A FOREST OPERATIONS MANAGEMENT PLAN FOR 7 STANDS WITHIN THE NOONAN RESEARCH FOREST OWNED BY THE UNIVERSITY OF NEW BRUNSWICK IN THE CITY OF FREDERICTON - NB

by

Leonardo Pimenta Arao de Brito

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Supervisor(s): Jasen Golding, MFE, FOREM, University of New Brunswick

Examining Board: Meng Gong, PhD, FOREM, University of New Brunswick
Thom Erdle, PhD, FOREM, University of New Brunswick
Jae Ogilvie, MScF, FOREM, University of New Brunswick

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ABSTRACT

Understanding and estimating cost of forest operations is critical to the economic success of the logging business and an important tool for forest management decisions. The purpose of this research is to develop an understanding of how to design, cost and implement a forest operations management plan. The research project is conducted within the Noonan Research Forest (NRF), an Acadian mixedwood forest parcel owned and managed by the University of New Brunswick, located approximately 25 km North-East of the city of Fredericton (45.993905 N, -66.410996 E). The management plan encompasses all requirements necessary to construct and calculate a machine rental rate or proforma for forest harvesting equipment and assess expected revenue prominent from a forest stand. The scope of this report is to analyze pre-collected inventory data of 7 forest stands within the NRF, summarizing forest attributes, with respective variance, and hence, recommend most suitable harvest prescriptions for each stand. Identification of a harvest system based upon prescription, computing costs for harvesting, processing, and transportation of products from stump to roadside. Then, upon to product market assessment, calculate distance and time from stand to mills based upon the most cost-effective delivery location. Lastly, this report aims to calculate the products stumpage value providing to the landowner with a better understanding of expected revenue and timber cost management.

DEDICATION

To my parents who paved the way for my big dreams.

ACKNOWLEDGMENT

I thank God for all the opportunities, trials, and strengths that had pushed me towards this path. I now understand that all those unfortunate episodes I have been through were merely steps leading me to this very moment of success.

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1.0 Introduction

Understanding and estimating cost of forest operations is critical to the economic success of the logging business and an important tool for forest management decisions (Bick, 2015). Various methods to calculate the costs for logging equipment were designed, since late nineteenth century, with two main objectives in mind: to identify the cost of a single machine requires as an investment; and to set the price charged for the work done using such equipment. (Ackermana et al, 2014). Logging costs are affected by external variables such as harvest system, piece size, density (stems/ha), volume (m^3), wood products, block access, road conditions, distance (from stump to roadside; and from block to mill). This report provides relevant information about the study area and proposed stands. A short-wood system was chosen for this study, being 1 - Single Grip Processor, 1 - Forwarder, and 1 - self-loading truck (27 ton capacity). Machine rates and throughput accounting were used to calculate hourly rate and unit cost for putting products roadside to the stand and delivered wood cost to the mill's gate.

1.1 New Brunswick Forest Ownership and Jurisdiction

Canada holds over 300 million hectares of forest land, where 92% is provincial or territorial Crown land. According to the Canadian Association of Forest Owners the remaining 8% is categorized as private land, and divided among federal lands (2%), industrial lands (1%), and private woodlands (5%). Although private lands represent a much smaller portion, they are responsible for 18% of the country's timber production. The big majority of private forest areas are located in the Maritime provinces: New Brunswick, Nova Scotia, and Prince Edward Island (Draper, 2017). The Province of New Brunswick has a total area of 6.1 million hectares of forest land, being divide

among Crown land (52%), private woodlots (47%), industrial freehold (18%), and federal jurisdiction (2%). Crown land is divided into ten harvest licensees, assigned to six large forest companies in the province (Crown Timber Licenses). Each of those companies has an individual Annual Allowable Cut (AAC) (Private wood supply, 2015). It is estimated that 1% of the total provincial forest area is annually harvested, with 33% artificially regenerated (planted areas), and 67% naturally regenerated (Pierret, 2018). According to the Department of Natural Resources and Energy Development of New Brunswick the most recent forest inventory (2017) states a current growing stock on Crown land equals to 335 million m^3. An 18% increase on such growing stock is expected over the next 20 years, based on expectations of future forest management (Pierret, 2018).

1.2 New Brunswick overview of wood-related industry

Forestry is the largest industrial sector in the Province of New Brunswick. It generates over $ 1.45 billion dollars to the province annually; sustains about 40 mills throughout rural and urban zones, including 6 pulp mills; and employs over 22,000 workers (Pierret, 2018). The forest industry progressively developed during the 90's. During this time, a large diversification of wood processes was set in place leading the forestry sector to a expand wood engineered products. Nevertheless, the pulp and paper sector were and remains the core of the forest industry (Pierret, 2018). The pulp and paper sector represents the main income of manufactured products in the province, representing three times more income from forestry and logging. The total export sales in 2016 were $ 1.7 billion dollars, among different manufactured wood products; being 61% in pulp and paper, 37% in wood products, and 2% in primary wood (Pierret, 2018). The United States consumes more than 78% of the New Brunswick's sawn lumber

exportations. Followed by India (7%), China (2%), Europe (2%), Central and South America (2%). In total the Province of New Brunswick exports to over 60 countries, representing 15% of Canada's provincial export (Pierret, 2018).

2.0 Study Area

2.1 Noonan Research Forest

The Noonan Research Forest (NRF) is a teaching and research forest area owned by the University of New Brunswick, and common use shared with the Canadian Forest Service, the Maritime College of Forestry Technology, and the Department of Natural Resources and Energy of New Brunswick (Yang, et al, 2017) (Figure 1).

The NRF is located approximately 30 km northeast of Fredericton, New Brunswick, Canada (N 45° 59′ 58″ , W 66° 25′ 20″). The study area is ~ 1,500 ha in size, holding 270 stands with variable size, ranging from 0.2 to 47.3 ha (MacPhee, et al, 2017). Species composition for the study area is typical of the Acadian Forest region, with stands composition varying from relatively pure conifer species: white pine (Pinus strobus L.); eastern hemlock (Tsuga canadensis (L.) Carr.); red spruce (Picea rubens Sarg.); and black spruce (Picea mariana); to mixed intolerant hardwood stands and mixed hardwood–conifer stands. Balsam fir (Abies balsamea (L.) Mill.) is the most abundant species on the NRF, being found in almost every stand (MacPhee, et al, 2017).

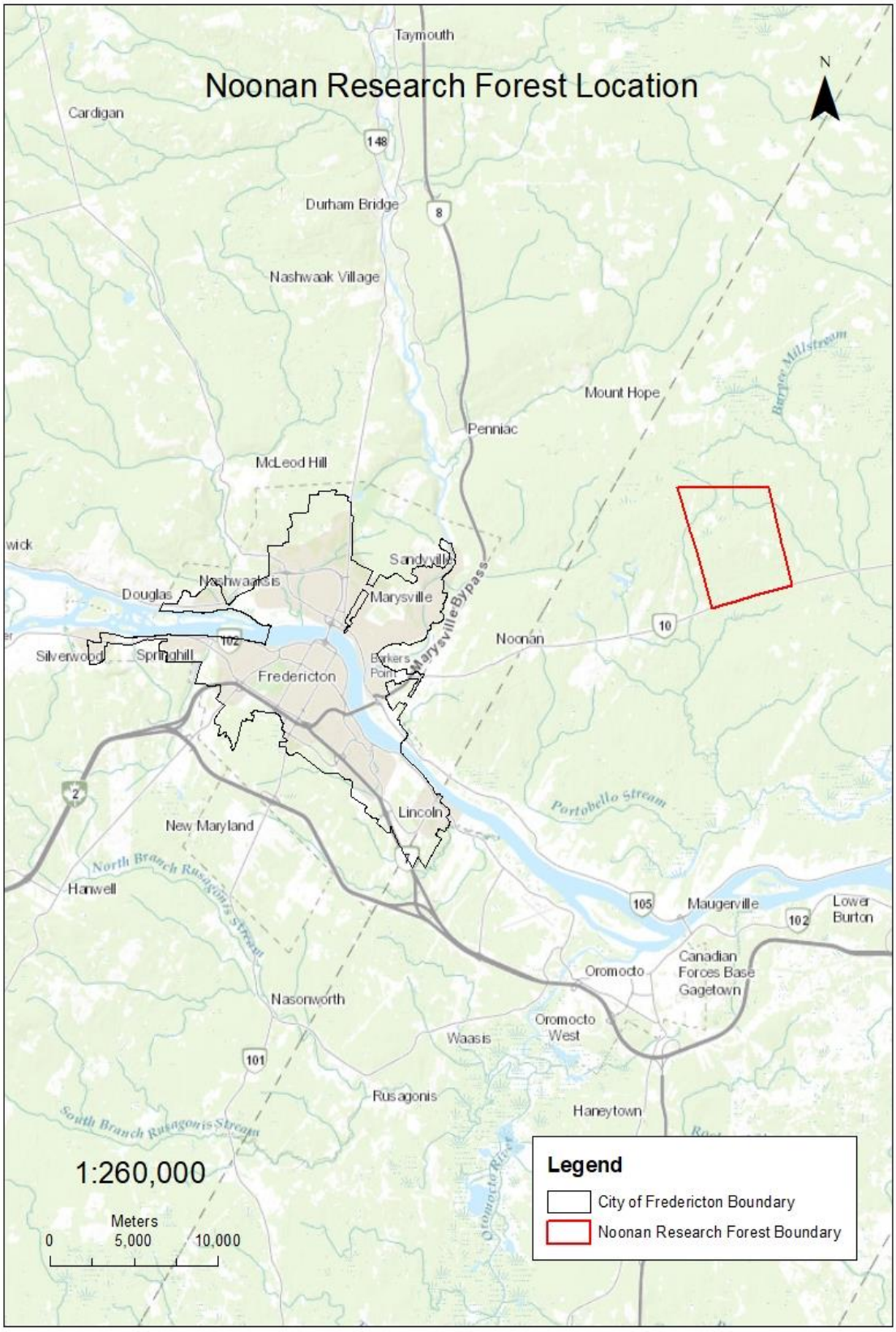


Figure 1:Map layout of the City of Fredericton and surrounding area, identifying the location of Noonan Research Forest (red color).

2.2 Harvesting History

The forest is predominantly composed of mature stands (>70 years old) with some regenerating stands following recent harvesting activities (5–30 years old). Two major timber harvesting intervals happened in the NRF. The first 1953-1975, occurred in order to harvest the salvage wood from stands affected by the Balsam Wooly Adelgid (Adelges piceae) and establish most of the current road infrastructure; the second interval was set in 1976-1986 based on a clear-cut harvesting prescription with minimal utilization of selection or shelterwood harvesting methods.

A detailed assessment has been developed in the NRF by students of the Capstone forest management course (2020) for the University of New Brunswick, summarizing the following topics: road inspections, water crossing, and wetlands (Nicholson, et al.,2020).

2.3 Roads Inspection

The road layer in the NRF was delineated in a total of 11 road sections and categorized into 3 classes (Class 1, 2 and 3) based on their operational conditions. The overall result indicates: 45% of the NRF road layer are classified as road class 1, meaning the infrastructure is in good operational condition, structurally sound, in its current condition no maintenance actions are required; 36% is classified as road class 2, meaning the infrastructure is in operational condition, structurally sound, no maintenance actions are required in its current state but should take place to prevent further deterioration; and finally 18% of NRF roads are classified as class 3, meaning the infrastructure is not in good operational condition, structurally unsound, in its current state maintenance actions are required to restore infrastructure to good operational condition (Figure 2).

2.4 Water Crossings

The principal functions of water crossings are preserving public safety, sustain road accessibility, and reduce environment concerns. Such factors assure the well-being of contractors, flowing of the forest operations, and trucking of products; also water crossing assist in minimizing erosion within the drainage system, and improve proper water network filtration. A total of 27 water crossings were analyzed in the NRF, including cross drains, culverts, and bridges, being categorized into levels of severity 1, 2, and 3. The assessment results indicates that 52% of cross drains and 33% of culverts are defined as severity level 3, meaning an immediate action is required; there is two bridges within the NRF, a recently built bridge and a decommissioned one. The active bridge is defined as severity level 2, meaning the infrastructure is in operational condition, although it requires a proper engineering inspection (Figure 2).

2.5 Wetlands Areas

The NRF has a total of 89 hectares of wetland areas being spread into six varying size areas (2.5 to 51.8 hectares). The wetlands areas in the NRF are categorized and ranked by functionality: water storage, sedimentation retention and stabilization, carbon sequestration, hydrologic group, and water quality. Analysis determines that on average 72% of all sedimentation is captured in the wetlands, as well as 66% of the annual water collected is retained. Moreover, the large diversity of structure and composition of wetlands in the NRF provide a suitable fauna habitat for many different species. The WESP-AC categorize species into aquatic invertebrates, amphibians and turtles, waterbird feeding, waterbird nesting, songbirds, raptors, mammals, and pollinators (Nicholson, et al.,2020). Nevertheless, a 30 m buffer zone area is properly applied to all wetlands within the NRF. Which assures there is no habitat loss due to human disturbance, including forest operations (Figure 2).

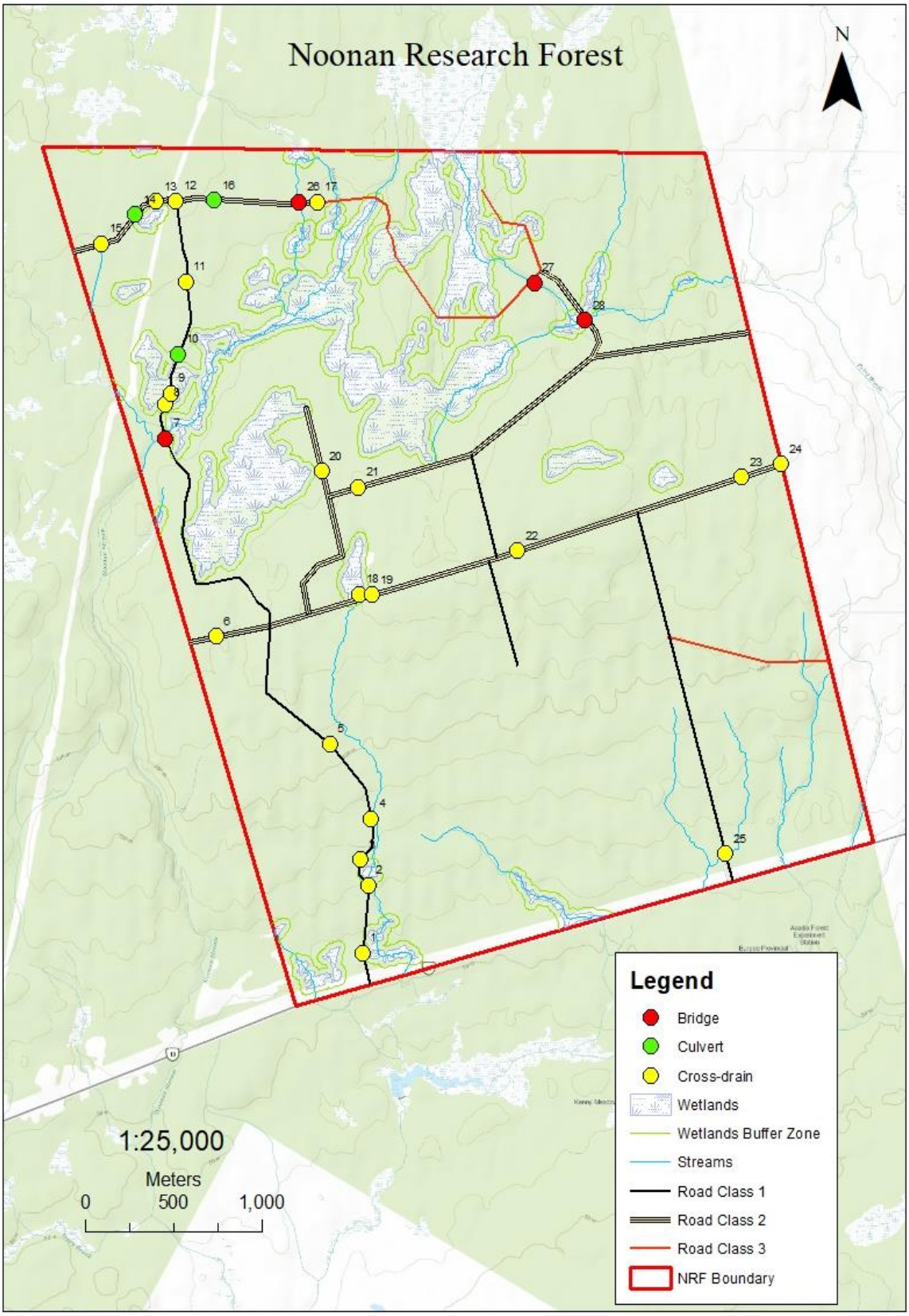


Figure 2: Identification of water crossing infrastructure within NRF (bridges, culverts, cross-drains), as well as road class, streams, and wetlands.

3.0 Goals

This report aims is to design a process for forest operations plan to the Office of Forest Lands Management (OFLM) at UNB allowing them to reasonably estimate the value ($) of 7 identified harvest stands within the Noonan Research Forest. Also encompassing aspects from forest inventory data analysis, cost estimation for harvesting intervention, and an expected revenue prominent from the chosen stands.

