MANUAL TENDING IS A VIABLE ALTERNATIVE TO HERBICIDE APPLICATION IN THE LAKE NIPIGON FOREST

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Dr. Jian Rang Wang Major Advisor	Dr. Mathew Leitch Second Reader

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ABSTRACT

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Key Words: Manual Tending, Herbicide Application, Aerial Herbicide, Free-Growing

This thesis explores the viable alternative to tending crop plantations by implementing manual tending instead of herbicide application in the Lake Nipigon Forest. The thesis provides a comparative analysis between manual tending and herbicide application and explores the advantages and disadvantages of both tending options. In this study, data was collected by the Lake Nipigon Forest Management Company using the Free-Growing regeneration assessment procedure for Ontario, and then was analyzed to see the success of utilizing a manual tending method instead of herbicide application. The T-tests determined the two methods were significant ($P<0.05$). On average the manually tended stands seen more well spaced free growing stems and better stocked. The implementation of manual tending has proven to increase the success of well-stocked stands, influence public view and contribute to employment in the community. Manual tending is not the best alternative but rather a viable alternative to herbicide application in the Lake Nipigon Forest.

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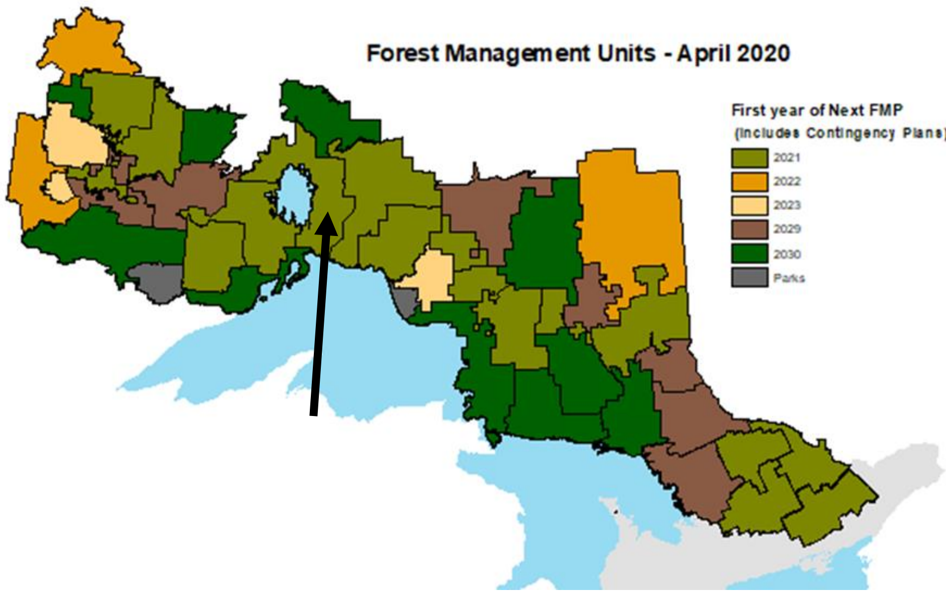
INTRODUCTION

The Lake Nipigon Forest (LNF) is located on the north shore of Lake Superior and is part of the Boreal Forest (Figure 1).



Source: Ontario

Figure 1. Lake Nipigon Forest Management Unit

The Lake Nipigon forest is comprised of a total area of 9,000.7 square kilometres (OMNR). The area of Productive Lands within the Licence Area is 7,964.0 square kilometres (OMNR). The objective of this study is to explore the viable option of implementing manual tending as a method to release the target crop species instead of the traditional herbicide application.

Forest vegetation management involves manipulating vegetation and the associated microenvironment to favour the survival and growth of trees (Little et al.

2006). Successful vegetation management strategies enhance productivity from an existing or declining land base by increasing fibre yields, reducing rotation times, and improving stem and stand uniformity, whilst also improving wood and/or pulping properties (Little et al. 2006). Vegetation management will eliminate competition from weed vegetation, and reduce or eliminate undesirable species. To realise the potential productivity of many forest sites, various vegetation control methods have been developed, including manual, mechanical, cultural, thermal, biological approaches, and the use of herbicides (Little et al. 2006) The release of plantations with Vision (glyphosate) has been the dominant treatment in Ontario's reforestation program when it comes to vegetation management (Bell et al. 1997). However, the Ontario public does not support aerial herbicide use even though glyphosate (N-phosphonomethylgycine), the active ingredient in the vision herbicide product, poses minimal toxicological risk to wildlife but at the end of the day, glyphosate still is toxic (Bell et al. 1997). Since the herbicide application is not fully supported, alternative vegetation management applications can be utilized to release crop species such as manual tending.

Manual tending is a vegetation management application that is designed to release established crop trees from competition (Wiensczyk et al. 2011). There are a few manual tending applications which include manual, motor-manual and mechanical brushing treatments (Wiensczyk et al. 2011). Manual and motor-manual involve using equipment such as machetes or brush saws to cut the shrubs and non crop tree species can increase crop tree survival and growth (Wiensczyk et al. 2011).

