necessarily easy for communities to navigate. For example, the process of applying and attaining a C-bLUP can be costly, as the communities of Pikangicum First Nation and Cat Lake–Slate Falls First Nations have found when undergoing the process. It would be important for each community to consider the next steps of the project, how they would acquire the necessary funds and resources, and what the long-term goals are for community improvement and forest management.

FUTURE STUDIES

This study highlights the need for a number of further studies. To proceed further with the potential installation of a BDHP in one rural and one remote community, a feasibility study is required which includes a business plan, engineering reports, and a more-detailed look into the policies which govern how resources may be used by a community. Before projects can begin, it is important to have an understanding of the policies and subsidies which impact how communities are able to access and acquire funds and resources. An in-depth review of the policies would present an interesting research project or study, as well as a review of the agencies that monitor and ensure regulations are being followed and those that provide incentives for renewable energy projects which may allow for a greater chance of success and longevity of BDHP installations. As communities choose to move forward with various renewable energy projects, there exists greater opportunities for future studies to explore conditions for successful implementation.

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APPENDICES

APPENDIX I FOREST INVENTORY ANALYSIS DATA

Site	Authority	Method	Species	Volume	Percent Species Composition
Rural	Crown	LUWSTF	Pj	10314214	46.17
Rural	Crown	LUWSTF	Pr	0	0
Rural	Crown	LUWSTF	Pw	0	0
Rural	Crown	LUWSTF	Bf	1880336	8.42
Rural	Crown	LUWSTF	Sb	8122868	36.36
Rural	Crown	LUWSTF	Sw	0	0
Rural	Crown	LUWSTF	Ce	100284	0.45
Rural	Crown	LUWSTF	La	0	0
Rural	Crown	LUWSTF	Pt	1083928	4.85
Rural	Crown	LUWSTF	Pb	0	0
Rural	Crown	LUWSTF	Bw	704128	3.15
Rural	Crown	LUWSTF	Map	0	0
Rural	Crown	LUWSTF	Ald	133712	0.6
Rural	Crown	LUWSTF	Wil	0	0
Rural	Crown	LUWSTF	Ch	0	0
Rural	Crown	LUWSTF	AmS	0	0
Rural	Crown	OMNRF	Pj	9567916	42.83
Rural	Crown	OMNRF	Pr	0	0
Rural	Crown	OMNRF	Pw	0	0
Rural	Crown	OMNRF	Bf	2958269	13.24
Rural	Crown	OMNRF	Sb	8253263	36.94
Rural	Crown	OMNRF	Sw	0	0
Rural	Crown	OMNRF	Ce	0	0
Rural	Crown	OMNRF	La	0	0
Rural	Crown	OMNRF	Pt	1197860	5.36
Rural	Crown	OMNRF	Pb	0	0
Rural	Crown	OMNRF	Bw	362161	1.62
Rural	Crown	OMNRF	Map	0	0
Rural	Crown	OMNRF	Ald	0	0
Rural	Crown	OMNRF	Wil	0	0
Rural	Crown	OMNRF	Ch	0	0
Rural	Crown	OMNRF	AmS	0	0
Remote	Crown	LUWSTF	Pj	10003071	87.81
Remote	Crown	LUWSTF	Pr	0	0