Goals for this report include:

1. To understand forest inventory as a first and most important step of a stand management plan.
2. Identify a suitable stand prescription based on inventory summary results, and product volume estimations.
3. Determine a harvest system based upon prescription, computing costs for harvesting, processing, and moving products from stump to roadside.
4. Calculate distance and time from stand to mills based upon the closest delivery location, as well as costs for transportation.
5. Assess for product stumpage value calculation and timber cost management.

4.0 Methodology

To date, the 7 chosen stands within the NRF have been pre commercially thinned 20 - 25 years ago. Therefore, the harvest intervention planned within this report is considered a 2nd phase of a larger management plan for the whole NRF (Nicholson, et al.,2020).

The present report has 3 major stages; 1 – Forest inventory: a forest inventory sample strategy was developed by the University of New Brunswick in the early 2000s and implemented to the NRF, late 2012, generating a large forest inventory data set. Using such inventory data, the 7 identified stands are assessed for stand species composition, basal area, density, and volume per hectare, with respective variance. Understanding inventory allows for identification of suitable stand prescriptions and product volume estimations. 2 – Financial assessment which identifies the most adequate harvest system based upon prescription, computing costs for harvesting, processing, and moving products from stump to roadside. Then, upon to product market assessment, calculate distance and time from stand to mills based upon to the closest delivery location, computing costs for product transportation. 3 – Lastly, after assessing for inventory analyzes, roadside and transportation costs, a calculation of stumpage value is provided to the landowner with a better understanding of timber cost management and revenue expectations.

4.1 Forest Inventory

The initial objective of a forest inventory and surveys is obtaining a reasonably accurate data set of forest resources. Species, diameter at breast height (DBH), tree height (total and merchantable) are considered basic requirements necessary to calculate stand volume (m^3), quantify forest structure, and unbiased estimates of means and totals (Yang, et al, 2017).

4.1.1 Original Sample Strategy

A forest inventory sample strategy was designed in the early 2000s by the faculty of forestry and Environmental Management (University of New Brunswick), in collaboration with the School of Forestry and Resource Conservation (National Taiwan University) alongside with the Nova Scotia Natural Resource (Yang T.R., et al, 2017). A systematic sample was conduct using a 100 m by 100 m fish-net grid and 3 grid intersections per stand were randomly sampled, resulting in the total of 705 center plots in the mature forest types (> 70 years old). The sample strategy was implemented in the summer and early fall of 2002 by the University of New Brunswick Forest lands summer field crew. A second forest inventory was set at the NRF 10 years later, a collaboration among the University of New Brunswick, University of Maine, and the Canadian Forest Service (MacPhee C., et al, 2017). Resulting in the total measurement of 1419 center plots.

Plot density was calculated using an angle gauge sweep with a basal area factor (BAF) of 2 m^2/ha, where each tree tallied is representative of 2 square meters per hectare. The angle gauge was placed at center plot pointing towards north, and it was rotated at clockwise direction. Diameter at breast height (DBH) was measured at 1.3 meters from tree's bole, for trees with diameter greater than 10 centimeters, and

boarder-line trees were inventoried by using the limiting distance equation (MacPhee C., et al, 2017). For height, a subset of tally trees were selected using a BAF sweep of 27 m^2/ha and measured using an Optic-Logic (Tullahoma, TN) LH300 hypsometer at linear distance of 20 meters from the base of the stem (MacPhee C., et al, 2017). Trees whose matched the "inclusion zone" (denominated "in" trees) were carefully inventoried, resulting in a diameter measurements of 17,049 stems covering 22 species, and height measurements of 922 of these stems covering 15 species (MacPhee C., et al, 2017).

4.1.2 Forest Inventory Analyzes

The operable stands within the NRF chosen for silviculture intervention equates ~170 hectares, split in 7 stands of varying sizes (Figure 3). All stands present a large diversity in species being the most abundant balsam fir and spruce, followed by red maple, trembling aspen, and white birch. The criteria for a stand being operable must show species with DBH greater than 10 cm and the volume per hectare must exceed 100 m^3. Stand metric attributes are calculated using Honer's equations (Honer et al, 1983). Such attributes include: species basal area (m^2), density (stems/ha), volume (m^3/ha), and merchantable volume (m^3/ha). Followed by statistical analysis including mean (m^3/ha), standard deviation (m^3/ha), coefficient of variation, standard error, and confidence interval, calculated with a 95% probability. The stand species composition can be described as the percentage of basal area dominance per species in each stand.

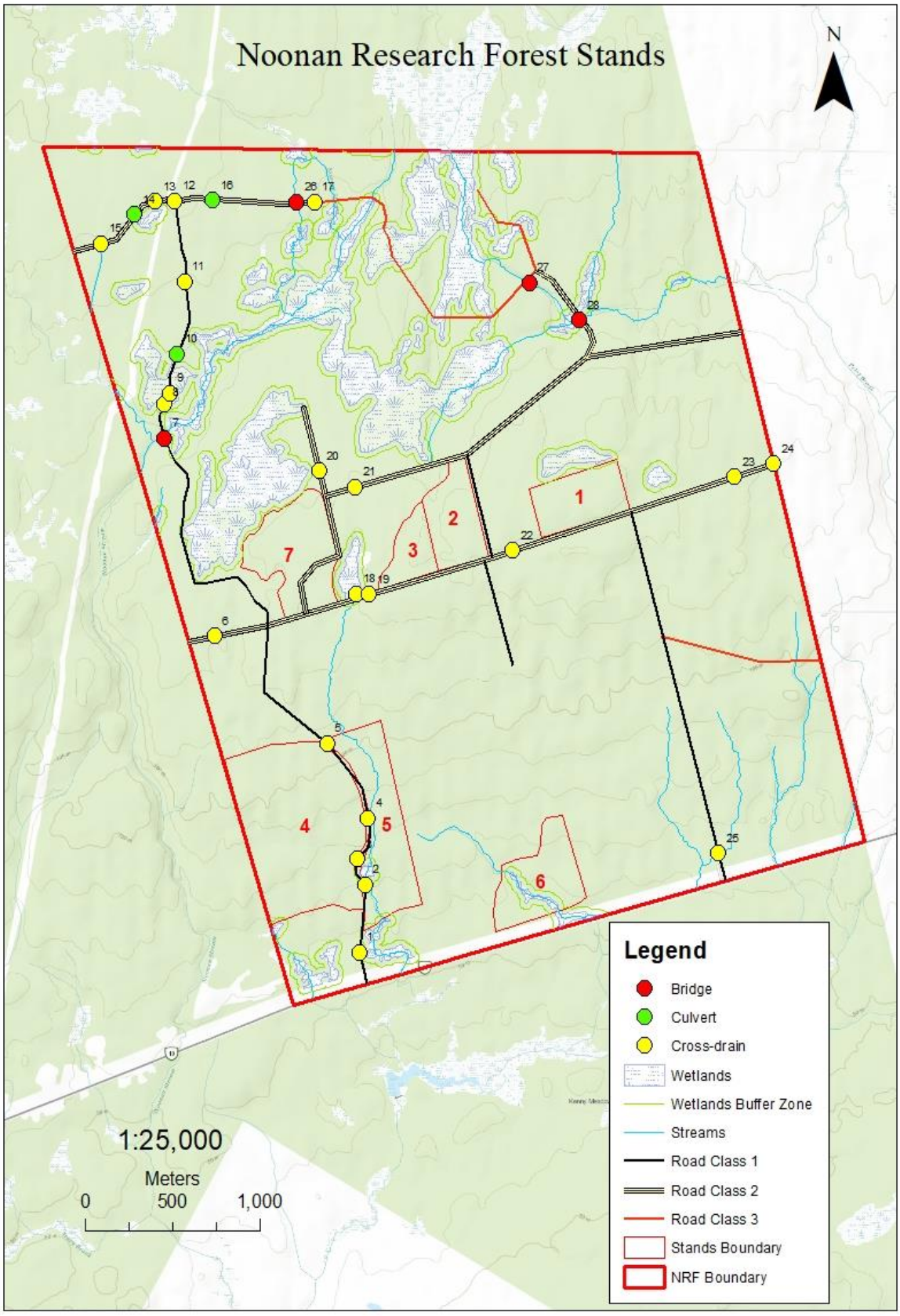


Figure 3: Location of 7 stands prescribed for treatment within NRF, showing road class and all accessibility aspects to each operable stand.

4.2 Prescription

All stands present a large diversity in species, where softwood species are beginning the process of canopy closure and the intolerant hardwoods in the understory are fighting for space. The stem exclusion phase will begin as soon as much of the growing space is occupied by existing trees and there is little to no available space to understory regeneration. By implementing a selective thinning removal, we will be able to harvest volume that would be lost to mortality. The decrease in density and competition will increase the quality and growth rate in the remaining trees. The Office of Forest Lands Management (OFLM) has identified their management goals for the NRF as direct and indirect.

Direct goals for the NRF:

- Financially responsibility to generate revenue for the Office of Forest Lands Management (OFLM), at the University of New Brunswick.
- Preserve the white pine, sugar maple, yellow birch, and white ash species component, and any sort of regeneration of such species.
- Leave the SNAG component standing for wildlife habitat.

Indirect goals for the NRF:

- Provide teaching and learning opportunities.
- Provide undergraduate and graduate research opportunities.
- Support the fauna and flora component.

In order to reduce the cost of stand intervention it must be managed in a fashion that address to the YSC Marketing Board standards prior to subsidize approval (York-Sunbury-Charlotte marketing board, 2021). The YSC Marketing Board pre-treatment criteria includes plantation or pre-commercially thinning stands at least 25 years old and not older than 40 years; crowns beginning to compete; less than 50 m^2/ha of BA; and the post-treatment criteria includes removed BA between 30% and 50% (including trails); and not high-grading selection (the biggest piece size individuals must be preserved) according to the New Brunswick Private Woodlot Silvicultural Manual (Government of New Brunswick, 2004).

The most adequate prescription consists of a Commercial Thinning of 35% to 40% removal of volume within each stand, targeting the abundant merchantable Balsam Fir and Spruce, alongside with intolerant hardwood component; preserving white pine, sugar maple, and yellow birch component; favoring the established regeneration; and not applying a high-grading selection. This way both OFLM requests and YSC Marketing Board criteria may be satisfied.

4.3 Harvest System

A short-wood system is the most suitable harvest system for such operations within the NRF, considering the type of work will be performed, a selective thinning (40% removal), where the operator must navigate standing trees to get access to the targeted trees; and sort tree piece size, and products pile. The harvest system is composed of 1 Single Grip Processor (SG), 1 Forwarder (porter), and 1 self-loading truck (27-ton capacity). It was assumed a schedule of 12 SMH /shift (schedule machine hour) for the SG Processor and 8 SMH /shift for the Forwarder, being 1 shift per day for both, with a 90% utilization rate; truck schedule hours are slightly different, 16h hours per shift and 1 shift per day, with a 93% utilization rate based on transportation scheduling. Based on the assumed schedule and parameters, the harvest system is balanced, and it should take no longer than 55 days for completion of the NRF contract.

For more information with respect to truck parameters, refer to the transportation section. Parameters for SMH, productivity and utilization per machine unit, fixed and variable input cost were provided through consultation with independent contractors, those who were willing to share information and data with respect to costing. A detailed table containing all mentioned parameters, as well as equipment data, insurance and payroll-levies is available in the appendix section (Appendix II).

5.0 Financial Assessment

To start a new logging business activity, deliver the demanded volume of wood on time, and at a competitive price rate, business owners, loggers (contractors) must invest in equipment (Eriksson & Lindroos, 2014). Equipment does not increase in value; actually, the use of such equipment only depreciates its value. The production itself brings return on investment and revenue but requires costs inputs (Bick, 2015). For every machine and piece of equipment, a Machine Rental Rate (MRR) calculator is necessary to identify all fixed and variable outputs costs and management overheads (Table 1.5).

5.1 Important concepts

Before moving into to the Machine Rental Rate, it is vital to explain some important concepts in order to fully understanding of all formulas used within the next section.

5.1.1 Schedule Machine Hours VS Productive Machine Hours

Schedule machine hours (SMH) include all time the machine is schedule to work. For instance, if a logger/contractor is scheduled to work a 10 hours-shift, that equals 10 SMH/day. Productive machine hours (PMH) express the time when the machine actually performs work. Excluding time lost for both mechanical and non-mechanical delays. If the same logger/contractor faces 30 minutes lunch break and an extra 30 minutes mechanical delay, that equals 9 PMH per day (10 hours-shift – 30 minutes lunch – 30 minutes delay).

5.1.2 Utilization

Utilization of a forest machine (U%) is the ratio of Productive Machine Hours (PMH) to Schedule Machine Hour (SMH) (Thompson, 2001). It can be used to calculated rates of a machine's average cost over it's lifetime. Forest supervisors and/or logging contractors can use utilization to compare harvest systems and machines more accurately within each system, and address issues affecting their productivity and therefore their production (Thompson, 2001).

Utilization can be affected by many factors, such as mechanical delays, non-mechanical delays, operational lost time, and general wasted time. Therefore, it must be based on accurate data. Currently forest machine are equipped with a high tech computer cab system, which keeps on track all machine parameters, including details of productive hours (Thompson, 2001).

$$\text{Utilization } (\%) = \frac{\text{PMH}}{\text{SMH}} \text{ X } 100$$

5.1.3 Productivity

Productivity is the result of a ratio between input and output of a system. Commonly used in forestry or logging studies with a focus on measuring the time consumption per unit output (volume of wood processed, m^3) (Sangstuvall, 2010). Harvesting productivity is expressed as volume (m^3) processed per unit time (m^3/PMH). Being affected by piece size, number of products delimbed, processed, and assorted. Forest hauling productivity is affected by transportation distance, load size, and grapple size (Sangstuvall, 2010).

5.1.4 Production

Production is the total productivity gathered in a defined time frame (daily, weekly, or operational year). Productivity and production ideally are measured in volume (m^3) per unit time. This way both parameters usually increase substantially with increases in piece size (Thompson, 2001).

$$\text{Production} = \text{Productivity x PMH (pre defined period)}$$

5.1.5 Annual PMH

The annual PMH is the total annual productive machine hours performed by a equipment unit taking in consideration the utilization rate.

$$\text{Annual PMH} = \frac{\text{hours}}{\text{shift}} \text{ x} \frac{\text{shifts}}{\text{day}} \text{x} \frac{\text{days}}{\text{year}} \text{x U\%}$$

5.2 Machine Rental Rate

For every machine and piece of equipment, a Machine Rental Rate (MRR) is necessary to identify all fixed and variable outputs costs and management overheads (Table 1). Such costs are exclusively converted and charged on a $/PMH basis (Ackermana et al., 2014). Also, it is important to highlight that, the unit cost of a forest machine can be specific to how companies refer to their volume, being Tonnes, MT, Cords, and such; for this report exclusively were used a cubic meter (m^3) as a unit for volume calculations.

Table 1: The cost structure of a logging business, showing all inputs parameters for the rental rate or machine proforma. Including the sum of fixed and variable costs, operator cost, extra contract services, and management overheads.

FIXED COST ($/PMH)	CONTRACT SERVICES ($/PMH)
Capital recovery depreciation	Road construction
Insurance	
License	
VARIABLE COST ($/PMH)	**MANAGEMENT OVERHEADS ($/$m^3$)**
Fuel	Accounting/ Bookkeeping fees
Lubrication	Office expenses
Repair material	Licenses
Service labor	Fines
Tracks or Tires	Legal fees
Hauling	Professional dues
OPERATOR'S COST ($/PMH)	Travel expenses
Payroll wages and salaries	Phone expenses
Payroll taxes	Medical expenses
	Training expenses

5.2.1 Fixed Costs

Fixed costs are costs per machine or any piece of equipment that do not change relative to production and productivity. Fixed costs are considered independent of the amount of work performed by the machine or the revenue it earns during the machine's expected economic life. In other words, fixed costs are associated only with owning the machine (Ackermana et al., 2014). Fixed costs include capital recovery depreciation, insurance, and licenses.

5.2.2 Capital Recovery Depreciation

The gradual loss of value of fixed assets through use and time is called depreciation. There are two types of depreciation: physical deterioration of equipment or software obsolescence. Depreciation of capital goods allows for an accurate reflection of the "state" of the company. The simplest way to calculate a depreciation rate of an asset according to the market value is:

Formula:

$$\text{Depreciation Cost} = \frac{(P-S)}{n} \quad (\$/\text{Year}) \text{ [1]}$$

Where:

P = Purchase price
S = Salvage value
n = Expected economic life of the machine in years

Notice that the salvage value of forestry equipment is strongly associated with the age of the machine when it is disposed of. Such value appears to drop considerably fast in the first few years and, after that, tends to decline more gradually (Ackermana et al., 2014). There are two ways to look at depreciation of an asset: economic depreciation, when an asset declines in market value over a given time interval, and accounting depreciation, where assets are capitalized, and the cost of an asset is distributed over its lifetime. Forestry contractors handle their equipment depreciation through accounting depreciation, where assets are capitalized according to a book value (accounting value at the end of year n, i.e.).