The data was collected from the Lake Nipigon Forest. Since herbicide is a touchy subject, the importance of finding a viable alternative for vegetation management and release of crop species is imperative. The purpose of this thesis is to justify why manual tending is a viable alternative to herbicide application when it comes to controlling species, stocking and WSFG stems.

OBJECTIVE

The purpose of this thesis is to analyze the data collected by the Lake Nipigon Forest Management on the LNF to determine the viable alternative of implementing manual tending to control crop species and competition, stocking, and well spaced free growing stems (WSFG) instead of the traditional herbicide application. This thesis will provide information on why manual tending is a viable option compared to herbicide application by providing a comparative analysis on the benefits of tending crop species.

HYPOTHESIS

Manual tending is a viable alternative to herbicide application when it comes to controlling species, stocking and WSFG stems. The null hypothesis is that both of the tending treatments are equal and have no significance in their mean values. The alpha value being used is 0.05 thus, t-tests will be used to see if there any significant differences between the both treatments and that if manual tending is a viable alternative to herbicide application when it comes to controlling species, stocking and WSFG stems

LITERATURE REVIEW

MANUAL TENDING

Tending is generally any operation carried out for the benefit of an already established forest crop at any stage of its life including cleaning, juvenile spacing, compositional treatments, improvement cutting, thinning, and pruning (OMNRF 2015). There is some overlap in the definition of different tending treatments and the treatment applied to any given site may serve more than one purpose (OMNRF 2015). For example, manual tending between the establishment and stem exclusion stages may include removal of brush (cleaning), removal of undesirable trees (compositional treatment), and spacing of crop trees (juvenile spacing) all in a single treatment (OMNRF 2015). Manual cleaning is the manual cutting (tending) with motorized or non-motorized tools (e.g. motorized brush saws, chainsaws, and axes), girdling, clearing or scalping with hoes, and hand pulling, trampling, or binding of unwanted vegetation (OMNRF 2015). Manual and motor manual cleaning are especially suited to harvest methods that leave an overstory canopy but can be costly, labour intensive, and involve greater risks to operator safety than most other cleaning methods (OMNRF 2015). Mechanical cleaning is the use of self-propelled, wheeled, or tracked prime movers with motorized cutting attachments to remove woody vegetation. Mechanical cutting, like manual cutting, is most effective in midsummer to reduce re-sprouting (OMNRF 2015). Manual tending and cleaning are interchangeable terms, and here on out it will be referred to as manual tending.

TYPES OF HERBICIDE AND HERBICIDE APPLICATION

Herbicide application is the utilization of chemical treatment to kill competition and release crop species (OMNRF 2015). There are five herbicide active ingredients registered for use in Canadian forestry (glyphosate, triclopyr, hexazinone, 2,4-D and simazine) (Campbell 1990). In Canadian forestry, glyphosate-based herbicides account for more than 96% of the forest area treated with herbicides in the past decade (Campbell 1990). The types of herbicide application include aerial, manual and mechanical (Wiensczyk et al. 2011). Campbell et al. (2001) state that chemical control treatments will not compact soil or increase the risk of erosion, do not create favourable seedbeds for windborne seed, and do not bring buried seed to the soil surface. The use of herbicide treatments being applied either aerially, manually and, mechanically also provides longer-term control than other vegetation management treatments because they kill the roots of competing plants, preventing or reducing resprouting (Campbell et al. 2001).

MANUAL TENDING INSTEAD OF HERBICIDE APPLICATION

ECOLOGICAL IMPACTS OF HERBICIDE

Biodiversity impacts from herbicide are not concrete but rather open to interpretation. Based on the extensive available scientific evidence, Rolando et al. (2017) concluded that glyphosate-based herbicides, as typically employed in planted forest management, do not pose a significant risk to humans and the terrestrial and aquatic environments. Thus, heralding that herbicides, a tool to intensify wood production, benefit forest biodiversity appears premature (Flueck and Flueck-Smith 2006). However, according to a study published by Wood (2019), the highest and most consistent levels of glyphosate and AMPA (aminomethylphosphonic acid) were found in herbaceous perennial root tissues, but shoot tissues and fruit were also shown to contain glyphosate in selected species. This isn't a direct impact to biodiversity but it does show that glyphosate can linger around after application. Moreover, when herbicides are sprayed by aircraft, the spray can deliver non-lethal doses of glyphosate to nearby non-target plants, some of which may store the compound indefinitely or break it down very slowly (Wood 2019). Furthermore, Shore (2019) interviewed Wood (2019), and found that there were unexpected levels of glyphosate in new shoots and berries of plants that survived an aerial herbicide application made one year earlier. These findings raise concerns about forage plants used extensively by First Nations in northern B.C. where most spraying occurs (Shore 2019). The 10 species tested were selected for their importance as traditional-use plants, because some First Nations had expressed concerns about the long-term effects of glyphosate on wild plants (Shore 2019). Glyphosate is typically broken down in soil by microorganisms over a period of months, but how long it persists in living plant tissues is unknown (Wood 2019). There is evidence that herbicide can affect plants after a year of application, and the direct impacts on biodiversity is still not conclusive and that more studies need to be done.