Remote	Crown	LUWSTF	Pw	0	0
Remote	Crown	LUWSTF	Bf	0	0
Remote	Crown	LUWSTF	Sb	135437	1.19
Remote	Crown	LUWSTF	Sw	0	0
Remote	Crown	LUWSTF	Ce	0	0
Remote	Crown	LUWSTF	La	0	0
Remote	Crown	LUWSTF	Pt	409827	3.6
Remote	Crown	LUWSTF	Pb	0	0
Remote	Crown	LUWSTF	Bw	623485	5.47
Remote	Crown	LUWSTF	Map	0	0
Remote	Crown	LUWSTF	Ald	200681	1.76
Remote	Crown	LUWSTF	Wil	19112	0.17
Remote	Crown	LUWSTF	Ch	0	0
Remote	Crown	LUWSTF	AmS	0	0
Remote	Crown	OMNRF	Pj	10351851	90.87
Remote	Crown	OMNRF	Pr	0	0
Remote	Crown	OMNRF	Pw	0	0
Remote	Crown	OMNRF	Bf	0	0
Remote	Crown	OMNRF	Sb	67568	0.59
Remote	Crown	OMNRF	Sw	0	0
Remote	Crown	OMNRF	Ce	0	0
Remote	Crown	OMNRF	La	0	0
Remote	Crown	OMNRF	Pt	346588	3.04
Remote	Crown	OMNRF	Pb	0	0
Remote	Crown	OMNRF	Bw	625607	5.49
Remote	Crown	OMNRF	Map	0	0
Remote	Crown	OMNRF	Ald	0	0
Remote	Crown	OMNRF	Wil	0	0
Remote	Crown	OMNRF	Ch	0	0
Remote	Crown	OMNRF	AmS	0	0

APPENDIX II NUMBER SPECIES ANALYSIS DATA

Site	Method	Rep	Species
Rural	LUWSTF	1	6
Rural	LUWSTF	2	7
Rural	LUWSTF	3	7
Rural	LUWSTF	4	7
Rural	LUWSTF	5	4
Rural	LUWSTF	6	7
Rural	LUWSTF	7	7
Rural	LUWSTF	8	6
Rural	LUWSTF	9	6
Rural	LUWSTF	10	6
Rural	LUWSTF	11	7
Rural	LUWSTF	12	5
Rural	LUWSTF	13	4
Rural	LUWSTF	14	4
Rural	LUWSTF	15	5
Rural	LUWSTF	16	3
Rural	LUWSTF	17	5
Rural	LUWSTF	18	5
Rural	LUWSTF	19	2
Rural	OMNRF	1	4
Rural	OMNRF	2	4
Rural	OMNRF	3	5
Rural	OMNRF	4	5
Rural	OMNRF	5	4
Rural	OMNRF	6	4
Rural	OMNRF	7	5
Rural	OMNRF	8	4
Rural	OMNRF	9	4
Rural	OMNRF	10	3
Rural	OMNRF	11	5
Rural	OMNRF	12	4
Rural	OMNRF	13	3
Rural	OMNRF	14	1
Rural	OMNRF	15	3
Rural	OMNRF	16	1
Rural	OMNRF	17	5

Rural	OMNRF	18	3
Rural	OMNRF	19	2
Remote	LUWSTF	1	5
Remote	LUWSTF	2	3
Remote	LUWSTF	3	3
Remote	LUWSTF	4	4
Remote	LUWSTF	5	3
Remote	LUWSTF	6	3
Remote	LUWSTF	7	2
Remote	LUWSTF	8	4
Remote	LUWSTF	9	5
Remote	LUWSTF	10	4
Remote	LUWSTF	11	4
Remote	LUWSTF	12	2
Remote	LUWSTF	13	4
Remote	LUWSTF	14	4
Remote	LUWSTF	15	7
Remote	LUWSTF	16	1
Remote	LUWSTF	17	3
Remote	LUWSTF	18	4
Remote	OMNRF	1	1
Remote	OMNRF	2	1
Remote	OMNRF	3	1
Remote	OMNRF	4	3
Remote	OMNRF	5	2
Remote	OMNRF	6	3
Remote	OMNRF	7	1
Remote	OMNRF	8	4
Remote	OMNRF	9	2
Remote	OMNRF	10	3
Remote	OMNRF	11	3
Remote	OMNRF	12	1
Remote	OMNRF	13	2
Remote	OMNRF	14	2
Remote	OMNRF	15	3
Remote	OMNRF	16	1
Remote	OMNRF	17	1
Remote	OMNRF	18	3