According to Canada Revenue Agency (CRA), book value is the initial payable price of any investment, which may differ from the market value. Also, the CRA allows a tax depreciation deduction of the property's cost. Such a percentage is called capital cost allowance (CCA). Currently, the CCA for logging machinery is 15% in the first year and 30% every year after, which contractors or companies can deduct or claim it back on their tax income on each respectively year (Government of Canada, 2021). Forestry and logging businesses are categorized as high-risk investments. Therefore, a higher interest rate (i) on such business is not uncommon compared with most other investments (home mortgages or vehicle loans).

The Capital Recovery Depreciation (CRD) component is the earning back of the initial funds and the interest on such investment, breaking it down into the expected economic life of the machine (in total PMH), providing an annualized return on investment.

Formula:

$$\text{CRD Cost} = \frac{(P - S) \text{ x } \frac{i \text{ x } (1+i)^n}{(1+i)^n - 1} + Si}{\text{Annual PMH}} \quad (\$/\text{PMH}) \text{ [2]}$$

Where:

P = Purchase price
S = Salvage value
i = Interest rate
*n = Expected life of machine in years (driven by PMH)

*Expected life of the machine in years (n) is a rate based on the ratio of the Expected economic life of the machine (PMH) to the annual scheduled PMH. Numbers for the expected economic life of the machine are provided by dealership companies based on historical values for the machine's condition before major repairs or refurbishment costs.

5.2.3 Insurance

According to the Financial Consumer Agency of Canada (FCA), an insurance policy is a contract between the insured (person protected by the insurance policy) and the insurer (insurance company). The insured person pays a premium fee annually, in exchange for a certain amount of money, paid for by the insurance company, in case a pre-specified list of events happens during the term of the policy (Government, of Canada 2019). Forestry and logging businesses are susceptible to several and unpleasant events in the field, such as machinery fire, theft, and vandalism, besides the unpredictable and rough weather conditions typical of the province of New Brunswick, which can surely cause damages to the equipment. A huge liability cost is also accounted for logging business, with respect to insurance, and companies must assure that everything is properly covered.

Insurance companies are not willing to pay the initial purchase price of such a machine but the current book value instead. As mentioned previously, the CRA

department allows a 15% depreciation on the first year of the machine and 30% depreciation every year after. This way, contractors may have to renegotiate their bank insurance rate every year in order to receive an up-to-date rate (%) and a reduced cost per PMH. Nevertheless, it is strongly recommended for contractors, or any other party involved in the business a close and careful review of the machine's insurance policy when it comes to coverage details and specifications.

A simple way to calculate the insurance rate on forestry machine is:

Formula:

$$Insurance\ Cost = \frac{(P - S)x\ InR}{Annual\ PMH} \quad (\$/PMH) \text{ [3]}$$

Where:

P = Purchase price
S = Salvage value
InR = Insurance rate

5.2.4 Variable Costs

Variable or consumable costs are captured when the machine is working, performing its scheduled task, traveling empty, or at least its engine is running (Ackermana et al., 2014). These are costs for fuel, lubrication, repair material, service labor, tracks or tires, and machine hauling. Such costs are entered as overall annual cost. Also, consumable costs can be challenging to calculate and work out (Ackermana et al., 2014). Thus, it is recommended that the business owner keep good and accurate long-term records data for consumables consumption and market price.

Operator costs are calculated in a special manner once they often consist of a mix of fixed and variable costs. Therefore, they are treated separately from the variable costs as a unique component of the MRR.

5.2.5 Fuel and Lubrication

Fuel cost is calculated based on the cost per liter at the pump and the machine consumption. In contrast, lube cost is calculated primarily on the total annual cost of such component, divided per total annual PMH. Machine consumption depends mainly on the work that it is planned to perform, the machine's engine power, mechanical standing, operator skills, and performance (Ackermana et al., 2014). The operator's skill set can be improved as training progresses. Training, however, is captured in the Overhead component.

Formula:

$$Fuel\ Cost = Fuel\ cost\ \left(\frac{\$}{L}\right) x\ MC\ (\frac{L}{PMH}) \qquad (\$/PMH)\ [4]$$

$$Lube\ Cost = \frac{Annual\ Lube\ cost\ (\frac{\$}{PMH})}{Annual\ PMH} \qquad (\$/PMH)\ [5]$$

Where:

L = litre of diesel
MC = Machine Consumption

5.2.6 Repair material and Service labor

Every machine requires repair materials and a qualified technician to perform such labor, which comes to a cost in the end. It is expected a close relation between repair cost and the expected economic life of the machine (Ackermana et al., 2014). When working with a newer machine, costs for maintenance materials and labor tend to be lower; furthermore, an increase in such costs should be noted towards the end of the machine's economic life.

Repair material and service labor are calculated simply on the total annual cost for each component based on historical data, divided per total annual PMH.

Formula:

$$Repair\ Cost = \frac{(RM + SL)}{Annual\ PMH} \quad (\$/PMH) \ [6]$$

Where:

RM = Repair material cost ($/PMH)
SL = Service labor cost ($/PMH)

5.2.7 Tracks or Tires

The budget of a set of tracks or tires is an expressive portion of the machine's purchase price base, and the cost for them is calculated based on their expected economic life (Ackermana et al., 2014). It is important to remember that the first set of tracks or tires comes with the machine; in most cases, thus it is included in the purchase price base.

Formula:

$$Tire\ Cost = \frac{\left\{\left[\frac{Machine\ life\ (PMH)}{Tire\ set\ life\ (PMH)}\right] - 1\right\}\ x\ Tire\ set\ cost\ (\$)}{Annual\ PMH} \quad (\$/PMH)\ [7]$$

5.3 Operator costs

Operator costs are the sum of operator wages and payroll levies, which will include Canada Pension Plan (CPP), Employment Insurance (EI), Federal and Provincial taxes (T4032 – NB). Salaries are calculated from the hourly wage per operator, number of operators per machine during a shift, hours per shift, shifts per day, days per year (operational year). It can be treated as a Fixed salary, where operators are paid based on the annual SMH; or as a Variable salary, where operators are paid accordingly to the number of hours performed.

The maximum number of workdays per year can vary among countries as per the number of holidays and vacation days (Ackermana et al., 2014). On top of that, in the Province of New Brunswick, roads are imposed a weight restriction during the wintertime (approximately from March 1st to May 20th) due to the weather conditions, with few exceptions of gravel and short paved roads. Therefore, logging trucks cannot haul products on such window. On average, there is a total of 215 workable days in the province.

It is recommended that operators' different wages should be treated as an individual case, for instance, night shift or overtime work alongside a bonus or premium compensation for those performing higher productivity. Operators' benefits such as subsistence allowance, personal protective equipment (PPE), training costs, phone

charges, insurance, and transportation should be capture in the Overhead component.

A couple of generic methods to calculate operator costs include:

Formula:

$$HR=Wage+Wage\ x\ Payroll\ levies \quad (\$/PMH)\ [8]$$

$$FOC = \frac{[(HR)x\left(\frac{operator}{unit}\right)x\left(\frac{SMH}{shift}\right)x\left(\frac{shifts}{day}\right)x\left(\frac{days}{year}\right)}{Annual\ PMH} \quad (\$/PMH)\ [9]$$

$$VOC = (HR)x\left(\frac{operator}{unit}\right)x\left(\frac{PMH}{shift}\right)x\left(\frac{shifts}{day}\right)x\left(\frac{days}{year}\right) \quad (\$/PMH)\ [10]$$

Where:

HR = Hourly rate
FOC = Fixed hours Operator Cost
VOC = Variable hours Operator Cost

5.4 Roadside Cost

Roadside cost is the total cost for harvesting, processing, and moving products from stump to the stand roadside loading yard. In summary, it includes equipment costs to determine a machine rental rate or proforma for each piece of equipment within the prescribed system.

Formula:

$$\text{Roadside Cost} = \sum \text{Harvest System Machines Unit Cost} \qquad (\$/m^3)\ [14]$$

5.5 Transportation Cost

Transportation is a significant cost for forest operations. In fact, transportation accounts for roughly 30% to 50% of the delivered wood cost depending on distance from block to mill (Ackermana et al., 2014). The unit cost of transportation can be calculated either based on time of transportation or traveled kilometer. Calculating the unit cost base on time of transportation is likely the most cost-effective way to do it in the Province of New Brunswick. With respect to road conditions, the province presents a well-maintained road system, which favors the flow of transportation of products.

For this report the transportation cost includes a MRR, similar to the roadside cost equipment, assessing for the hourly rate. The unit cost is calculated based on (1) volume per load, (2) loading, unloading, and waiting time (min/cycle), (3) road class parameters, and (4) truck's average speed loaded and empty. All calculations are converted in a minute per cycle basis.

The road distance calculation should be done based on road class (primary, secondary, and tertiary), where each individual class presents a unique average speed for truck loaded and empty (Appendix III). Moreover, the waiting time for load and unload products on the truck is heavily affected by the loader equipment and type of product (pulp often takes longer compared to stud or logs). Usually loading is more expensive in the field, rather then the mill yard, where there is a larger loader, which can quickly load and unload truck, reducing waiting time.

Formula:

$$\text{Avg speed} = \frac{\text{Distance (Km)}}{\text{Time (h)}} \quad \text{(Km/h) [12]}$$

$$\text{TRC (PMH)} = \left(\frac{\text{Road class distance (Km)}}{\text{Avg speed loaded } (\frac{\text{Km}}{\text{h}})}\right) + \left(\frac{\text{Road class distance (Km)}}{\text{Avg speed unloaded } (\frac{\text{Km}}{\text{h}})}\right) \quad \text{(Km/h) [13]}$$

$$\text{TSP (PMH)} = \sum \text{TRC} + \text{WT} \quad \text{(PMH) [14]}$$

Where:
Avg speed = Average speed (Km/h)
TRC = Time spent per road class (PMH)
TSP = Time spent per product (PMH)
WT = Waiting time for load and unload of products (PMH)

5.6 Management Overheads

Overheads are, in summary, any expense accounted for supporting the business flow while not being directly related to the final product or service. It is vital to identify and calculate such costs to charge for the business' service accurately (Ackermana et al., 2014). The overhead component within the MRR encompasses accounting, administrative/ office expenses, licenses, fines, legal fees, professional dues, travel, phone, medical, training, and vehicle expenses. Moreover, any other activity is not directly associated with wood product manufacturing.

It is essential to highlight that overheads account only for costs associated with an individual stand, project contract, or annual operable year (m^3, Tonnes, or Cords) (Ackermana et al., 2014).

Formula:

$$\text{Overheads} = \frac{\text{Total overheads}}{\text{Total contract volume}} \quad (\$/m^3) \text{ [11]}$$

5.7 Stumpage Value

Finally, the stumpage rate is the value ($/m^3, $/Ton, or $/cord) paid to the landowner after all costs for harvesting, for transportation and overheads are being paid off. In the province of New Brunswick, there are two common methods for a landowner to sign a contract and guarantee his pay, a lump sum payment ($) or an agreement upon rate ($/m^3). A lump sum is based on accurate forest inventory where the landowner and the contractor responsible for the stand agree in a certain amount for the standing wood. At this point there is a lot of uncertainty for the contractor, once the wood is subject to market price fluctuation and he needs to harvest and haul all the products as quickly as possible in order to avoid money loss. On the other hand, an agreement upon rate the landowner is under lot of uncertainty, where he needs to keep track on loads and system utilization, in order to avoid mix loads and reduce on the payload.

Formula:

$$\text{Stumpage rate} = \text{WMP} - \text{DC} - \text{OH} \qquad (\$/m^3 \text{ or } \$/\text{cord}) \text{ [15]}$$

Where:

WMP = Wood market price (rate paid for products at the mill's gate)
DC = Delivered wood cost (Roadside cost + Transportation cost)
OH = Overheads

6.0 Results

6.1 Stand Summary and Financial Assessment Results

In summary, the 7 harvestable sites within the NRF total ~19200 m^3 merchantable volume. A ~40% selective commercial thinning prescription removes approximately ~7400 m^3 (Table 1.2). Such stands present a high volume for the following species: Balsam Fir, Spruce, Red Maple, Trembling Aspen, and White Birch.

Table 1.2: Total estimated volume (m^3) for all 7 stands, showing dominance by balsam fir and spruce, being followed by red maple, trembling aspen, and white birch. Restricted species such as white pine and white ash, does not show volume removal and shall not be removed, as per OFLM request.

Species	Total Volume (m^3)	40% Removal (m^3)
Balsam Fir	7,203	2,881
Spruce	5,359	2,144
Red maple	2,463	985
Trembling Aspen	1,714	686
White Birch	1,356	543
White Pine *	703	N/A
Big-Toothed Aspen	252	101
Grey birch	110	44
Tamarack	32	13
Alder	24	10
White ash *	11	4
Strip Maple	10	4
Snag **	0	0
Grand Total	19,237	7,414

*Such species shall not be removed, as per OFLM request.
**Snags shall be leave standing for wildlife habitat.

The total estimated volume removed from all stands, with respective products percentage allows a predicted revenue of $ 57,047 (Table 02). The total volume of all stands of HW equates ~2300 m^3, being 92% of that pulp products; with a stumpage rate of $28.00 per cord allows a predicted revenue of ~ $ 24,500.00 (Table 02). While the total volume of SW is close to 5000 m^3, split in pulp, stud, and logs products with varying percentage, allowing a predicted revenue of ~$ 32,500. Unfortunately, the assessment performed in the NRF is not eligible for the YSC Marketing Board subsidize once all 7 chosen stands present age superior to 40 years old (Appendix XI).

Table 2: Total volume of HW and SW for all harvestable stands within the NRF, with respective products specifications, stumpage rate, and predicted income per product.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (m3)	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	2376	Pulp	92%	2186	874	$ 28	$ 24,457
Softwood	5038	Pulp	50%	2498	999	$ 5	$ 4,995
		Stud	11%	571	228	$ 38	$ 8,727
		Logs	20%	993	397	$ 48	$ 18,868
Total				6247	2499		$ 57,047

The following section shows detailed information for each specific operable stand, described within the NRF. Details include species composition, basal area, density and volume per hectare, total volume removed, products estimate, stumpage rate, and predicted income. Lastly, a detailed table of basal area, height, density, and volume/ha according to DBH class is available in the section below, for each individual stand. Also, the raw data for each stand is available on the appendix section (Appendix IV to X).

6.1.1 Stand 1

Stand 1 is 15.18 hectares, composed of SW_84% and HW_15%. Species are ranked according to the basal area dominance (Figure 4). The current density of Stand 1 equals 2495 ± 312 stems per hectare, and the volume per hectare equals 90 ± 15 m^3 (Table 3). The total volume removed is estimated to be 569 m^3 (Table 5) among all species present within the stand, and the predicted income is expected to be $2,144.00 (Table 6).

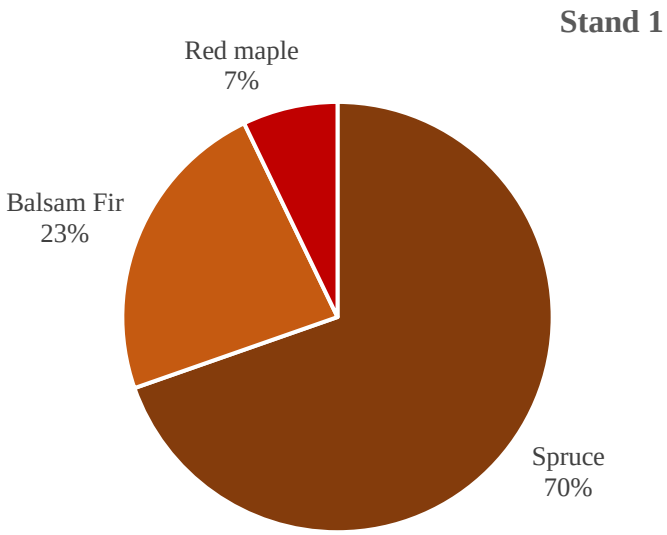


Figure 4: Stand 1 basal area dominance per species, showing a large spruce dominance, followed by balsam fir and red maple.

Table 3: Stand 1 general information, showing stand attributes such as: basal area, density, and volume per hectare.

Stand Description	
Stand type	SW_84%, HW_15%
Stand area (ha)	15
Volume (m^3/ha)	90 ± 15
Density (stems/ha)	2,495 ± 312
Basal Area (m^2/ha)	25
Harvest Condition	Operable
Habitat Presence	Snags

Table 4: Stand 1 specification for basal area, density, and volume per hectare per species.

Species	BA (m^2/ha)	Density (st/ha)	CI (95%)	Vol (m^3/ha)	CI (95%)
Spruce	18	1,681	± 404	66	± 17
Balsam Fir	05	569	± 342	18	± 17
Red maple	01	202	± 435	05	± 30
Snag	0.3	47	N/A	N/A	N/A
Total	25	2,495		90	

Table 5: Stand 1 total volume and prescription removal per species within the stand.