PUBLIC VIEWS OF HERBICIDE APPLICATION AND MANUAL TENDING

The public view of herbicide raises a concern, and the idea of a manual tending alternative can be a solution. Hyer (2019) states that the concerns with glyphosate fall into three areas: effects on non-human species, humans and economics. Non-human effects include wildlife (including moose) that are declining along with loss of biodiversity and critical habitats. The effects of herbicide can also change forest composition such as eliminate broad-leaved species in which moose and other ungulates rely on for food and habitat (Hyer 2019). Moreover, a variety of published scientific reports show that glyphosate is toxic in many ways. An epidemiological study of Ontario farmers showed that glyphosate exposure increased risk of late spontaneous abortions and premature births (Hyer 2019). Some recent analyses reviewing a number of studies suggest an association between glyphosate use and the risk of a cancer called non-Hodgkin lymphoma (Hyer 2019). In 2018, Monsanto was forced to pay $289 million in damages in just one lawsuit and there are hundreds, potentially thousands, of other lawsuits pending (Hyer 2019). Monsanto has allegedly manipulated scientific evidence thereby downplaying the health risks of their glyphosate-based products (Hyer 2019). Herbicide viewed from the public can be economical for local communities. A viable alternative to aerial spraying is manual tending of hardwood competition by forest workers thus creating employment (Hyer 2019). Thus, manual tending is viewed better socially than herbicide application. This can prove that in the eyes of the public, manual tending is viable alternative for crop species release than the traditional herbicide application.

EFFECTIVENESS OF MANUAL TENDING ON REGENERATION SUCCESS

Manual and motor-manual cutting treatments can increase crop tree survival and growth and the effectiveness of brushing treatments in releasing crop trees depends on the autecology of the species being cut, the type of cut, and the timing (Wiensczyk et al. 2011). Some species are more easily controlled than others. In general, brushing treatments provide long term control of coniferous competing species, but only short-term control of most deciduous woody vegetation (Wiensczyk et al. 2011). Most hardwoods sprout rapidly after cutting, producing an increased number of shoots per stump, and the total number of stems and percent cover may increase after treatment (Wiensczyk et al. 2011). The type of cut and height of the cut can affect the vigour of sprouts (Wiensczyk et al. 2011). Cutting aspen at heights 50 cm to 75 cm above ground level during June–July significantly reduces the number of root suckers. Also, species that sprout from the root collar (mountain maple, white birch, and pin cherry) should be cut at 15 cm or less to reduce sprouting (Wiensczyk et al. 2011). Shattered and ragged cuts produce fewer and less vigorous sprouts than clean cuts (Wiensczyk et al. 2011). Following these methods on the timing, type of cuts and the autecology of the species being cut will effectively release crop trees from their competition.

Several studies have found that manual brushing improved crop tree growth (Hart and Comeau 1992). No long-term studies comparing manually and chemically released crop trees are available in British Columbia. In northwestern New Brunswick, results showed that manual brushing to control mountain maple did improve the growth of balsam fir (Mclean and Newton 1983). Both types of treatments increased the volume of the balsam fir, although the herbicide treatments gave a better response (an average

211% increase over the control versus a 64% increase for the manual brushing). Petersen and Newton (1985) studied the effects of different brush removal treatments on the growth of Douglas-fir in Oregon. Manual brushing gave larger diameters and heights on the Douglas-fir than on the control, and herbicides used on the snowbrush produced even larger volumes. The greatest stem and diameter response was found when all non-crop vegetation (snowbrush and forbs) was controlled using herbicides. Bigley (1988) found that Douglas-fir saplings released early in the growing season from overtopping red alder responded more favourably to manual release than those saplings manually released mid-way through the growing season. The latter tended to have constant or declining photosynthetic rates. Bigley (1988) noted that the saplings were unable to adapt to the sudden change in light conditions later in the growing season, likely because they had shade rather than sun leaves.

In a study conducted by Bell et al. (1997), manual tending treatments and herbicide application were used to accomplish the same forest management objective which is to selectively suppress early successional vegetation for a period of time. In the article glyphosate proved to be more effective, but manual tending also did the same job and is a viable alternative to herbicide application.

COST AND PRODUCTIVITY ANALYSIS OF TENDING TO HERBICIDE

When it comes to cost and productivity, aerial herbicide application is the better option. In Alberta during the year 1989, the AFS cleaned and tended about 1600 hectares with brush saws to release conifers in young plantations and the average cost was $548 per hectare with a treatment rate of 0.31 hectares/man/day (Ehrentraut and Branter 1990). Also, in a study conducted by Bell et al (1997) in which analyzed cost, efficacy and productivity, the authors found the helicopter treatments were the most cost and time efficient instead of a manual tending job. The brush saw operators cleaned 25.2 ha, an average of 17,770 stems/ha, in 154.4 productive hours whereas the helicopter cleaned 45.4 net ha with an average of 22,000 treated stems/ha, in 0.6 productive hours (Bell et al. 1997).

MATERIALS AND METHODS

The study was carried out in the Lake Nipigon Forest using the Well-Spaced Free Growing Regeneration Assessment Procedure for Ontario. The Well-Spaced Free-Growing Regeneration Assessment Procedure for Ontario is designed to determine the regeneration status of a young stand (White et al. 2005). The manual provides a detailed description of the office and field tasks and provides practical aids and tools to assist in conducting assessments using this procedure (White et al. 2005). The data compiled and analyzed in this study were renewed areas artificially by seeding and planting, and areas left for natural regeneration received different tending treatments to determine if these areas achieved free growing status. Block maps of the areas were provided and Avenza maps was used to help spatially in recording the data (Figure 2).