APPENDIX III WOOD PROPERTIES ANALYSIS DATA

Site	Species	Wood Density Green (kg/m^3)	Wood Density Air-dry (kg/m^3)	Heat Value Green (MJ/kg)	Heat Value Air-dry (MJ/kg)	Percent Ash
Rural	Ald	594	546	13.1	19.8	0.07
Rural	Bf	521	480	13.4	20.2	0.07
Rural	Pb	587	540	12.8	19.4	0.11
Rural	Sb	557	513	15.9	23.7	0.06
Rural	Ch	679	625	15.2	22.7	0.06
Rural	La	680	626	14	21.1	0.04
Rural	Ce	439	395	16.7	24.9	0.05
Rural	Pw	558	511	13.5	20.4	0.03
Rural	Sw	528	485	12.8	19.4	0.07
Rural	Pj	621	565	13.7	20.7	0.03
Rural	Map	606	558	12.3	18.7	0.06
Rural	Pr	601	553	14.2	21.3	0.04
Rural	Pt	596	549	13.1	19.7	0.03
Rural	Bw	775	713	13.8	20.8	0.06
Rural	Wil	504	464	14.4	21.6	0.07
Publish	Ald	491	460	13.1	19.8	0.68
Publish	Bf	431	394	13.3	20	0.81
Publish	Pb	485	461	13.5	20.4	0.38
Publish	Sb	521	480	12.4	18.8	0.58
Publish	Ch	719	677	15.2	22.7	0.68
Publish	La	636	590	14	21.1	0.17
Publish	Ce	376	337	14.6	21.9	0.26
Publish	Pw	461	416	14.9	22.4	0.30
Publish	Sw	459	424	12.6	19	0.22
Publish	Pj	539	492	12.8	19.4	0.20
Publish	Map	567	539	12.3	18.7	0.68
Publish	Pr	497	458	14.1	21.3	0.30
Publish	Pt	493	463	12.9	19.5	0.38
Publish	Bw	672	647	12.6	19.1	0.31
Publish	Wil	491	460	14.4	21.6	0.68
Remote	Ald	602	554	15.3	22.9	0.07
Remote	Bf	509	469	14.5	21.8	0.56
Remote	Pb	587	540	14.2	21.3	0.39

Remote	Sb	541	497	13.8	20.8	0.26
Remote	La	680	626	14	21.1	0.04
Remote	Sw	528	485	12.8	19.4	0.07
Remote	Pj	616	566	14	21.1	0.28
Remote	Pt	685	631	14	21	0.39
Remote	Bw	653	601	14.4	21.6	0.24
Remote	Wil	504	464	15.3	22.9	0.07

APPENDIX IV ETHICS APPROVAL

General Info

FileNo: 1464087
Title: Biomass Heat as a Catalyst for Community Development in the Boreal Forest
Start Date: 01/10/2014
End Date: 05/11/2016
Keywords: First Nations, renewable energy, forest resource inventory, remote/rural communities

Related Awards

Award #	Title	Award Status	PI Last Name	PI First Name	Sponsors Summary	Notes
1463105	First Nations Renewable Energy Initiatives and Economic Development in Northern Ontario	Active	Shahi	Chander	Social Sciences and Humanities Research Council/Insight Development Grant(Active) 11-50-15000505 2013/06/01 - 2015/05/31	

Project Members

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Comments: Tenured

Others

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STU	Robitaille	Paul	Natural Resources Management\Natural Resources Management	Co-Investigator
STU	Seymour	Stephanie	Natural Resources Management\Natural Resources Management	Student
STU	Hosszu	Mike	Natural Resources Management\Natural Resources Management	Student

Attachments

Description	File Name	Version Date
	TCPS2-Mike.pdf	
	TCPS2-Stephanie.pdf	
	TCPS2-Chander.pdf	
	TCPS2-Peggy.pdf	
	revised proposal.pdf	
	1464087-proposal.pdf	
	1464087-approval.pdf	
Robitaille signature	1464087 signature Robitaille.pdf	
	RobitaillePaul20151021.pdf	