Species	Total Stand Volume (m^3)	40% Removal
Spruce	1,045	418
Balsam Fir	292	117
Red maple	86	34
Snag	N/A	N/A
Total	1,423	569

Table 6: Stand 1 products specification and predicted income, according to the YSC Marketing Board stumpage values.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	35	Pulp	92%	13	$ 28	$ 356
Softwood	535	Pulp	67%	142	$ 5	$ 712
		Stud	10%	21	$ 38	$ 809
		Logs	3%	6	$ 48	$ 267
Total	569					$ 2,144

6.1.2 Stand 2

The Stand 2 is a total of 15 hectares that is composed of SW_50% and HW_50%. Species are ranked according to the basal area dominance (Figure 5). The "Others" category on the pie chart encompasses all species that show dominance inferior to 6% of the total. The current density of Stand 2 equals 2263 ± 249 stems per hectare, and the volume per hectare equals 88 ± 9 m^3 (Table 7). The total volume removed is estimated to be 478 m^3 with exception of white pine as per OFLM request (Table 9), and the predicted income is expected to be $2,917.00 (Table 10).

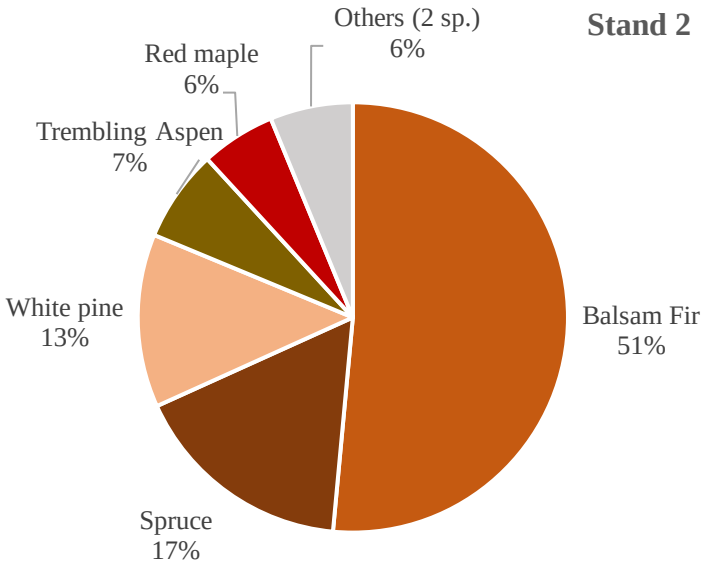


Figure 5: Stand 2 basal area dominance per species, showing stand dominance by balsam fir, spruce, and white pine.

Table 7: Stand 2 general information, showing stand attributes such as: basal area, density, and volume per hectare.

Stand Description	
Stand type	SW_50%, HW_50%
Stand area (ha)	15
Volume (m^3/ha)	88 ± 9
Density (stems/ha)	2,263 ± 249
Basal Area (m^2/ha)	22
Harvest Condition	Operable
Habitat Presence	Snags

Table 8: Stand 2 specification for basal area, density, and volume per hectare per species.

Species	BA (m^2/ha)	Density (st/ha)	CI (95%)	Vol (m^3/ha)	CI (95%)
Balsam Fir	11	1,246	± 295	44	± 09
Spruce	04	255	± 299	14	± 11
White Pine	02	147	± 355	08	± 10
Tremb. Aspen	01	97	± 331	05	± 11
Red Maple	02	216	± 262	06	± 11
Big-Toothed A.	01	101	± 49	06	± 48
White Birch	01	200	± 143	04	± 03
Total	22	2,263		88	

Table 9: Stand 2 total volume and prescription removal per species within the stand.

Species	Total Stand Volume (m^3)	40% Removal
Balsam Fir	666	266
Spruce	211	84
White Pine	125	N/A
Quaking Aspen	71	28
Red Maple	94	37
Big-Toothed A.	85	34
Paper Birch	66	26
Total	1,319	477

Table 10: Stand 2 products specification and predicted income, according to the YSC Marketing Board stumpage values.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	127	Pulp	92%	47	$ 28	$ 1,303
Softwood	351	Pulp	60%	84	$ 5	$ 420
		Stud	11%	16	$ 38	$ 603
		Logs	9%	12	$ 48	$ 591
Total	478					$ 2,917

6.1.3 Stand 3

The Stand 3 is a total of 8.5 hectares that is composed of SW_92% and HW_08%. Species are ranked according to the basal area dominance (Figure 6). The current density of Stand 3 equals 1932 ± 710 stems per hectare, and the volume per hectare equals 91 ± 36 m^3 per hectare (Table 11). The total volume removed is estimated to be 310 m^3 (Table 13) with exception of white pine as per OFLM request, and the total predicted income is expected to be $1,264.00 (Table 14).

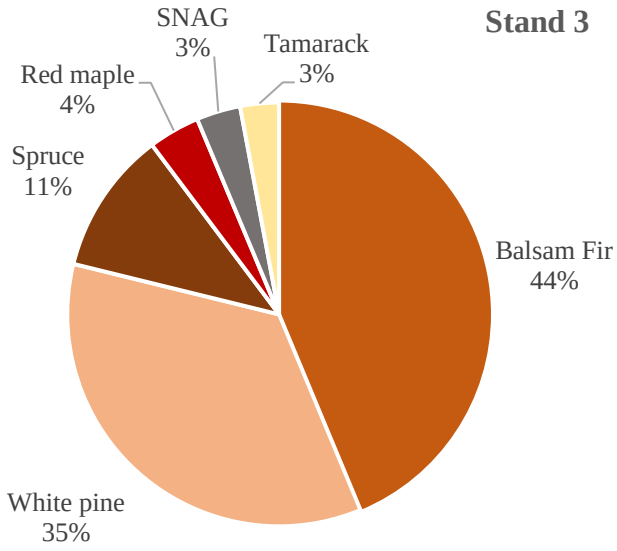


Figure 6: Stand 3 basal area dominance per species, showing a large dominance of balsam fir and white pine. WP and SNAG should be preserved, as per OFLM request.

Table 11: Stand 3 general information, showing stand attributes such as: basal area, density, and volume per hectare.

Stand Description	
Stand type	SW_92%, HW_08%
Stand area (ha)	8.5
Volume (m^3/ha)	91 ± 36
Density (stems/ha)	1,932 ± 710
Basal Area (m^2/ha)	25.5
Harvest Condition	Operable
Habitat Presence	Snags

Table 12: Stand 3 specification for basal area, density, and volume per hectare per species.

Species	BA (m^2/ha)	Density (st/ha)	CI (95%)	Vol (m^3/ha)	CI (95%)
Balsam Fir	11	868	± 318	43	± 43
White pine	07	243	± 460	27	± 06
Spruce	04	06	± 377	13	N/A
Red maple	02	369	± 188	06	± 13
SNAG	01	32	N/A	N/A	N/A
Tamarack	0.5	414	± 480	02	± 27
Total	25.5	1,932		91	

Table 13: Stand 3 total volume and prescription removal per species within the stand.

Species	Total Stand Volume (m^3)	40% Removal
Balsam Fir	364	145
White pine	234	94
Spruce	108	43
Red maple	48	19
SNAG	N/A	N/A
Tamarack	20	8
Total	775	311

Table 14: Stand 3 products specification and predicted income, according to the YSC Marketing Board stumpage values.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	19	Pulp	92%	7	$ 28	$ 199
Softwood	197	Pulp	56%	44	$ 5	$ 220
		Stud	21%	16	$ 38	$ 622
		Logs	6%	5	$ 48	$ 222
Total	217					$ 1,264

6.1.4 Stand 4

The Stand 4 is a total of 59 hectares that is composed of SW_42% and HW_58%. Species are ranked according to the basal area dominance (Figure 7). The "Others" category on the pie chart encompasses all species that show dominance inferior to 6% of the total. The current density of Stand 4 equals 2523 ± 198 stems per hectare, and the volume per hectare equals 92 ± 9 m^3 per hectare (Table 15). The total removed volume is estimated to be 2134 m^3 with exception of white pine as per OFLM request, and the total predicted income is expected to be $15,323.00 (Table 18).

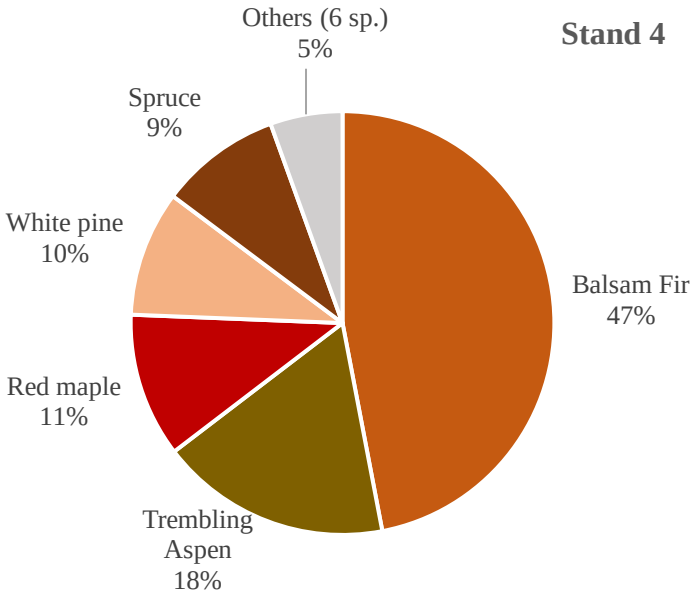


Figure 7: Stand 4 basal area dominance per species, showing a large dominance of balsam fir and trembling aspen. WP shall not be removed, and RM shall receive a lower removal intensity, as per OFLM request.

Table 15: Stand 4 general information, showing stand attributes such as: basal area, density, and volume per hectare.

Stand Description	
Stand type	SW_42%, HW_58%
Stand area (ha)	59
Volume (m^3/ha)	92 ± 9
Density (stems/ha)	2,523 ± 198
Basal Area (m^2/ha)	23
Harvest Condition	Operable
Habitat Presence	Snags

Table 16: Stand 4 specification for basal area, density, and volume per hectare per species.

Species	BA (m^2/ha)	Density(st/ha)	CI (95%)	Vol (m^3/ha)	CI (95%)
Balsam Fir	10	1,104	± 225	43	± 10
Trembling Aspen	05	518	± 211	19	± 09
Red maple	03	387	± 227	13	± 09
Spruce	02	229	± 249	10	± 09
White birch	0.8	136	± 247	04	± 07
White pine	0.5	03	± 31	01	± 06
SNAG	0.4	87	± 194	N/A	N/A
Alder	0.2	35	± 84	0.4	± 03
Grey birch	0.2	15	± 131	0.7	± 02
Big-t. Aspen	0.1	04	± 41	0.3	± 0.4
White ash	0.04	02	N/A	0.2	N/A
Total	23	2,523		92	

Table 17: Stand 4 total volume and prescription removal per species within the stand.

Species	Total Stand Volume (m^3)	40% Removal
Balsam Fir	2,566	1,027
Quacking aspen	1,112	445
Red maple	783	313
White pine	67	N/A
Spruce	567	227
White birch	213	85
SNAG	N/A	N/A
Grey birch	41	16
Big-toothed Aspen	17	7
White ash	11	4
Alder	24	9
Total	5,403	2,134

Table 18: Stand 4 products specification and predicted income, according to the YSC Marketing Board stumpage values.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	880	Pulp	92%	324	$ 28	$ 9,063
Softwood	1254	Pulp	58%	289	$ 5	$ 1,445
		Stud	11%	55	$ 38	$ 2,121
		Logs	11%	57	$ 48	$ 2,695
Total	2134					$ 15,323

6.1.5 Stand 5

The Stand 5 is a total of 26.6 hectares that is composed of SW_49% and HW_51%. Species are ranked according to the basal area dominance (Figure 8). The "Others" category on the pie chart encompasses all species that show dominance inferior to 6% of the total. The current density of Stand 5 equals 2733 ± 369 stems per hectare, and the volume per hectare equals 92 ± 12 m^3 per hectare (Table 19). The total removed volume is estimated to be 944 m^3 (Table 21), and the total predicted income is expected to be $6,839.00 (Table 22).

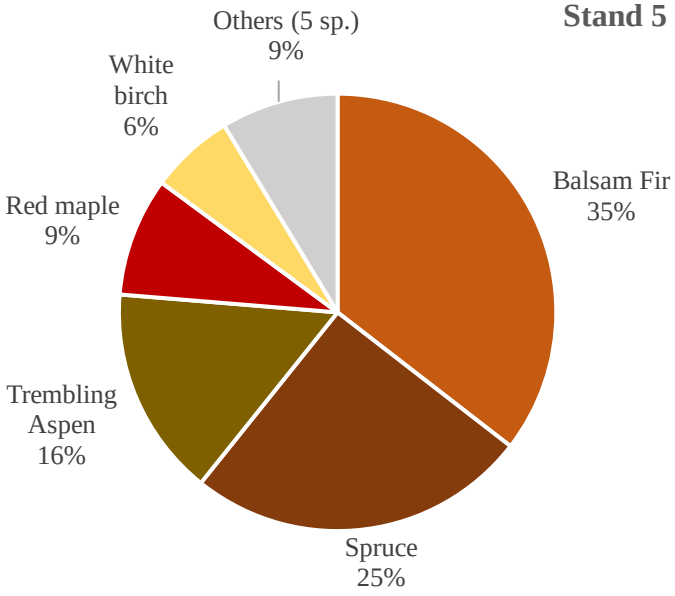


Figure 8: Stand 5 basal area dominance per species, showing dominance of balsam fir, spruce and intolerant HW.

Table 19: Stand 5 general information, showing stand attributes such as: basal area, density, and volume per hectare.

Stand Description	
Stand type	SW_49%, HW_51%
Stand area (ha)	26.6
Volume (m^3/ha)	92 ± 12
Density (stems/ha)	2,733 ± 369
Basal Area (m^2/ha)	27
Harvest Condition	Operable
Habitat Presence	Snags

Table 20: Stand 5 specification for basal area, density, and volume per hectare per species.

Species	BA (m^2/ha)	Density(st/ha)	CI (95%)	Vol (m^3/ha)	CI (95%)
Balsam Fir	10	1,101	± 470	36	± 12
Trembling Aspen	04	456	± 337	16	± 10
Spruce	04	293	± 756	11	± 26
Red Maple	03	328	± 214	11	± 08
White Birch	03	360	± 381	10	± 13
White Pine	0.8	46	± 483	03	± 42
Grey Birch	0.7	72	± 64	02	± 0.4
Big-Toothed Asp.	0.4	39	N/A	01	N/A
SNAG	0.2	26	N/A	N/A	N/A
Tamarack	0.1	11	N/A	0.44	N/A
Total	27	2733		92	

Table 21: Stand 5 total volume and prescription removal per species within the stand.

Species	Total Stand Volume (m^3)	40% Removal
Balsam Fir	970	388
Spruce	283	113
Trembling Aspen	425	170
Red Maple	291	116
White Birch	267	107
White Pine	75	N/A
Big-Toothed Aspen	45	18
Grey Birch	69	28
SNAG	N/A	N/A
Tamarack	12	5
Total	4871	944

Table 22: Stand 5 products specification and predicted income, according to the YSC Marketing Board stumpage values.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	438	Pulp	92%	161	$ 28	$ 4,513
Softwood	506	Pulp	60%	121	$ 5	$ 606
		Stud	14%	28	$ 38	$ 1,085
		Logs	7%	13	$ 48	$ 635
Total	944					$ 6,839

6.1.6 Stand 6

The Stand 6 is a total of 19.6 hectares that is composed of SW_49% and HW_51%. Species are ranked according to the basal area dominance (Figure 9). The "Others" category on the pie chart encompasses all species that show dominance inferior to 6% of the total. The current density of Stand 6 equals 2685 ± 465 stems per hectare, and the volume per hectare equals 153 ± 22 m^3 per hectare (Table 23). The total removed volume is estimated to be 1169 m^3 (Table 25), and the total predicted income is expected to be $ 8,827.00 (Table 26).

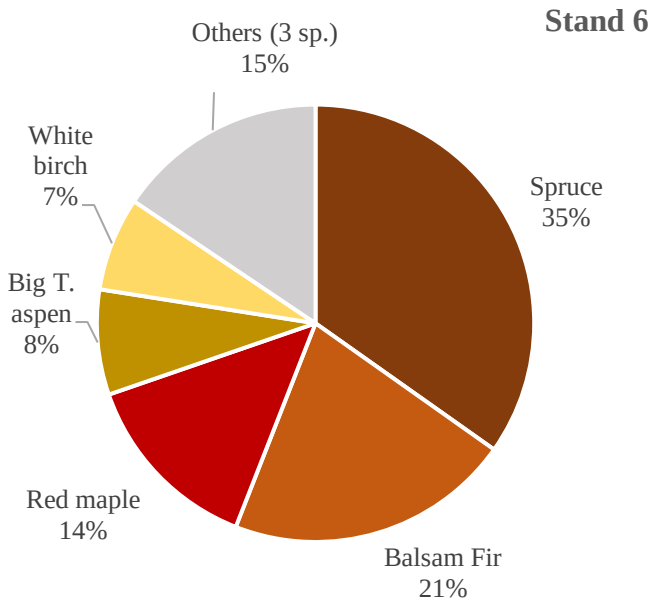


Figure 9: Stand 6 basal area dominance per species, showing dominance of spruce, balsam fir and red maple. RM shall receive a lower removal intensity.