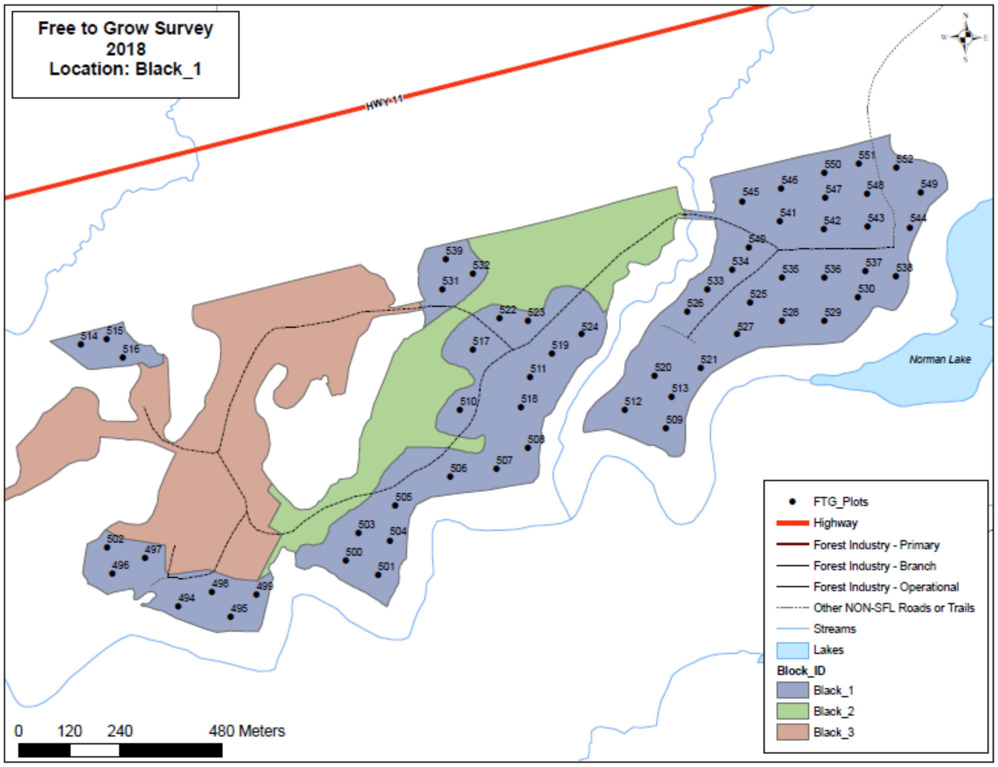
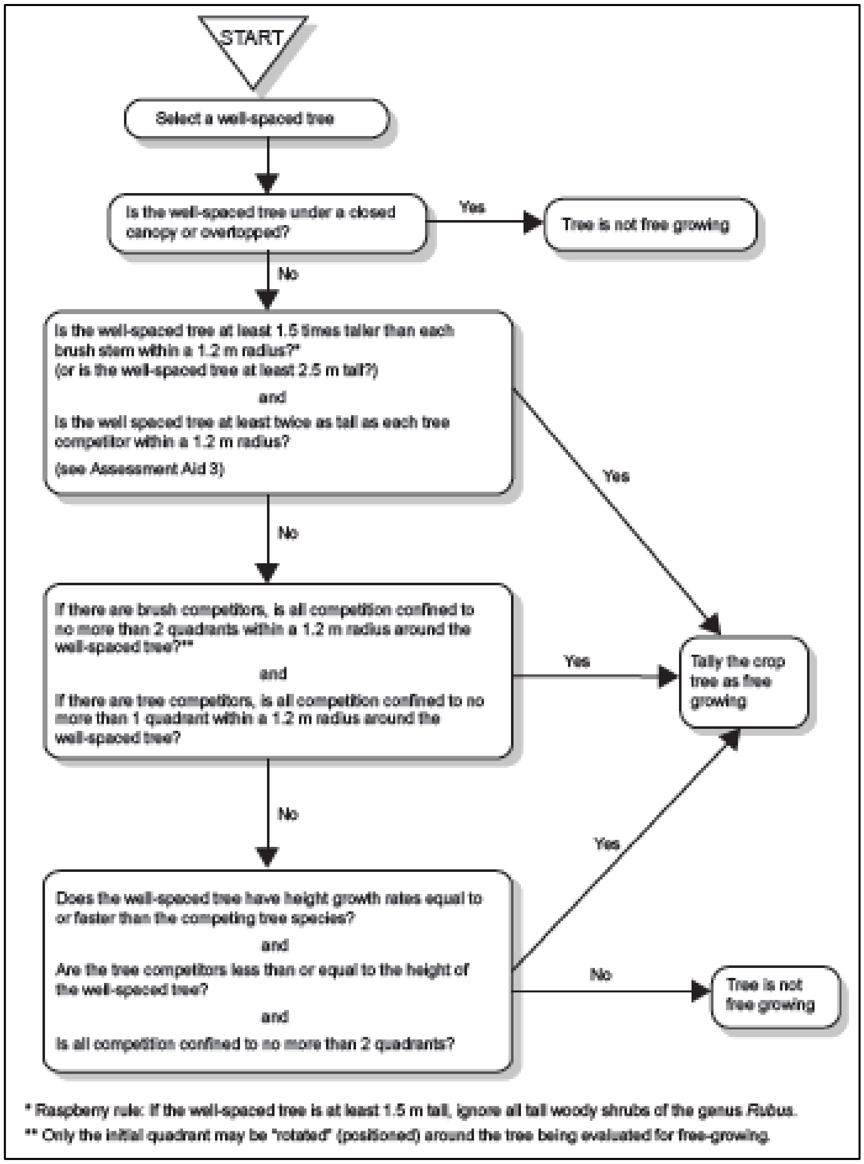