Table 23: Stand 6 general information, showing stand attributes such as: basal area, density, and volume per hectare.

Stand Description	
Stand type	SW_49%, HW_51%
Stand area (ha)	19.6
Volume (m^3/ha)	153 ± 22
Density (stems/ha)	2,685 ± 465
Basal Area (m^2/ha)	35
Harvest Condition	Operable
Habitat Presence	Snags

Table 24: Stand 6 specification for basal area, density, and volume per hectare per species.

Species	BA (m^2/ha)	Density (st/ha)	CI (95%)	Vol (m^3/ha)	CI (95%)
Spruce	15	520	± 256	50	± 22
Balsam Fir	11	1,336	± 493	43	± 16
Red maple	04	214	± 183	16	± 10
White birch	02	50	± 28	07	± 01
SNAG	01	26	N/A	N/A	N/A
Big-toothed A.	01	11	± 6	04	± 0.3
White pine	0.8	09	N/A	03	N/A
Trembling Aspen	0.8	52	N/A	02	N/A
Total	35	2686		153	

Table 25: Stand 6 total volume and prescription removal per species within the stand.

Species	Total Stand Volume (m^3)	40% Removal
Spruce	1,185	474
Balsam Fir	1,023	409
Red maple	384	153
Big-toothed aspen	105	42
White birch	169	68
SNAG	N/A	N/A
White pine	74	N/A
Trembling Aspen	56	22
Total	2997	1169

Table 26: Stand 6 products specification and predicted income, according to the YSC Marketing Board stumpage values.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	286	Pulp	92%	105	$ 28	$ 2,941
Softwood	883	Pulp	49%	172	$ 5	$ 858
		Stud	12%	43	$ 38	$ 1,656
		Logs	20%	71	$ 48	$ 3,372
Total	1169					$ 8,827

6.1.7 Stand 7

The Stand 7 is a total of 25 hectares that is composed of SW_57% and HW_43%. Species are ranked according to the basal area dominance (Figure 10). The "Others" category on the pie chart encompasses all species that show dominance inferior to 6% of the total. The current density of Stand 7 equals 2118 ± 443 stems per hectare, and the volume per hectare equals 195 ± 22 m^3 per hectare (Table 27). The total removed volume is estimated to be 1903 m^3 (Table 29), and the total predicted income is expected to be $19,733.00 (Table 30).

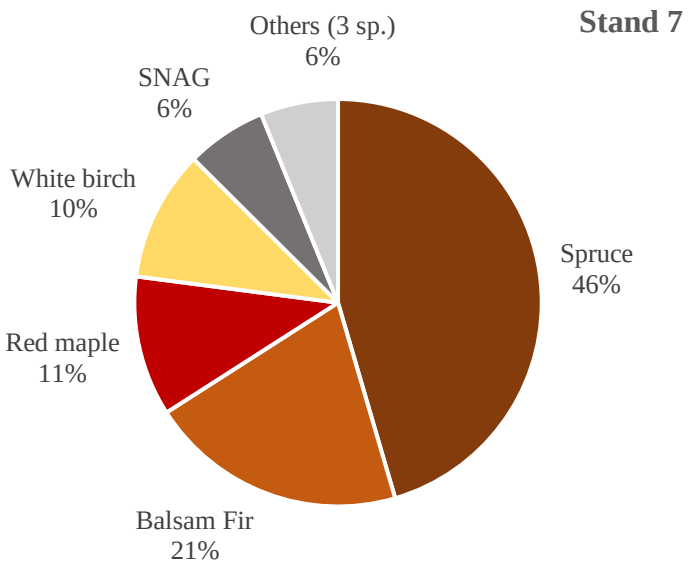


Figure 10: Stand 7 basal area dominance per species, showing dominance of spruce and balsam fir. RM shall receive a lower intensity removal, as per OFLM request.

Table 27: Stand 7 general information, showing stand attributes such as: basal area, density, and volume per hectare.

Stand Description	
Stand type	SW_57%, HW_43%
Stand area (ha)	25
Volume (m^3/ha)	195 ± 22
Density (stems/ha)	2,118 ± 443
Basal Area (m^2/ha)	44
Harvest Condition	Operable
Habitat Presence	Snags

Table 28: Stand 7 specification for basal area, density, and volume per hectare per species.

Species	BA (m^2/ha)	Density (st/ha)	CI (95%)	Vol (m^3/ha)	CI (95%)
Spruce	15	530	196	85	22
Balsam Fir	13	1,132	386	57	20
Red Maple	06	290	125	34	12
White Birch	04	145	144	28	26
SNAG	03	175	N/A	N/A	N/A
White Pine	01	18	N/A	05	N/A
Trembling A.	0.3	04	N/A	02	N/A
Strip Maple	0.1	08	N/A	0.4	N/A
Total	44	2118		195	

Table 29: Stand 7 total volume and prescription removal per species within the stand.

Species	Total Stand Volume (m^3)	40% Removal
Spruce	1,959	784
Balsam Fir	1,321	528
Red Maple	777	311
Paper Birch	641	256
SNAG	N/A	N/A
White Pine	127	N/A
Trembling Aspen	51	20
Strip Maple *	09	04
Total	4,884	1,903

Table 30: Stand 7 products specification and predicted income, according to the YSC Marketing Board stumpage values.

Species Comp	Tvol Removed (m3)	Product	Product %	Vol (cord)	Stumpage Rate ($/cord)	Predicted Income ($)
Hardwood	591	Pulp	92%	217	$ 28	$ 6,082
Softwood	1312	Pulp	28%	147	$ 5	$ 734
		Stud	9%	48	$ 38	$ 1,830
		Logs	44%	233	$ 48	$ 11,086
Total	1903					$ 19,733

6.2 Roadside Cost Results

After all fixed and variable output costs estimations are converted on a $/PMH basis, a total hourly rate of $148.00 /PMH is calculated for the SG Processor, and a total of $119.00 /PMH for the Forwarder. The unit cost ($/$m^3$) can be calculated as the hourly rate divided by machine's productivity. The assumed productivity for the SG Processor is 10 (m^3/PMH) (Table 31), therefore the estimated cost for such equipment to fell, delimb and buck 1 m^3 of products equals to $15.00 (Table 31). Similar to the SG with respect to costing and an estimated productivity for the Forwarder is 15 (m^3/PMH), and the estimated unit cost to move products from stump to the roadside of the stand equals to $8.00 /$m^3$ (Table 31). Thus, the roadside cost of operations within the NRF equals to the sum of unit cost of both machines, a total of $24.00 /$m^3$ (Table 31). At this point is essential to highlight the relevance of machine's productivity and how it can drastically impact the unit cost. Once the unit cost ($/$m^3$) is treated as a ratio between the hourly rate ($/PMH) by the machine's productivity (m^3/PMH), consequently the higher is the machine's productivity the lower is the unit cost, and vice-versa. An analyses of productivity rates and how that does impact the final delivered wood cost is present within the discussion section.

Considering the assumed number for SMH, machine utilization, and the total contract volume (m^3), both SG Processor and Forwarder requires an estimated total of 55 days to fell, delimb, manufacture, and move products to stand roadside within the NRF.

Table 31: Outputs costs for each component of the machine rental rate, hourly rate, unit cost, and total roadside cost.

Equipment	SG - Processor	Forwarder
Utilization (PMH/SMH)	90%	90%
Productivity (m^3/PMH)	10	15
FIXED COST ($/PMH)		
CRD	$ 46.00	$ 40.00
Insurance	$ 13.00	$ 11.00
License	$ -	$ -
VARIABLE COST ($/PMH)		
SR Material	$ 12.00	$ 9.00
SR Labour	$ 17.00	$ 9.00
Fuel Cost	$ 22.00	$ 15.00
Lube Cost	$ 2.00	$ 2.00
Tire Cost	$ -	$ 3.00
Transportation	$ 2.00	$ 4.00
Wage	$ 34.00	$ 26.00
Hourly Rate ($/PMH)	$ 148.00	$ 119.00
Unit Cost ($/$m^3$)	$ 15.00	$ 8.00
Unit cost + Profit ($/$m^3$)	$ 15.75	$ 8.40
Roadside Cost ($/$m^3$)		$ 24.00

6.3 Delivered locations

The delivered locations were chosen based on the type of product each mill purchases and the nearest mill's distance from the NRF (Figure 11). Devon Lumber is the closest chosen destination for SW studwood products, located at 200 Gibson St, Fredericton, NB E3A 4E3, equating a total of 16 km from the NRF. JD Irving - Grand Lake Timber is the chosen destination for SW sawlogs, located at 290 Main St, Chipman, NB E4A 2M7, equating a total distance of 57 km from the NRF; lastly the furthest destination is AV. Nackawic Inc, the chosen deliver location for pulpwood products (SW and HW), located at 103 Pinder Rd, Nackawic, NB E6G 1W4, equating a total distance of 83.5 km far from the NRF. Details for road type and road average speed are available on the trucking schedule section.

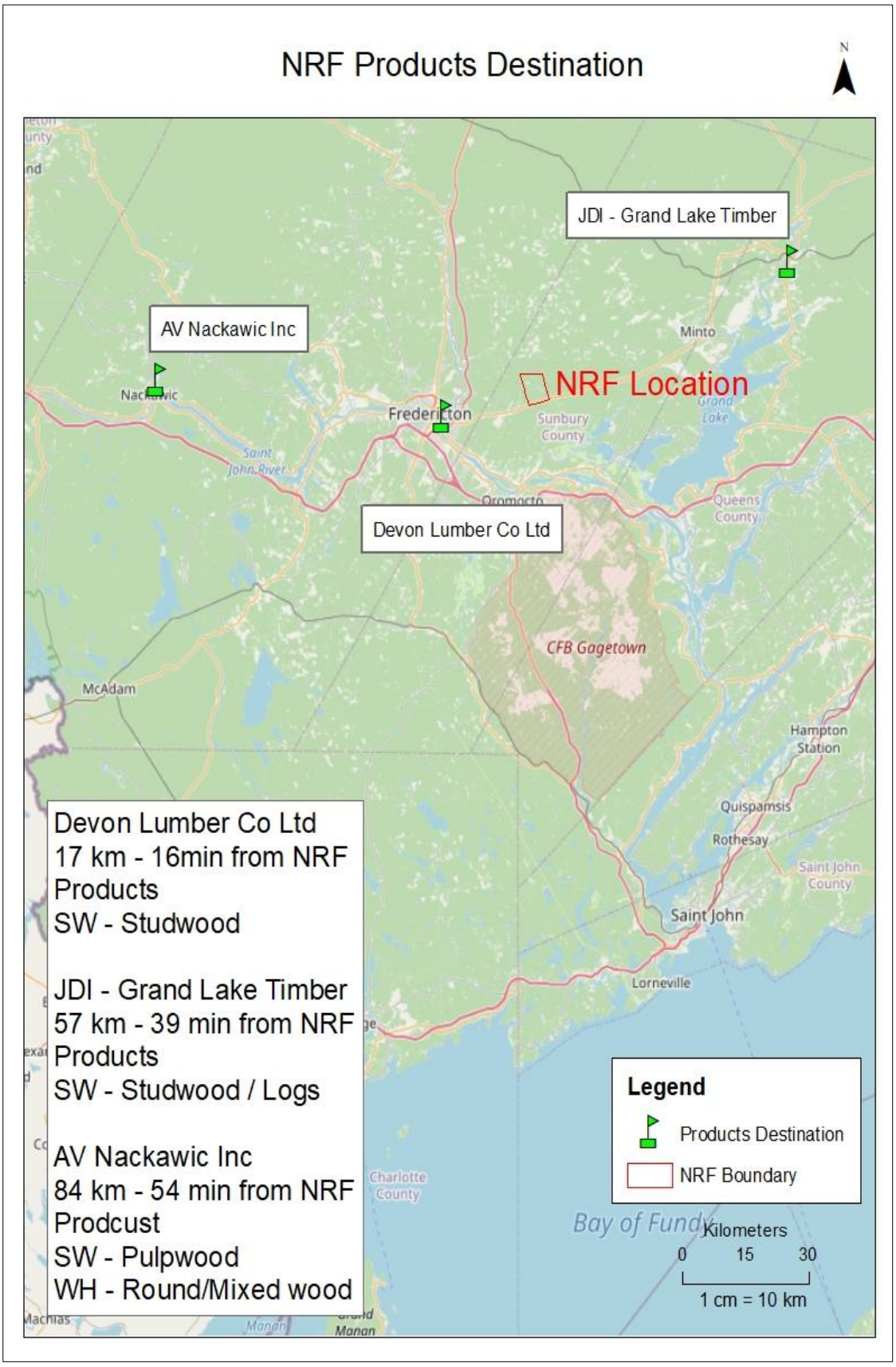


Figure 11: Delivered chosen locations for products manufactured within the NRF. Devon Lumber is the closest location to the NRF, while AV Nackawic is the farthest deliver location.

6.4 Trucking Schedule Results

Trucking schedule is calculated based on transportation distance, road class, load size, and time spent moving products. There are necessary steps to conduct a trucking schedule, (1) calculating time spent to transport a load of an individual product, and (2) managing the number of loads (different products) are possible to haul within the given truck shift schedule.

The estimated time to move a product load is converted to a PMH basis and is presented on Table 32. As it was mentioned in the transportation cost methodology, loading is more expensive in the field, rather than the mill yard, where there is a larger loader, which can quickly load and unload truck, reducing waiting time. For this report it was assumed an average of 40 minutes for both loading and unloading time cycles. The farthest delivered destination, AV. Nackawic, requires an estimated total of 3.39 PMH to load a truck in the NRF stands, transport to the mill's yard and unload it, and go back to the NRF stands. While the estimated transportation time to Devon Lumber is only 1.96 PMH. An analysis of trucking distance and payload is presented within the discussion section.

Table 32: Total time for round trips of products (truck loaded and empty), plus total waiting time per cycle (loading and unloading of truck), converted in a PMH basis.

Destination	Products	Time per trip (PMH)
AV. Nackawic	SW Pulp	3.39
Devon Lumber	SW Stud	1.96
JDI – Grand Lake Timber	SW Logs	2.54
AV. Nackawic	HW Pulp	3.39

After calculating the time spent transporting a load of an individual product, the challenge is to estimate a balance for the truck to maximize time loaded and traveling, or utilization.

As a result, the present report proposes a 3 daily schedules for the assumed truck, considering the total volume (m^3) moved, and the volume per product within the NRF stands (Table 33). Each schedule should last a required number of days based on the volume per product. Schedule 1 for instance, includes 2 trips of pulpwood (SW and HW), 2 trips of SW logs, and 2 trips of SW studwood, equating a 99% utilization, considering a 16h shift and it should last for at least 11 days (considering the volume of studwood).

Table 33: Daily trucking schedule for one single truck (27-ton capacity), showing respective utilization for each schedule, as well as number of days required to truck all products.

Sched	LOAD 1	LOAD 2	LOAD 3	LOAD 4	LOAD 5	LOAD 6
1	SW Pulp	HW Pulp	SW Logs	SW Logs	SW Stud	SW Stud
2	SW Pulp	SW Pulp	HW Pulp	SW Logs	SW Logs	
3	SW Pulp	SW Pulp	HW Pulp	HW Pulp		

6.5 Transportation Cost Results

Applying the estimated utilization from trucking schedule (Table 33) to the MRR considering all assumed parameters for the self-loading truck (27 ton), the hourly rate for the chosen truck comes to a cost of $ 154.00 / PMH (Table 34). Knowing that, each product holds an individual hauling time, Table 35 presents the unit cost ($/m^3) of transportation per product.

Table 34: Machine Rental Rate for a truck 27-ton capacity, showing fixed and variable costs computed based on assumed parameters, as well as the total hourly rate for moving products.

Equipment	Self-loading truck	
Utilization (PMH/SMH)	93%	
Load capacity	27 ton	
FIXED COST ($/PMH)		
CRD	$	19.00
Insurance	$	6.00
License	$	1.00
VARIABLE COST ($/PMH)		
SR Material	$	15.00
SR Labour	$	11.00
Fuel Cost	$	71.00
Lube Cost	$	4.00
Tire Cost	$	3.00
Transportation	$	-
Wage	$	24.00
Hourly Rate ($/PMH)	$	154.00

Table 35: Estimated individual unit cost per product prominent from the NRF, based on the truck hourly rate and distance from the NRF to each mill destination.

Truck self-loading (27 ton)	SOFTWOOD			HARDWOOD
Products	PULPWOOD	STUDWOOD	SAWLOG	PULPWOOD
Cost/Trip	$ 523.00	$ 302.00	$ 391.00	$ 523.00
Unit Cost ($/m3)	$ 19.00	$ 11.00	$ 14.00	$ 19.00
Unit cost + Profit ($/m^3)	$ 20.00	$ 12.00	$ 15.00	$ 20.00

6.6 Management Overheads Results

The overhead component within the contracting services includes accounting, administrative/ office expenses, licenses, fines, legal fees, professional dues, travel, phone, medical, training, and vehicle expenses, and any other activity which is not directly associated with wood product manufacturing. It is essential to highlight that overheads account only for costs associated with an individual stand, project contract, or annual operable year (m^3, Tonnes, or Cords) (Ackermana et al., 2014). Moreover, not all contractors have the same management overheads.

Similar to the harvesting equipment and trucking, with respect to costing, numbers are estimated for the overhead component and calculated in an annual basis (215 days) with an estimated contract of 75,000 m^3, which accounts for a total of $293,000.00 (Table 35.2). Proportionally for the time length of the NRF contract (55 days), the estimated management overheads equates ~$4.00 /$m^3$ (Table 35.2).

Table 35.2: Estimated overheads cost on an annual basis, showing the total cost for an operable year (215 days), and the proportional total cost for the NRF contract (55 days). Numbers are expressed in a 10^3 notation.

Adm	$	100.00
Office	$	12.00
Floating	$	75.00
Truck Expenses	$	15.00
Training	$	35.00
Technology	$	10.00
Service Vehicle	$	25.00
Fire Fighting	$	10.00
Pre-Harvesting Plan	$	10.00
Professional Fees	$	1.00
Total Annual (215 days)	$	293.00
NRF contract ($/$m^3$)	$	4.00

6.7 Delivered Wood Cost Results

Lastly, the sum of roadside cost, transportation cost, and overheads correspond to the total delivered wood cost (Table 36). The price paid at the mill's gate for products minus the estimated delivered wood cost allows an estimative of what is available for stumpage value delivered to the landowner. The table below summarizes the unit cost ($/m^3) for overheads, roadside cost, transportation cost, and therefore the total estimated delivered wood cost. For example, with SW Pulp the transportation unit cost equals $20.00, plus roadside cost ($24.00), plus overheads ($2.00), equates an SW_Pulp total delivered wood cost of $46.00 /m^3. Likewise, SW_Stud unit cost for transportation equals $11.00, plus roadside cost ($24.00), plus overheads ($2.00), equates a total delivered wood cost of $37.00 /m^3 (Table 36). The same methodology is applied to the SW_Log and HW_Pulp products.

Table 36: Total estimated delivered wood cost per individual product prominent from the NRF. The delivered wood cost is the total sum of overheads cost, roadside cost, and transportation cost per product.

Overheads ($/m3)	$ 4.00			
Roadside Cost ($/m3)	$ 24.00			
Products	SW PULP	SW STUD	SW LOG	HW PULP
Transportation Cost ($/m3)	$ 20.00	$ 11.00	$ 15.00	$ 20.00
Delivered Wood Cost ($/m3)	$ 48.00	$ 39.00	$ 43.00	$ 48.00

6.8 Stumpage Value Results

Finally, the stumpage rate is the value ($/m^3) paid to the landowner after all costs for harvesting, for transportation and overheads are being paid off (Table 37). For this report, considering all assumed rates, the stumpage price is calculated by simply taking the delivered wood price, paid at the mill's gate minus the total delivered wood cost. For example, SW_Pulp has been receiving $48.00 /m^3 at the mill's gate, at a cost to harvest and transport of $47.94 /m^3, therefore, what is available to the landowner equates a total of $0.06 /m^3 for softwood pulp (Table 37). The same methodology calculation applies to the other products.

Table 37: Estimated stumpage rate provided to the landowner, based on price paid at the mill's gate ($/m^3) minus delivered wood cost ($/m^3).

Products	SW PULP	SW STUD	SW LOG	HW PULP
Wood Market Price ($/m^3)*	$ 48.00	$ 60.00	$ 77.00	$ 53.00
Delivered Wood Cost ($/m^3)	$ 47.94	$ 39.00	$ 43.00	$ 48.00
Stumpage Price ($/m^3)	$ 0.06	$ 21.00	$ 34.00	$ 5.00

*Price paid at the mill's gate for each specific product destination.

Rates paid at the mill's gate might change without notice, the YSC Marketing Board provide weekly reports from mill's and products specifications update (York-Sunbury-Charlotte marketing board, 2021). The YSC Marketing Board also provide an average stumpage rate based on large, collected data from contractors across the York-Sunbury-Charlotte region (Table 37.2). The stumpage rate calculate on this report (Table 37), is not too far off from the average rate provide by the YSC Marketing board (Table 37.2). The higher numbers for SW Stud and SW Logs on this report acceptable due to the proximity of both products destinations. Devon Lumber mills is located only ~17km from the NRF, and JDI Grand Lake ~60km, which provide to the landowner an

opportunity cost, where he can receive a height rate due to the location of his land with a lower cost for product transportation.

Table 37.2: Stumpage rate provided by the YSC Marketing Board, with max and min values, based on a collected large data of stumpage rates.

Products	SW PULP	SW STUD	SW LOG	HW PULP
Max Stumpage Rate ($/m^3)	$ 4.00	$ 19.60	$ 27.20	$ 14.00
Min Stumpage Rate ($/m^3)	$ -	$ 10.00	$ 14.00	$ 11.20
Average Stumpage Rate ($/m^3)	$ 2.00	$ 15.00	$ 20.00	$ 12.00

7.0 Discussion

With respect to the machine rental rate (MRR) there is a few variable components worth a discussion. They are the productivity rate (m^3/PMH), utilization rate, and fuel cost ($/L), which can affect the unit cost ($/$m^3$), and therefore the roadside cost. The discussion section aims to forecast a 20% variation in all three rates and explain how the unit cost would be impacted (Table 38). All presented charts below shows a "Base" scenario (blue), which represents the current scenario, including all estimated parameters for this report, and a the 20% forecasted scenario (red).

7.1 Base scenario or Status Quo

All predicted costs for the roadside cost were based on critical machine parameters, the utilization and productivity (m/^{3}/PMH). Which can both impact the hourly rate (m^3/PMH) and the unit cost ($/m^3). The assumed utilization for both machines is 90%, and the assumed productivity is: SG Processor – 10 m^3/PMH, and Forwarder – 15 m^3/PMH. The assumed fuel cost ($/L) for both forest machines is $ 0.75 per litre of diesel, a tax-exempt cost as an farmers Government incentive (Table 38).

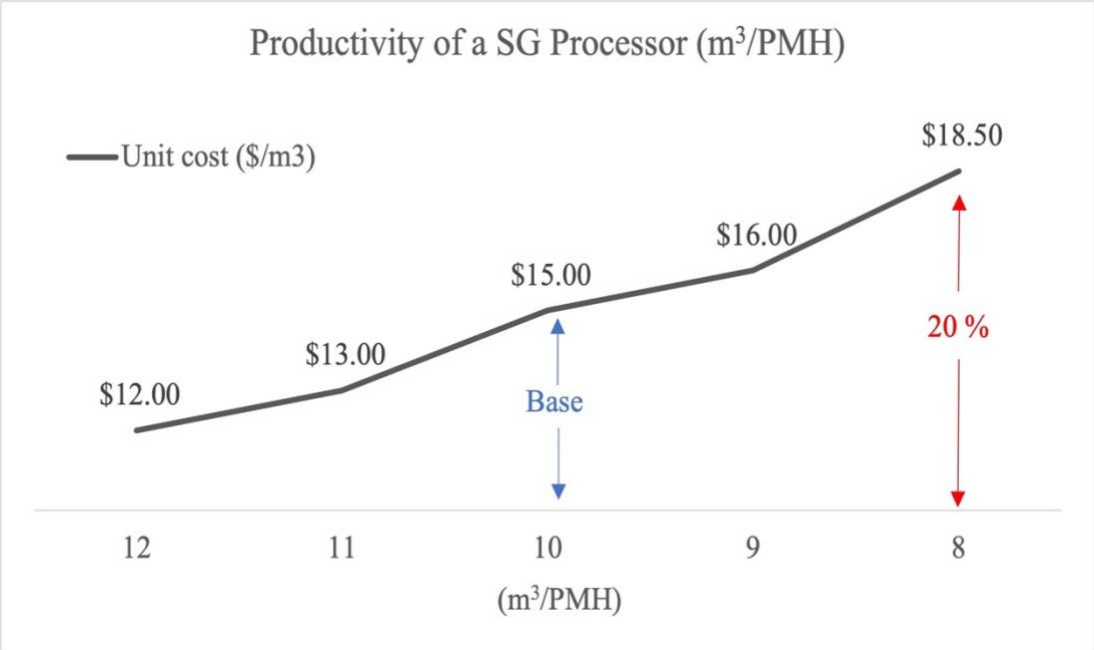
Table 38: Summary of scenarios forecast with respect to variation in productivity (m^3/PMH), utilization (%), and fuel cost ($/L), demonstrating how the unit cost ($/m^3) is affected.

Productivity of a SG Processor (m3/PMH)					
Scenario	Base	1	2	3	4
Productivity (m3/PMH)	10	9	8	7	6
Unit cost ($/m3)	$ 15.00	$ 16.00	$ 18.50	$ 21.00	$ 25.00
Utilization of a SG Processor					
Scenario	Base	1	2	3	4
Utilization (%)	90%	85%	80%	75%	70%
Unit cost ($/m3)	$ 15.00	$ 15.50	$ 16.00	$ 17.00	$ 18.00
Fuel Cost of a SG Processor ($/L)					
Scenario	Base	1	2	3	4
Fuel Cost ($/L)	$ 0.75	$ 1.00	$ 1.25	$ 1.50	$ 1.75
Unit cost ($/m3)	$ 15.00	$ 15.58	$ 16.33	$ 17.83	$ 18.58

7.2 Productivity of a SG Processor

Harvesting productivity is expressed as number of trees processed per unit time (m^3/PMH), and it has the largest impact on unit cost relative to other cost drivers (Sangstuvall, 2010). Being affected the most by the operator skills, with respect to fine motor skills, ability to plan ahead, and capability of multitasking; productivity can also be affected by piece size, number of products delimbed, processed, and assorted; site conditions, and applied prescription (Germain et al., 2019). The assumed productivity rate for the SG Processor is 10 m^3/PMH and a decrease of 20% on such rate will increase the unit cost up to \$18.50 /m^3, a total of \$3.50 increase per m^3 (Figure 11.2).

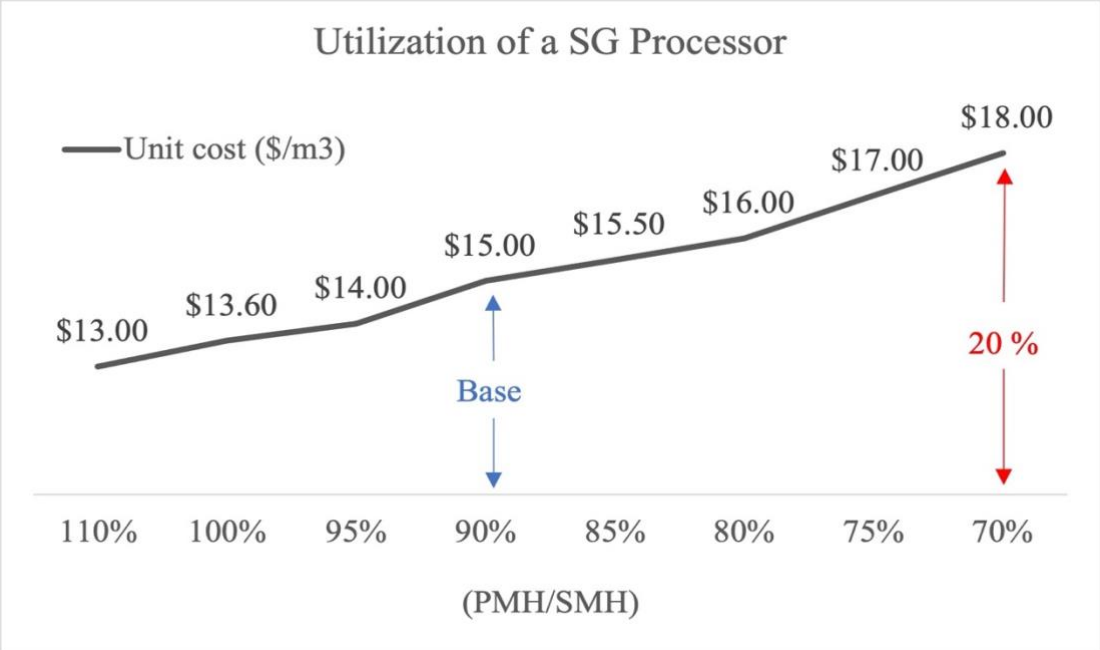
Figure 11.2: Relation between the unit cost of a SG Processor and its productivity, showing a drop of 20% in the productivity rate results in a \$3.50 increase per m^3.



7.3 Utilization of a SG Processor

Utilization of a forest machine (U%) is the ratio of Productive Machine Hours (PMH) to Schedule Machine Hour (SMH) and it reflects how much a machine has been utilized within the given schedule hours (Thompson, 2001). It also can be affected by many factors, such as mechanical delays, non-mechanical delays, operational lost time, and personnel time. The assumed utilization for the presented harvest system is 90%, meaning there is no wasted time, only operator breaks. A 20% drop on the utilization rate is not uncommonly seen on field (due to wasted time), and it will bring the unit cost up to \$18.00 /m^3, a total of \$3.00 increase per m^3 (Figure 12).

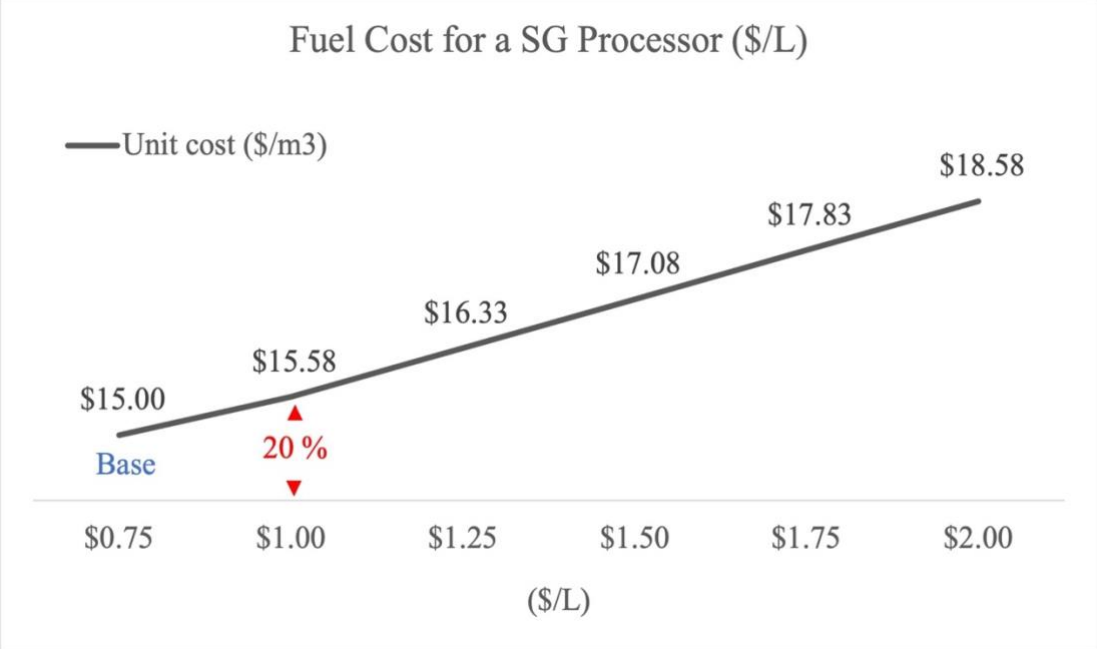
Figure 12: Relation between the unit cost of a SG Processor and its utilization, showing a drop of 20% results in a \$3.00 increase in unit cost.



7.4 Fuel Cost of a SG Processor

There is a wrong conception spread world-wide about fuel cost within the unit cost for forest machines. The assumed fuel cost ($/L) for both forest machines was $0.75 per litre of diesel, a tax-exempt cost as a farmers Government incentive, and even so is subject to market fluctuations. The fuel cost certainly does impact the hourly rate and unit cost of a forest machine, however not as drastically as the productivity and utilization rate. A 20% increase will bring the cost of fuel up to $ 0.95 cents per litre, and the unit cost up to $ 15.58 per m^3, a total increase of $ 0.58 cents per m^3 (Figure 13). Following the current unexpected market fluctuation in the price of diesel, $ 2.00 per litre, means a 167% increase from the status quo price, which brings the unit cost up to $ 18.58 /m^3, a total increase of $ 3.58 per m^3, and yet inferior to productivity and utilization rate drops.

Figure 13: Impact of a fuel cost increase on the unit cost of a SG Processor.



8.0 Conclusion

The main goal of this report was to develop an understanding of how to conduct a complete forest operations plan for 7 forest stands located in the Noonan Research Forest, owned by the University of New Brunswick. Starting from the forest inventory data collection and analysis; gathering all necessary fixed and variables cost to build a machine rental rate for forest harvesting and trucking of products; and how to calculate the expected revenue.