Figure 2. The block maps used to conduct surveys on artificially or naturally renewed areas.

Source: hme Enterprises Ltd.

An example of the manual and its steps is shown in the flowchart to determine a well spaced free growing (WSFG) tree or a well spaced (WS) tree (Figure 3).



Source: White et al. 2005

Figure 3. Flow chart for determining a well-spaced free growing tree.

512 plots were gathered in the herbicide tended blocks, and a total of 182 plots were executed in the manually tended blocks. The history of the blocks is summarized with the year the blocks were harvested, regenerated, and treated. (Table 1).

Table 1. Summary of Regeneration, Harvesting, and Treatment in the Blocks.

Block ID	Year Harvested	Regeneration Method	Year Renewed	Treatment
Black-1	2011	Seed	2013	Herbicide
Black-2	2011	Seed	2013	Herbicide
Black-3	2011	Natural	N/A	Herbicide
Black-4	2012-2013	Natural	N/A	Herbicide
Black-5	2010	Plant	2012-2013	Herbicide
Black-6	2012	Plant	2013	Herbicide
Black-7	2011	Plant	2013	Herbicide
Black-8	2012	Seed	2013	Herbicide
Black-9	2011	Plant	2014	Manual

Source: hme Enterprises Ltd.

Within these plots, different species were tallied and placed into height classes (Table 2) and then went under the free growing assessment.

Table 2. Height Classes Criterion.

	Height Class (m)		
Species	1	2	3
Sb Sw Bf Ce	0.3 – 0.79	0.8 – 2.0	>2.0
Pj Pr Pw La	0.3 – 0.9	1.0 – 2.0	>2.0
Hardwoods	0.3 – 1.9	2.0 – 2.9	>3.0

Source: White et al. 2002

These artificially renewed areas and naturally renewed areas either received an aerial and ground herbicide tending treatment or a manual tending treatment. The plantations and seeded areas were planted with either *Pinus banksiana* or *Picea mariana.* These plantations were harvested, and planted or seeded, and received both tending treatments years after. The tending operations were carried out during mid-August. The data in this study was analyzed to compare the differences between aerial herbicide to the manual tending in tree heights, species composition and well spaced free growing stems (WSFG). The student's t-tests were conducted in Microsoft Excel. The null hypothesis is that both tending treatments are equal and the alpha value is 0.05.

RESULTS

The height class distribution of the trees treated by the herbicide tending method has the most trees in height class 2, the least in height class 3, and the 2nd most in height class 1 (Figure 4).

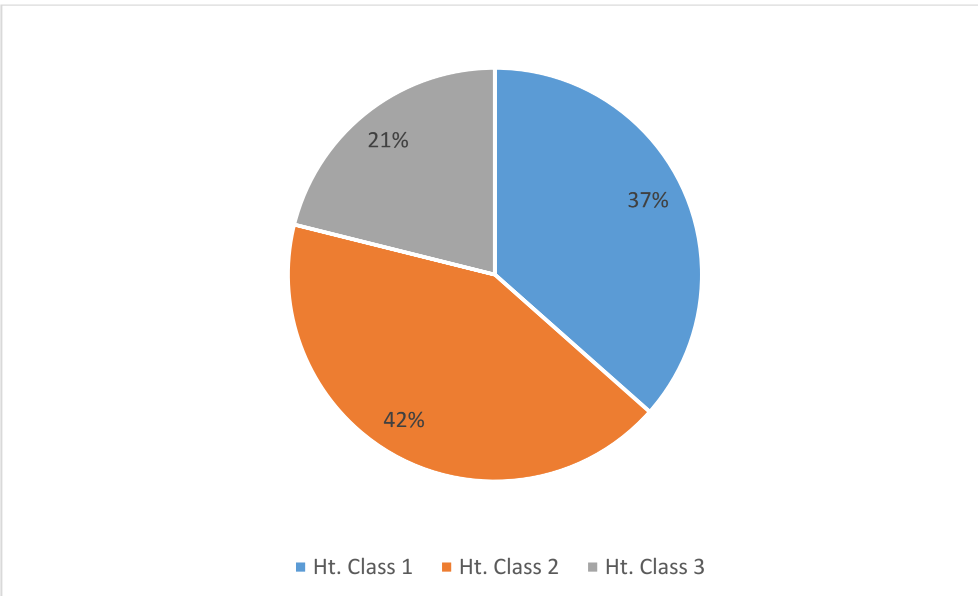


Figure 4. Herbicide height class distribution.

The height class distribution of the trees treated by manual tending has the most trees in height class 2, the least in height class 1, and the 2nd most in height class 3 (Figure 5).

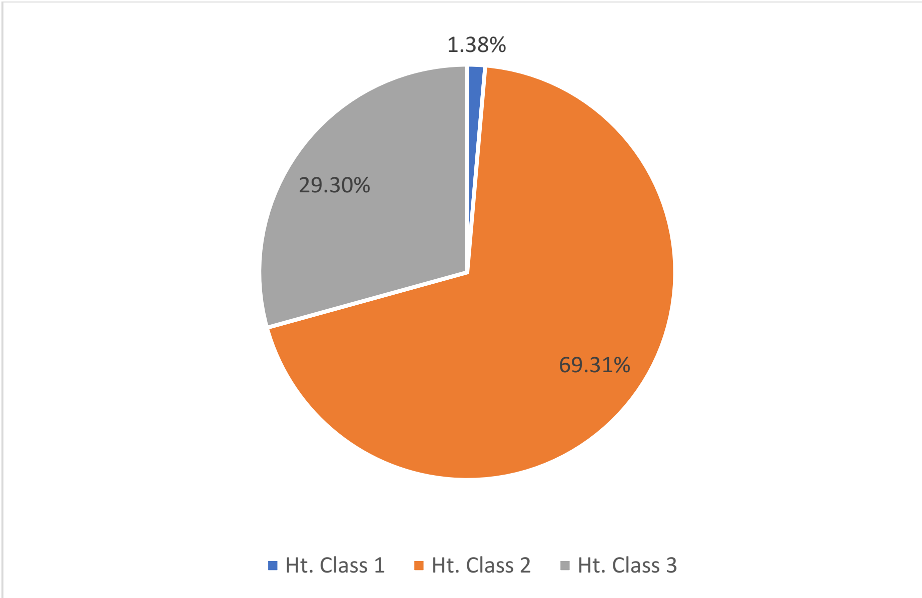


Figure 5. Manual tending height class distribution.

The total species composition was calculated between both tending methods and the leading species among both treatments was *Pinus banksiana* (Figure 6). The 2nd most prevalent species for the herbicide treatment is *Populus tremuloides* and for the manual tending treatment, the 2nd most prevalent species is *Picea mariana* (Figure 6).

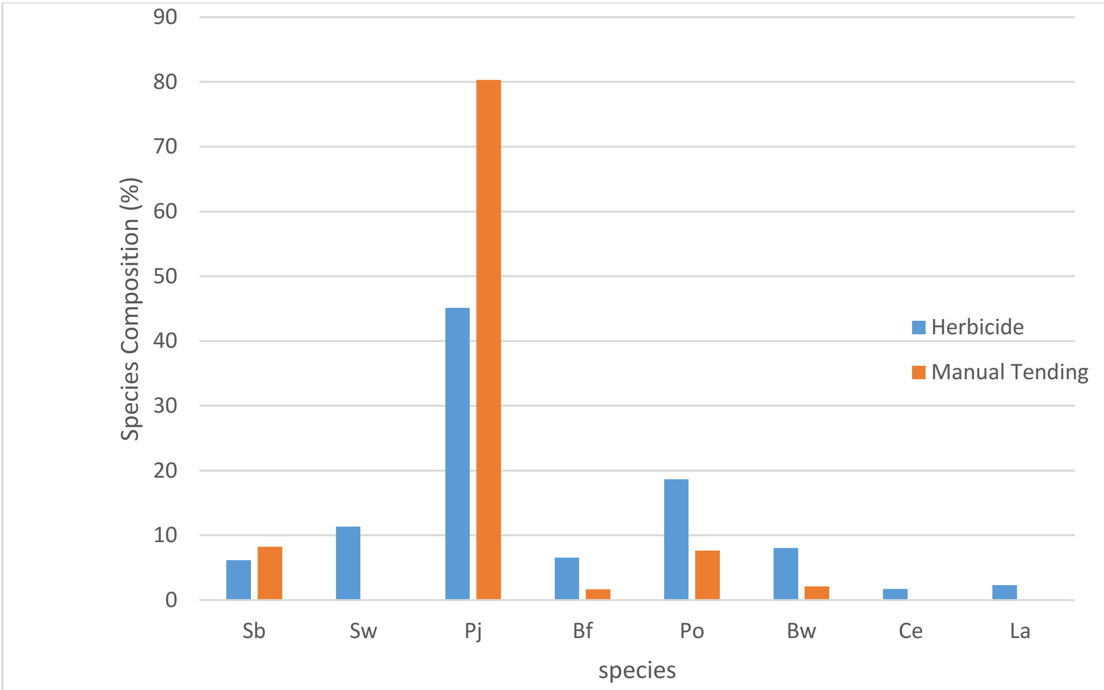


Figure 6. Species composition between both tending methods for black spruce (Sb), white spruce (Sw), jack pine (Pj), balsam fir (Bf), poplar (Po), white birch (Bw), cedar (Ce), and larch (La).