The goal was accomplished through (1) analysis of forest inventory calculating for the total stand: species composition, basal area, density, and volume per hectare with respective variance; as well as estimating volume for products of each species. The estimated total volume per species is: Balsam fir (~7,200 m^3), Spruce (~5,400 m^3), Red maple (~2,500 m^3), trembling aspen (~1,700 m^3), and White birch (~1,400 m^3), alongside with other species with lower volume. (2) An ideal silviculture prescription was defined in a fashion way that fulfill the OFML requests; unfortunately, the assessment performed in the NRF is not eligible for the YSC Marketing Board subsidize once all 7 chosen stands present age superior to 40 years old.. The chosen prescription was a Selective commercial thinning with 35% to 40% removal of all selected species within each stand, targeting the abundant merchantable Balsam Fir and Spruce, along with intolerant hardwood component; preserving the white pine and yellow birch component; favoring the established regeneration. The estimated total volume per products is: SW_Pulp (~25,000 m^3), SW_Stud (~600 m^3), SW_Logs (~990 m^3), and HW_Pulp (~22.000 m^3). (3) The most suitable harvest system for such prescription is a shortwood system implementing a single grip harvester, forwarder and center mount truck. All fixed and variable components costs were assumed and used to calculate the total roadside cost, as well as the closest mill destination were chosen,

making possible the trucking schedule arrange, this way the transportation cost was also estimated. The estimated total roadside cost equals ~$24.00/$m^3$, and the transportation cost per product equals: SW_Pulp (~$20.00/$m^3$), SW_Stud (~$12.00/m^3), SW_Logs (~$15.00/$m^3$), and HW_Pulp (~$20.00/m^3). Alongside with a $2.00 rate for management overheads. (4) The stumpage price was properly calculated, being: SW_Pulp ($3.00/$m^3$), SW_Stud (~23.00 /$m^3$), SW_Logs (~37.00/$m^3$), and HW_Pulp (~$8.00/m^3). Such rate was compared with a long data stumpage record from the YSC marketing board, providing to the OFML a better understanding of cost management. The expect revenue was calculated based on the stumpage rate provided by the YSC Marketing Board, accounting for a total expected revenue of ~$57,000. (5) Lastly, three forecasted scenarios were presented showing a 20% variation on the productivity rate, utilization rate, and fuel cost and how the unit cost ($/$m^3$), showing that productivity has the largest impact on unit cost relative to other cost drivers.

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Appendix

Appendix I: Species Composition for the Noonan Research Forest (NRF).

Scientific name	Common name	ID
Abies balsamea (L.) Mill.	Balsam fir	BF
Acer pensylvanicum	Striped maple	ST
Acer rubrum L.	Red maple	RM
Acer saccharum Marsh.	Sugar maple	SM
Acer spicatum Lam.	Mountain maple	MOM
Alnus sp.	Alder	AL
Betula alleghaniensis Britton.	Yellow birch	YB
Betula papyrifera Marsh.	White birch	WB / PB
Betula populifolia Marsh.	Grey birch	GB
Fagus grandifolia Ehrh.	American beech	AB
Fraxinus americana L.	White ash	WA
Larix laricina (DuRoi) K. Koch.	Tamarack	TA
Ostrya virginiana (Mill.) K. Koch.	Ironwood	IR
Picea sp.	Spruce	SP
Pinus banksiana Lamb.	Jack pine	JP
Pinus resinosa	Red pine	RP
Pinus strobus L.	Eastern white pine	WP
Populus grandidentata Michx.	Big-toothed aspen	BT
Populus tremuloides Michx.	Trembling aspen	QA
Prunus sp.	Cherry	PR / PC
Salix sp.	Willow	WIL
Sorbus sp.	Mountain-ash	MA
Taxus canadensis	Ground Hemolck	GH
Thuja occidentalis L.	Eastern white cedar	WC / EC
Tsuga canadensis (L.) Carr.	Eastern hemlock	EH
Ulmus sp.	Elm	AE
	Shrub	SHB
	Snag	SNAG

Appendix II: Assumed numbers for: fixed and variables input parameters, equipment data, insurance rate, interest, payroll-levies, expected profit, and machine schedule hours.

Operating Parameters	Sg Processor	Forwarder	Truck 1
UNB Contract Volume (m^3)	7414	7414	7414
Interest Rate (Inv. Return)	5 %	5 %	6 %
Insurance %	3 %	3 %	4 %
Fring Ben. or Payroll Levies	17 %	17 %	17 %
Expected Profit	5 %	5 %	4 %
Machine Schedule	Sg Processor	Forwarder	Truck 1
Number of Units	1	1	1
Operators/Unit	1	1	1
Shifts/Day	1	1	1
Hours/Shift	12	8	16
Operating Days/Contract	55	55	50
Work Schedule	Sg Processor	Forwarder	Truck 1
Productivity (m^3/Pmh)	13	22	-
Utilization %	90%	90%	-
Smh/Year Available	720	456	-
Pmh/Year Available	648	410.4	-
Labour Data	Sg Processor	Forwarder	Truck 1
Wage ($/Smh)	$ 26.00	$ 20.00	$ 19.50
Equipment Data	Sg Processor	Forwarder	Truck 1
Purchase $	$ 625,000.00	$ 375,000.00	$ 285,000.00
Life (Pmh)	20000	22000	30000
Life or Financing (Years)	6	6	5
Salvage	$ 95,000.00	$ 75,000.00	$ 40,000.00
License ($/Yr)	0	0	$ 976.74
Sr Material ($/Pmh)	$ 12.00	$ 9.00	$ 15.00
Sr Labour ($/Smh)	$ 15.00	$ 8.00	$ 10.00
Fuel (L/Pmh)	30	20	55
Fuel Cost ($/L)	$ 0.75	$ 0.75	$ 1.29
Lube Cost ($/Smh)	$ 1.50	$ 1.50	$ 3.50
Tire Life (Pmh)	0	7330	6000
Tire Cost ($/Set)	$ -	$ 32,000.00	$ 22,000.00
Transporation/Rate	$ 0.35	$ 0.35	$ -
Transportation (Km/Shift)	75	75	0

Appendix III: Real parameters for road class average speed, alongside to real distance from stand to each specific mill location. Time spent per product is calculated based on road average speed for travelling with truck loaded and empty. Total distance inside the NRF is estimated in 4km.

Road Class Average Speed					
Road Class	Highway	Secondary	Tertiary	In Block	
Avg Sleep Loaded (Km/Hr)	85	65	40	10	
Avg Speed Unloaded (Km/Hr)	95	75	60	20	
Distance From Block to Mill					
Road Class	Highway	Secondary	Tertiary	In Block	Total
Softwood					
Av. Nackwic – Pulp (Km)	59.6	15.5	8.4	4	87.5
Devon Lumber – Stud (Km)	-	16.6	-	4	20.6
Grand Lake Timber – Log (Km)	-	57	-	4	61
Hardwood					
Av. Nackwick – Pulp (Km)	59.6	15.5	8.4	4	87.5
Time Spent Per Product					
Road Class	Highway	Secondary	Tertiary	In Block	Wait Time
Softwood					
Av. Nackwic – Pulp (hr)	1.33	0.45	0.35	0.6	0.4
Devon Lumber – Stud (hr)	-	-	0.69	0.6	0.4
Grand Lake Timber – Log (hr)	1.27	-	-	0.6	0.4
Hardwood					
Av. Nackwick – Pulp (hr)	1.33	0.45	0.35	0.6	0.4

Appendix IV: Raw data Stand 1.

Trees per class

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	2	5	9	9	3		1	2			1
RM	3	1					3	1			
SNAG		1	1								
SP	5	13	20	36	23	3	1				

Average of DBH

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	7.05	9.04	11.27	12.82	15.07		18.50	21.25			26.60
RM	6.80	8.90	0.00				18.80	20.60			
SNAG		9.40	11.10								
SP	7.62	9.02	11.37	13.19	14.98	16.87	18.80				

Avg of BA

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	0.39	0.91	1.63	1.47	0.50		0.15	0.32			0.15
RM	0.55	0.18					0.47	0.15			
SNAG		0.20	0.18								
SP	1.15	2.36	3.69	6.22	3.76	0.48	0.16				

Average of Ht

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	5.78	6.91	7.59	8.18	8.79		9.18	10.72			11.83
RM	6.58	6.46					13.36	13.87			
SNAG											
SP	7.23	7.34	8.76	9.01	9.96	10.30	11.10				

Average of Vol/tree

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	0.01	0.02	0.03	0.05	0.07		0.12	0.16			0.30
RM	0.01	0.02					0.16	0.20			
SNAG											
SP	0.01	0.02	0.04	0.05	0.08	0.10	0.14				
Grand Total											

Density_Class_ha

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	101	142	164	114	28		6	9			3
RM	152	28					17	5			
SNAG		28	18								
SP	253	369	364	455	213	21	6				

Average volume_Class_ha

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	0.87	2.55	4.97	5.30	1.88		0.65	1.47			0.79
RM	1.47	0.48					2.62	0.90			
SNAG											
SP	2.70	7.13	12.88	23.78	16.62	2.23	0.79				

Appendix V: Raw data Stand 2.

Trees per class

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	8	15	16	9	13	5	2	1	2	2	1
BT		1	2	4							
PB	1	5	2								
QA			3	2	2	1	1				
RM		6	4						1		
SP	1	2	4	5		5		2	1		
WP	1			4	4	2	2	1			

Average of DBH

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	7.44	8.99	11.14	13.29	15.08	16.80	18.65	20.60	22.60	24.55	26.70
BT		9.20	11.60	12.60							
PB	6.20	8.68	11.10								
QA			11.17	13.50	14.95	17.20	18.80				
RM		9.15	10.83						22.70		
SP	7.50	8.70	10.88	12.76		17.36		21.45	23.00		
WP	6.30			13.33	15.38	17.65	19.00	20.50			

Avg of BA

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	1.54	2.37	2.48	1.38	1.88	0.69	0.27	0.13	0.26	0.26	0.13
BT		0.17	0.34	0.55							
PB	0.13	0.74	0.31								
QA			0.47	0.32	0.29	0.14	0.14				
RM		0.98	0.59						0.13		
SP	0.20	0.30	0.59	0.71		0.74		0.29	0.14		
WP	0.14			0.62	0.60	0.30	0.28	0.13			

Average of Ht

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	7.74	8.05	10.44	10.78	10.35	11.09	10.85	10.56	11.79	12.57	12.92
BT		14.54	15.79	14.80							
PB	13.05	7.44	11.06								
QA			8.44	11.63	9.82	10.26	10.96				
RM		11.97	7.93						12.89		
SP	11.75	10.20	8.38	9.58		14.44		14.87	11.05		
WP	5.84			10.05	12.08	10.15	10.18	8.71			

Average of Vol/tree

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	0.01	0.02	0.04	0.06	0.08	0.11	0.13	0.16	0.21	0.26	0.32
BT		0.03	0.05	0.07							
PB	0.02	0.02	0.04								
QA			0.03	0.06	0.06	0.09	0.12				
RM		0.03	0.03						0.21		
SP	0.02	0.03	0.03	0.06		0.14		0.22	0.21		
WP	0.01			0.05	0.09	0.10	0.12	0.13			

Density_Class_ha

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	354	373	255	99	106	31	10	4	7	6	2
BT		25	32	44							
PB	44	124	32								
QA			48	22	16	6	5				
RM		149	64						3		
SP	44	50	64	55		31		8	3		
WP	44			44	32	12	10	4			

Average volume_Class_ha

Classes	6	8	10	12	14	16	18	20	22	24	26
BF	3.93	7.62	10.08	5.81	8.13	3.30	1.30	0.64	1.39	1.46	0.74
BT		0.78	1.70	3.18							
PB	0.74	2.37	1.31								
QA			1.34	1.24	1.04	0.55	0.58				
RM		3.82	1.75						0.68		
SP	0.73	1.29	2.16	3.05		4.36		1.79	0.69		
WP	0.35			2.35	2.79	1.18	1.19	0.51			

Appendix VI: Raw data Stand 3.

Trees per class

Species / Class	6	8	10	12	14	16	18	20	24
Balsam Fir		6	5	4	12	8	2	1	
Red Maple		4	1			1			
SNAG									1
Spruce	1	2	1	4	3	1			
Tamarak				1			1		
White Pine		1	3	3	4	6	5	1	1

Average of DBH

Species / Class	6	8	10	12	14	16	18	20	24
Balsam Fir		8.85	10.86	12.50	14.99	17.30	18.85	20.60	
Red Maple		9.05	10.30			16.60			
SNAG									24.70
Spruce	6.90	8.70	11.30	12.80	14.97	17.90			
Tamarak				13.20			19.00		
White Pine		10.00	11.17	12.77	14.83	16.82	18.70	21.00	25.10

Avg of BA

Species / Class	6	8	10	12	14	16	18	20	24
Balsam Fir		1.84	1.47	1.09	3.44	2.34	0.55	0.27	
Red Maple		1.28	0.27			0.27			
SNAG									0.26
Spruce	0.33	0.59	0.32	1.14	0.86	0.31			
Tamarak				0.30			0.28		
White Pine		0.39	0.94	0.85	1.12	1.66	1.35	0.28	0.27

Average of Ht

Species / Class	6	8	10	12	14	16	18	20	24
Balsam Fir		7.07	8.35	7.64	9.63	10.23	12.68	9.86	
Red Maple		6.96	7.25			17.73			
SNAG									
Spruce	5.49	6.14	7.19	9.95	8.44	8.89			
Tamarak				8.67			10.25		
White Pine		6.75	7.47	8.04	10.88	10.30	11.22	9.77	11.48

Average of Vol/tree

Species / Class	6	8	10	12	14	16	18	20	24
Balsam Fir		0.02	0.03	0.04	0.07	0.10	0.15	0.15	
Red Maple		0.02	0.03			0.15			
SNAG									
Spruce	0.01	0.02	0.03	0.06	0.07	0.09			
Tamarak				0.05			0.13		
White Pine		0.02	0.03	0.04	0.08	0.10	0.13	0.14	0.24

Density_Class_ha

Species / Class	6	8	10	12	14	16	18	20	24
Balsam Fir		298	159	88	195	99	20	8	
Red Maple		199	32			12			
SNAG									6
Spruce	88	99	32	88	49	12			
Tamarak				22			10		
White Pine		50	95	66	65	75	49	8	6

Average volume_Class_ha

Species / Class	6	8	10	12	14	16	18	20	24
Balsam Fir		5.46	5.24	3.89	14.16	9.91	2.94	1.20	
Red Maple		3.09	0.80			1.80			
SNAG									
Spruce	0.73	1.63	0.94	5.05	3.27	1.14			
Tamarak				1.12			1.30		
White Pine		0.80	2.66	2.85	5.05	7.20	6.50	1.14	1.33

Appendix VII: Raw data Stand 4.

Trees per class

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Alder	3												
Balsam Fir	23	43	42	61	45	26	22	9	6	6	1	1	
Big-Toothed Aspen					2								
Grey Birch		1	1		2								
Paper Birch	5	5	5	4	5								
Quaking Aspen	5	24	35	28	18	12	7	1					
Red Maple	9	12	29	14	12	3	2	2	1		1		
SNAG	5	1	3	1	1	1	1	1					
Spruce	2	11	17	11	6	5	2	3		1			1
White Ash					1								
White Pine							1				1		3

Average of DBH

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Alder	6.70												
Balsam Fir	7.21	9.17	10.94	12.97	15.02	17.20	19.07	20.90	23.03	24.65	26.70	28.10	
Big-Toothed Aspen					15.75								
Grey Birch		9.60	10.60		15.00								
Paper Birch	7.36	9.36	11.16	13.00	15.02								
Quaking Aspen	7.32	9.17	11.07	13.06	15.11	17.11	18.66	20.90					
Red Maple	7.21	9.07	10.96	12.66	15.13	16.23	19.30	20.95	23.00		27.70		
SNAG	6.88	9.00	11.47	12.90	14.90	16.70	19.40	20.10					
Spruce	7.20	9.29	10.96	13.07	14.88	16.84	18.55	21.20		25.80			32.40
White Ash					15.80								
White Pine							19.80				27.70		59.10

Avg of BA

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Alder	0.18												
Balsam Fir	0.02	1.88	1.67	2.38	1.73	1.00	0.82	0.33	0.22	0.21	0.04	0.03	
Big-Toothed Aspen					0.08								
Grey Birch		0.05	0.04		0.08								
Paper Birch	0.08	0.23	0.21	0.16	0.19								
Quaking Aspen		1.05	1.43	1.11	0.70	0.46	0.25	0.04					
Red Maple	0.25	0.51	1.16	0.52	0.47	0.10	0.08	0.07	0.04		0.04		
SNAG	0.01	0.04	0.13	0.04	0.04	0.04	0.04	0.03					
Spruce	0.10	0.49	0.68	0.44	0.23	0.18	0.07	0.11		0.04			0.04
White Ash					0.04								
White Pine							0.04				0.04		0.39

Average of Ht

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Alder	8.01												
Balsam Fir	6.52	7.68	8.38	9.21	10.38	10.62	11.20	12.06	11.43	12.64	11.49	10.70	
Big-Toothed Aspen					10.17								
Grey Birch		9.24	12.07		11.53								
Paper Birch	7.32	7.94	8.71	11.24	11.36								
Quaking Aspen	8.59	8.66	9.84	10.59	10.65	12.99	10.68	14.42					
Red Maple	9.22	9.70	11.03	11.06	11.34	12.02	11.69	14.37	14.48		15.03		
SNAG													
Spruce	8.43	8.09	9.05	9.61	11.74	10.47	9.69	11.40		10.13			15.31
White Ash					11.5051482								
White Pine							9.70024745				10.9905163		18.4565823

Average of Vol/tree

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Alder	0.01												
Balsam Fir	0.01	0.02	0.03	0.05	0.08	0.10	0.14	0.18	0.21	0.26	0.29	0.32	
Big-Toothed Aspen					0.07								
Grey Birch		0.02	0.04		0.08								
Paper Birch	0.01	0.02	0.03	0.06	0.08								
Quaking Aspen	0.01	0.02	0.03	0.05	0.07	0.11	0.12	0.19					
Red Maple	0.01	0.02	0.04	0.05	0.07	0.10	0.13	0.19	0.23		0.33		
SNAG													
Spruce	0.01	0.02	0.04	0.06	0.09	0.11	0.13	0.18		0.23			0.52
White Ash					0.09								
White Pine							0.12				0.27		0.58

Density_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Alder	52												
Balsam Fir	5	285	178	180	97	43	29	10	5	4	1	1	
Big-Toothed Aspen	9				4								
Grey Birch	3	7	4		4								
Paper Birch	20	33	21	12	11								
Quaking Aspen		159	149	83	39	20	9	1					
Red Maple	60	80	123	41	26	5	3	2	1		1		
SNAG	4	7	13	3	2	2	1	1					
Spruce	24	73	72	32	13	8	3	3		1			0
White Ash					2								
White Pine							1				1		1

Average volume_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Alder	0.59												
Balsam Fir	0.05	5.60	5.89	9.25	7.52	4.43	3.91	1.69	1.08	1.17	0.18	0.17	
Big-Toothed Aspen					0.29								
Grey Birch		0.15	0.19		0.36								
Paper Birch	0.21	0.67	0.72	0.71	0.89								
Quaking Aspen		2.94	4.88	4.21	2.72	2.22	1.06	0.21					
Red Maple	0.69	1.68	4.58	2.21	1.94	0.51	0.33	0.40	0.20		0.21		
SNAG													
Spruce	0.29	1.54	2.63	1.80	1.17	0.88	0.33	0.57		0.17			0.24
White Ash					0.19								
White Pine							0.15				0.17		0.82

Appendix VIII: Raw data Stand 5.