The total WS and WSFG stem distribution was calculated between both tending methods and both WS and WSFG stems was dominant in the manually tended areas (Figure 7).

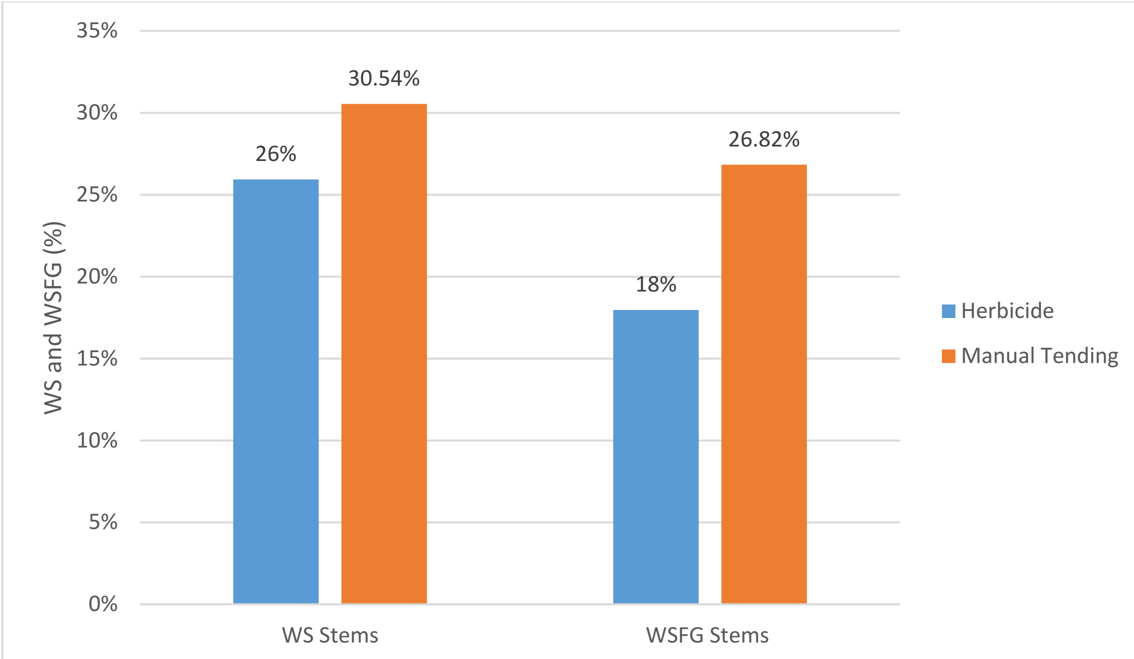


Figure 7. Well spaced (WS) and Well Spaced Free Growing (WSFG) distribution between both tending methods.

The manual tending treatment to the herbicide treatment for a t-test did show significance in the mean values for WSFG stems per plot (Table 3). The P-values for the one-tail (1.48151E-09) and the two-tail (2.96301E-09) was less than the alpha value of 0.05. On average, the manual tending areas per plot had more WSFG stems than the herbicide areas per plot.

Table 3. t-test comparing manual tending and herbicide for WSFG stems.

	Manual Tending	Herbicide
Mean	2.329113924	1.715139442
Variance	1.07570749	1.661207466
Observations	158	502
Hypothesized Mean Difference	0	
df	323	
t Stat	6.104002648	
P(T<=t) one-tail	1.48151E-09	

t Critical one-tail	1.64958482
P(T<=t) two-tail	2.96301E-09
t Critical two-tail	1.967335607

The manual tending treatment to the herbicide treatment for a t-test did show significance in the mean values for stocking per plot (Table 4). The P-values for the one-tail (1.48E-09) and the two-tail (2.96301E-09) was less than the alpha value of 0.05. The manual tending areas per plot had more stocking than the herbicide areas per plot on average.

Table 4. t-test comparing manual tending and herbicide for stocking.

	Manual Tending	Herbicide
Mean	1455.696203	1071.962151
Variance	420198.2383	648909.1662
Observations	158	502
Hypothesized Mean Difference	0	
df	323	
t Stat	6.104002648	
P(T<=t) one-tail	1.48E-09	
t Critical one-tail	1.64958482	
P(T<=t) two-tail	2.96301E-09	
t Critical two-tail	1.967335607	

DISCUSSION

The null hypothesis of both tending treatments and their mean values being the same and showing no significance can be rejected given the findings and statistical tests from the experiment. The t-test for the WSFG stems per plot between both treatments was significant with P-values of 1.48151E-09 for the one-tail, and a P-value of 2.96301E-09 for two-tail (Table 3). The alpha value used was 0.05, and the P values are less than the alpha value. The 2nd t-test for the stocking per plot between both treatments was also significant. The P-values of 1.48E-09 for the one-tail and 2.96301E-09 for the two-tail are less than the alpha value 0.05 (Table 4). Therefore, there is enough evidence from the data and findings to reject the null hypothesis of both treatments and their mean values being the same, and that manual tending is a viable alternative to herbicide treatment when it comes to controlling species, WSFG stems, and stocking per plot.

When examining the height class distribution of the trees treated by manual tending and herbicide, both treatments vary. In the manual tended areas, height class 3 has 29.30 % of the trees, height class 2 has 69.31% of the trees, and height class 1 has 1.38% of the trees (Figure 5). In the herbicide treated areas, height class 3 has 21% of that total trees, height class 2 has 42% of the trees, and height class 1 has 37% (Figure 4). The manual tended areas was harvested in year 2011, and then renewed by planting in year 2014 (Table 1). For the herbicide treated areas, the years they were harvested varied between 2010, 2011, 2012, and 2013, and were either regenerated by aerial seed, planted or left for natural regeneration in years 2012 and 2013 (Table 1). The height class distribution of the blocks that were manually tended have a better distribution, and were also planted a year after the herbicide blocks. This could be because of operator control of cleaning and taking the best trees. The number of trees found in height class 1 for the manually tended areas (1.38%) are less than the trees found in height class 1 for the herbicide treated areas (37%). The number of trees found in height class 3 for the manually tended areas is more (29.30%) than the number of trees found in height class 3 for the herbicide tended areas (21%). The number of trees found in height class 2 for the manually tended areas is more (69.31%) than the number of trees found in height class 2 for the herbicide tended areas (42%). Herein, both treatments were able to release crop species from vegetation by herbicide application and manual tending treatments by having a distribution of height classes across their areas. Though, manual tending did have more trees in height class 3 and less in height class 1 as opposed to the herbicide treated areas thus proving manual tending is a viable alternative to herbicide application when it comes to controlling species height and WSFG stems.

The total species composition was calculated between both tending methods and the leading species among both treatments was *Pinus banksiana* at 80.32% and 45.11% (Figure 6). The 2nd most prevalent species for the herbicide treatment was *Populus tremuloides* at 45.10% and for the manual tending treatment, the 2nd most prevalent species was *Picea mariana* at 8.24 % (Figure 6). This could be explained by looking at the history of the blocks where the manual tended blocks received planting of Pinus banksiana and *Picea mariana*, and the herbicide treatment of receiving seeding planting of *Pinus banksiana*, and leave for natural regeneration would could have had a *Populus tremuloides* component (Table 1). The herbicide treatment did not do a good job eliminating broad-leaved competition such as *Populus tremuloides* at 18.68% and *Betula papyrifera* at 8.06%, whereas in the manually tended areas, *Populus tremuloides* was at 7.65 % and *Betula papyrifera* at 2.11% (Figure 6). The manually tended areas were able to control competing vegetation more than the herbicide areas. Manual tending has more control than herbicide since there are boots on the ground as opposed to being in the air.

The total WS and WSFG stem distribution was calculated between both tending methods and both WS and WSFG stems was dominant in the manually tended areas (Figure 7). In the manually tended areas, 30.54% of the trees were classified as WS and 26.82% of the trees were classified as WSFG. In the herbicide tended areas, 26% of the trees were classified as WS and 18% of the trees were classified as WSFG. The manual tended areas have more WS and WSFG stems than the herbicide treated areas which can be explained by having more control and decision making when cleaning and thinning the stems. Also, since the manual tended areas received planting and the herbicide tended blocks received either planting, natural, or aerial seed can be a factor why the manual tended blocks have more WSFG stems (Table 1). The aerial herbicide blocks only eliminated vegetation, and may have released the crop species, but did not have any control on spacing, cleaning and thinning crop species.

CONCLUSION

Manual tending is a viable alternative to herbicide application when it comes to controlling species, stocking and WSFG stems. The null hypothesis of both tending treatments and their mean values being the same and showing no significance can be rejected given the findings and statistical tests from the experiment. The t-test for the WSFG stems per plot between both treatments was significant ($P<0.05$). The 2nd t-test for the stocking per plot between both treatments was also significant ($P<0.05$). Thus, there is enough evidence from the data and findings to reject the null hypothesis of both treatments and their mean values being the same, and that manual tending is a viable alternative to herbicide treatment when it comes to controlling species, stocking and WSFG stems.

Also, the manual tending areas per plot had more WSFG stems than the herbicide areas per plot on average. The manual tending areas per plot had more stocking than the herbicide areas per plot on average. The species composition across both treatments had more crop species such as *Pinus banksiana* and *Picea mariana* in the manual tending areas as opposed to the herbicide treated areas. Both treatments had significant distribution of height classes among their areas, though the manually tended areas had more trees in height class 3, and less trees in height class which proves manual tending is viable alternative to herbicide.

When it comes to cost and productivity, the data wasn't able to calculate the time per hectare for the treatments to be done, but from reviewing literature, herbicide is better cost per hectare. However, when it comes to control, manual tending did a better job at spacing, thinning, and cleaning competition, and preserving crop species.

The data collected is from the Lake Nipigon Forest and the employees executing The Well-Spaced Free-Growing Regeneration Assessment Procedure for Ontario. Since herbicide is a touchy subject, the importance of finding a viable alternative for vegetation management and release of crop species is imperative. As a result, this study found that manual tending is not the best option, but rather a viable option when compared to herbicide application in the Lake Nipigon Forest.

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