Trees per class

Species / Class	6	8	10	12	14	16	18	20	22	26	30
Balsam Fir	10	14	18	17	17	11	6	2	1	1	
Big-Toothed Aspen		1	1			2					
Grey Birch		1	4	1							
Paper Birch	3	10	2	4	4		1				
Quaking Aspen	6	3	2	12	6	9	2	2			
Red Maple	4	3	4	5	9		1		1		
SNAG		1		1							
Spruce	3	4	3	4	8	2					1
Tamarak			1								
White Pine		1			1	2	2	2			

Average of DBH

Species / Class	6	8	10	12	14	16	18	20	22	26	30
Balsam Fir	7.07	8.94	10.88	13.01	15.08	17.19	18.78	21.30	22.60	26.30	
Big-Toothed Aspen		8.60	11.00			17.45					
Grey Birch		8.80	11.50	12.60							
Paper Birch	7.20	9.25	11.20	12.93	14.80		18.40				
Quaking Aspen	7.25	9.17	11.60	12.94	14.72	16.82	18.95	20.70			
Red Maple	6.90	8.77	10.88	12.66	14.56		19.10		22.20		
SNAG		8.80		12.40							
Spruce	7.83	9.18	11.67	13.38	15.19	16.50					93.70
Tamarak			10.60								
White Pine		8.50			15.30	16.80	18.80	21.30			

Avg of BA

Species / Class	6	8	10	12	14	16	18	20	22	26	30
Balsam Fir	1.26	1.59	1.94	1.82	1.79	1.15	0.59	0.21	0.10	0.09	
Big-Toothed Aspen		0.11	0.11			0.22					
Grey Birch		0.11	0.48	0.10							
Paper Birch	0.39	1.22	0.23	0.42	0.41		0.09				
Quaking Aspen	0.80	0.36	0.24	1.27	0.60	0.90	0.20	0.19			
Red Maple	0.48	0.33	0.43	0.51	0.88		0.10		0.09		
SNAG		0.11		0.10							
Spruce	0.46	0.48	0.37	0.45	0.86	0.19					0.89
Tamarak			0.10								
White Pine		0.10			0.11	0.20	0.20	0.21			

Average of Ht

Species / Class	6	8	10	12	14	16	18	20	22	26	30
Balsam Fir	5.92	7.35	7.27	8.49	9.08	9.27	10.61	9.58	12.92	10.48	
Big-Toothed Aspen		9.83	11.38			11.32					
Grey Birch		9.14	9.87	10.01							
Paper Birch	7.03	8.79	10.08	10.34	10.97		11.77				
Quaking Aspen	6.65	8.78	8.72	9.01	10.26	12.35	11.29	12.80			
Red Maple	8.10	8.91	10.51	10.40	10.45		15.66		16.27		
SNAG											
Spruce	5.85	6.15	8.50	9.91	10.63	11.23					14.95
Tamarak			9.44								
White Pine		9.08			6.84	9.31	7.55	7.98			

Average of Vol/tree

Species / Class	6	8	10	12	14	16	18	20	22	26	30
Balsam Fir	0.01	0.02	0.03	0.05	0.07	0.09	0.13	0.15	0.23	0.27	
Big-Toothed Aspen		0.02	0.04			0.10					
Grey Birch		0.02	0.04	0.05							
Paper Birch	0.01	0.02	0.04	0.06	0.08		0.14				
Quaking Aspen	0.01	0.02	0.03	0.04	0.07	0.11	0.12	0.17			
Red Maple	0.01	0.02	0.04	0.05	0.07		0.16		0.25		
SNAG											
Spruce	0.01	0.02	0.03	0.06	0.08	0.11					0.51
Tamarak			0.04								
White Pine		0.02			0.05	0.09	0.09	0.12			

Density_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	26	30
Balsam Fir	322	253	208	137	100	50	21	6	2	2	
Big-Toothed Aspen		18	12			9					
Grey Birch		18	46	8							
Paper Birch	96	181	23	32	24		4				
Quaking Aspen	193	54	23	96	35	41	7	6			
Red Maple	129	54	46	40	53		4		2		
SNAG		18		8							
Spruce	96	72	35	32	47	9					1
Tamarak			12								
White Pine		18			6	9	7	6			

Average volume_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	26	30
Balsam Fir	2.84	4.79	6.10	6.57	6.95	4.57	2.78	0.85	0.54	0.46	
Big-Toothed Aspen		0.38	0.44			0.88					
Grey Birch		0.41	1.74	0.44							
Paper Birch	0.98	3.96	0.89	1.81	1.89		0.50				
Quaking Aspen	1.53	1.02	0.67	4.17	2.38	4.32	0.88	1.00			
Red Maple	1.30	1.06	1.65	2.04	3.69		0.59		0.61		
SNAG											
Spruce	0.85	1.19	1.20	1.83	3.90	1.02					0.65
Tamarak			0.44								
White Pine		0.39			0.30	0.79	0.65	0.69			

Appendix IX: Raw data Stand 6.

Trees per class

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	13	18	28	22	13	9	4	3	4			1	1
Big-Toothed Aspen										1	2		5
White Birch				3		1	1	4		2		1	2
Quaking Aspen	1	1											3
Red Maple	1	3	5	2	3	2	1	4	3	3	1	1	4
SNAG					2			1	1	4			2
Spruce	2	6	5	12	12	15	7	6	2	4	2	4	10
White Pine								1		1	1	1	1

Average of DBH

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	7.38	9.03	11.13	12.95	15.12	17.12	19.28	20.97	23.50			28.10	30.60
Big-Toothed Aspen										25.90	26.95		34.20
White Birch				12.90		17.80	18.50	20.73		25.05		29.10	32.65
Quaking Aspen	7.00	8.10											38.43
Red Maple	7.80	8.53	10.86	13.60	14.17	16.70	19.20	20.93	23.30	24.93	27.40	29.00	33.60
SNAG					14.45			21.80	23.60	24.90			32.15
Spruce	7.60	9.30	11.20	13.08	15.26	17.06	19.30	20.77	22.35	26.00	26.70	28.85	33.91
White Pine								21.50		25.90	27.80	29.3	50.3

Avg of BA

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	2.07	2.41	3.65	2.70	1.60	1.08	0.48	0.35	0.48			0.11	0.11
Big-Toothed Aspen										0.12	0.23		0.68
White Birch				0.36		0.13	0.11	0.45		0.23		0.11	0.25
Quaking Aspen	0.14	0.11											0.52
Red Maple	0.18	0.36	0.62	0.27	0.32	0.23	0.12	0.46	0.35	0.34	0.12	0.11	0.53
SNAG					0.22			0.13	0.12	0.45			0.24
Spruce	0.34	0.85	0.66	1.50	1.50	1.80	0.85	0.68	0.22	0.49	0.22	0.45	1.34
White Pine								0.12		0.12	0.12	0.12	0.30

Average of Ht

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	6.10	6.99	8.11	8.72	9.46	10.76	11.49	11.03	12.09			12.90	13.27
Big-Toothed Aspen										14.07	14.40		15.06
White Birch				9.40		12.13	12.40	12.69		14.22		15.01	16.79
Quaking Aspen	6.80	8.58											15.94
Red Maple	9.79	9.08	10.17	11.42	11.39	12.68	13.57	15.11	16.50	16.70	15.48	15.82	17.24
SNAG													
Spruce	7.94	9.58	10.09	12.80	13.45	14.23	13.53	13.98	14.97	13.91	16.80	14.37	17.39
White Pine								18.08		12.11	14.82	17.60	17.18

Average of Vol/tree

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	0.01	0.02	0.03	0.05	0.07	0.10	0.14	0.17	0.22			0.37	0.43
Big-Toothed Aspen										0.27	0.33		0.46
White Birch				0.05		0.11	0.15	0.18		0.29		0.41	0.51
Quaking Aspen	0.01	0.02											0.49
Red Maple	0.01	0.02	0.03	0.06	0.08	0.11	0.15	0.20	0.26	0.31	0.34	0.40	0.50
SNAG													
Spruce	0.01	0.02	0.04	0.07	0.10	0.14	0.17	0.21	0.27	0.31	0.42	0.43	0.58
White Pine								0.25		0.25	0.36	0.48	0.54

Density_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	484	377	375	205	89	47	17	10	11			2	1
Big-Toothed Aspen										2	4		7
White Birch				28		5	4	13		5		2	3
Quaking Aspen	37	21											4
Red Maple	37	63	67	19	21	10	4	13	8	7	2	2	6
SNAG					14			3	3	9			3
Spruce	74	126	67	112	82	79	29	20	6	9	4	7	15
White Pine								3		2	2	2	1

Average volume_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	4.39	6.83	12.07	10.07	6.36	4.89	2.29	1.66	2.38			0.63	0.64
Big-Toothed Aspen										0.64	1.30		3.41
White Birch				1.45		0.59	0.60	2.46		1.34		0.70	1.51
Quaking Aspen	0.30	0.38											2.17
Red Maple	0.45	1.25	2.31	1.03	1.54	1.13	0.60	2.64	2.14	2.16	0.67	0.69	2.97
SNAG													
Spruce	0.87	3.08	2.69	7.95	8.30	10.88	4.86	4.29	1.51	2.85	1.67	2.92	8.57
White Pine								0.85		0.59	0.71	0.83	0.81

Appendix X: Raw data Stand 7.

Trees per class

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	10	18	17	14	11	9	9	10	6	7	7	5	10
Paper Birch		1		3		4	7	8	5	6	6	4	2
Quaking Aspen													3
Red Maple		1	3	9	7	9	11	9	6	3	3	1	3
SNAG	1	2	1	4	4	2	2	2	2	5	3	1	3
Spruce	4	3	4	6	10	11	6	5	6	14	7	10	49
Strip Maple				1									
White Pine						1	1			2	1	1	3

Average of DBH

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	6.72	9.05	10.64	13.03	14.65	16.87	19.30	21.10	23.23	25.39	27.07	28.78	33.60
Paper Birch		9.90		13.27		17.23	19.43	20.78	22.74	25.17	26.77	29.03	32.05
Quaking Aspen													32.83
Red Maple		8.10	11.27	13.22	15.20	16.72	18.75	20.88	23.23	24.50	27.17	30.00	34.57
SNAG	6.60	8.95	10.80	12.88	14.98	16.80	18.20	21.65	22.75	25.04	27.20	28.80	33.83
Spruce	7.83	8.53	11.08	13.33	14.93	17.09	19.13	20.94	22.48	24.89	27.19	28.99	36.81
Strip Maple				12.40									
White Pine						17.00	19.90			24.35	26.50	28.3	49.33333333

Avg of BA

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	1.09	2.00	1.67	1.44	1.05	0.87	0.90	0.97	0.58	0.68	0.66	0.46	1.09
Paper Birch		0.13		0.32		0.40	0.71	0.75	0.46	0.57	0.55	0.37	0.20
Quaking Aspen													0.31
Red Maple		0.09	0.33	0.95	0.72	0.85	1.04	0.85	0.58	0.27	0.28	0.10	0.35
SNAG	0.11	0.22	0.10	0.40	0.40	0.19	0.18	0.20	0.19	0.47	0.29	0.09	0.33
Spruce	0.59	0.30	0.43	0.64	0.99	1.09	0.59	0.48	0.54	1.31	0.67	0.93	6.42
Strip Maple				0.09									
White Pine						0.10	0.11			0.18	0.09	0.09	0.71

Average of Ht

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	6.48	7.85	8.81	9.03	9.57	10.41	11.67	11.90	12.40	13.07	13.24	13.76	14.46
Paper Birch		11.09		13.63		14.78	16.00	16.41	16.20	17.16	16.03	17.52	19.30
Quaking Aspen													19.39
Red Maple		7.85	10.17	12.39	13.69	13.81	13.77	15.03	17.01	15.41	17.21	18.84	18.59
SNAG													
Spruce	9.55	9.33	11.29	12.91	13.75	13.34	14.85	14.37	15.45	15.35	16.43	15.84	17.02
Strip Maple				10.49									
White Pine						13.15	14.27			17.37	15.98	19.91	14.14

Average of Vol/tree

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	0.01	0.02	0.03	0.05	0.07	0.10	0.14	0.18	0.22	0.27	0.32	0.39	0.46
Paper Birch		0.03		0.07		0.13	0.18	0.22	0.27	0.33	0.37	0.45	0.56
Quaking Aspen													0.60
Red Maple		0.02	0.03	0.06	0.09	0.12	0.15	0.20	0.26	0.29	0.37	0.47	0.53
SNAG													
Spruce	0.01	0.02	0.04	0.07	0.10	0.13	0.18	0.22	0.28	0.33	0.41	0.46	0.57
Strip Maple				0.05									
White Pine						0.12	0.17			0.35	0.38	0.54	0.46

Density_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	308	311	188	108	62	39	31	28	14	13	11	7	12
Paper Birch		17		23		17	24	22	11	12	10	6	2
Quaking Aspen													4
Red Maple		17	33	69	40	39	38	25	14	6	5	1	4
SNAG	31	35	11	31	23	9	7	6	5	10	5	1	4
Spruce	123	52	44	46	56	48	21	14	14	27	11	14	60
Strip Maple				8									
White Pine						4	3			4	2	1	4

Average volume_Class_ha

Species / Class	6	8	10	12	14	16	18	20	22	24	26	28	30
Balsam Fir	2.94	6.23	6.49	5.45	4.49	3.93	4.31	4.86	3.01	3.66	3.70	2.72	5.64
Paper Birch		0.46		1.61		2.27	4.22	4.91	3.04	3.80	3.62	2.57	1.37
Quaking Aspen													2.20
Red Maple		0.30	1.15	4.12	3.50	4.54	5.53	4.89	3.63	1.67	1.83	0.66	1.96
SNAG													
Spruce	1.69	1.24	1.96	3.31	5.82	6.24	3.73	3.02	3.85	8.94	4.73	6.56	34.09
Strip Maple				0.39									
White Pine						0.52	0.57			1.35	0.63	0.76	1.68

Appendix XI: Eligibility criteria for potential subsidization thought YSC Marketing Board for activities to be performed on the NRF, outlined through the operational plan.

Prescribed Intervention	Stand Criteria
Pre-Commercial Thinning (PCT)	• Heigh for HW species 5-9 m • Heigh for SW species 2-7 m
Commercial Thinning (CT)	• 25-40 years old • Basal Area < 50 m^2/ha
Shelterwood (SHW)	• < 60% Stocked • Average DBH > 14 cm
Clear-Cut (CC)	• Varies, N/A

Curriculum Vitae

Candidate's full name: Leonardo Pimenta Arao de Brito

Universities attended:

University of New Brunswick (2019 – 2021), Master of Forestry

Federal University of Goias, Brazil (2010 – 2016), Bachelor of Science in Forest Engineering

Publications:

Brito, L., Medina, G., Venturoli, F. (2018). Recuperacao de Matas Ciliares. M. L. Medina, G. Agricultura Familiar em Goias: Licoes para o assessoramento tecnico. 4. Ed. UFG, 2018.

Conference presentations:

None