EFFECTS OF SILVICULTURAL TREATMENT HISTORY ON THE SILVICULTURAL STATUS OF A STAND

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ABSTRACT

Stanbury, A. 2019. Potential factors that influence the silvicultural status of a stand based on its silvicultural background.

Keywords: Silvicultural status, silvicultural effectiveness monitoring, regeneration treatment, well-spaced free growing, silviculture

The silvicultural effectiveness monitoring program is important in determining the silvicultural status of a stand. Each stand can be classified as being a silvicultural success (SS), regeneration success (RS), or not satisfactorily regenerated (NSR). The status of the stand may be due to the silvicultural history of the block. Data was obtained from the Ministry of Natural Resources and Forestry (MNRF) from the silvicultural effectiveness monitoring program within the boreal forest of northeastern Ontario. The objective of this thesis is to observe any trends between the silviculture background of a stand and its silvicultural status. Regeneration methods (plant, seed, natural methods), site preparation (mechanical, chemical or absent), and vegetation management (absent or present) of each block will be analyzed. Data from one forest management unit, the Gorden Cosens Forest, is used for this study. After review of relevant literature, four null hypotheses were developed: that 1) regeneration method, 2) vegetation management, and 3) site preparation do not have a statistically significant effect on the status designation or the average well-spaced free growing (WSFG) stems/ha of a block. The fourth hypothesis is that the year of assessment will not have a significant effect on the designation of a stand (SS, RS, NSR). A three-way ANOVA was conducted to analyze the first three hypotheses and a one-way ANOVA was conducted to test the fourth hypothesis. Results from the three-way ANOVA indicate that regeneration method, vegetation management, and site preparation did not have a statistically significant effect on the status of the stand or average WSFG stems/ha. Results of the one-way ANOVA reveal that year of assessment did have a statistically significant effect on status designation. Lack of data and missing replicates within the dataset can be the reason of the non-significance found in this study. On the other hand, the significant difference between year of assessment can be due to the success of the planting or seed year which can be related to budget constraints or environmental conditions at the time. Inconsistency in assessment method and between surveyors may also play a role in the variation between years. Therefore, a higher detailed analysis of the conditions at the time of regeneration would be beneficial to understand the difference in stand success and/or average WSFG stems/ha between years.

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AKNOWLEDGEMENTS

I would like to acknowledge my thesis advisor Dr. Jian Wang and my second reader Bill Greenaway (R.P.F) for their time and effort to supplying helpful information, ideas and valuable communication into formulating my thesis. I would also like to thank Joshua Breau (R.P.F) from the Ministry of Natural Resources and Forestry (MNRF) for organizing and supplying data used for my thesis. Additionally, I would like to thank all resource management technicians and technical specialists from the MNRF for the collection of the original data through silvicultural effectiveness monitoring. Lastly, I would like to thank all NRMT professors, classmates, and friends and family for the support I received during four years at Lakehead University.

INTRODUCTION

Healthy forests have the incredible ability to offer numerous benefits to the world. Not only do forests provide economic value from the direct extraction of its resources (timber, firewood, medicines, etc.), forests provide many essential ecological functions derived directly or indirectly from trees, other vegetation, water, wildlife, and minerals (carbon sequestration, erosion control, wildlife habitat, etc.). Besides, these forests also provide intangible benefits such as landscape aesthetics, cultural practices, and recreation. Forestry can be broadly described as the combination of science, business, art, and practice of organizing, managing, and utilizing the resources that forests have to offer. Silviculture has its place in forestry in that it deals with the methods for establishing and maintaining healthy ecosystems deemed significantly important (Nyland 2016). Silviculture can be defined as the art and science of producing and tending forest stands by applying scientifically acquired knowledge to control establishment, composition, growth, health, and quality based on tree silvics (OMNR 2015). The field of silviculture responds to the demands that are placed on forests for their goods and services and strives to satisfy landowner or company objectives that meet economic and ecological needs. Regeneration, tending, and harvesting are three basic components that make up the practice of silviculture. Therefore, the silviculture process strives for long-term ecosystem vitality, stability, and resiliency (Nyland 2016).

To ensure the sustainability of Ontario's forest resources, a silvicultural effectiveness monitoring program is in place. This program provides the basis for measuring, collecting, analyzing, and reporting on the renewal and state of Ontario's public forests after depletion (OMNR 2001). Silvicultural effectiveness can be observed at the stand, management unit, and regional or provincial level. At the management unit level, the goal is to fulfill the activities outlined in the forest management plan (FMP), at provincial levels, the goal is to preserve a healthy and sustainable forest ecosystem. The program intends to provide answers to three questions: what did we intend to accomplish? what did we accomplish? and how well did we do it? In general terms, effectiveness monitoring is used to determine if management activities are producing the expected results. The desired or expected future forest condition or objectives are determined in the forest management planning process which includes the minimum regeneration standards and management standards, this is required to assess the success and effectiveness of silvicultural activities. Information gathered from silvicultural effectiveness monitoring (SEM) is of importance to the people and companies managing the forest, and by the owners of the forests. It allows foresters to examine the effectiveness of certain treatments and determine if they are meeting expectations or not, to investigate why the stand was not successful and to apply appropriate modifications (OMNR 2001).

The forest management planning manual defines free-to-grow (FTG) or free-growing as stands that meet stocking, height, and/or height growth rate as specified in the ground rule and are healthy and free from competition (OMNR 2001). This concept is used provincially in determining regeneration success for the clear-cut silvicultural system. The well-spaced free-growing regeneration assessment procedure for Ontario is a ground-based assessment used to describe the stand at the time of assessment and provide a basis for forecasting future stand development. A well-spaced tree will meet the minimum distance required between crop trees to allow adequate growing space. With this, the number of well-spaced and free growing trees per hectare in a stand, calculated using ground-based assessments, will be used to determine the status of the stand. A developing stand may be viewed as a silvicultural success, regeneration success, or not satisfactorily regenerated. A silvicultural success is achieved when all the standards contained in the silvicultural ground rule (SGR) applied to that stand have been met. A stand is a regeneration success when regeneration meets the standards of an SGR other than the one originally associated with that stand (White et al 2005).

Silvicultural ground rules (SGR) will contain the standards for target and acceptable species, the desired future forest condition, as well as management standards regarding wildlife habitat. If these standards are not met, and the treatments are a failure, the stand is deemed to be not satisfactorily regenerated. Target species refers to the tree species listed in the SGR and are required to be present. These species are ecologically suited to the stand and have characteristics that are consistent with the management objective. Acceptable species are the tree species that are allowed to be present for measuring silvicultural effectiveness as long as they are compatible with the ecosystem, the target species, and management objectives (OMNR 2001). The SGR will describe treatment options that are most appropriate to achieve the target forest unit, this includes site preparation, regeneration, and tending activities. According to the SGR, some stands may require mechanical or chemical site preparation to manage soil conditions and competition. The stand may be regenerated using the natural approach, planting, or seeding. Tending treatment options are also identified in the SGR which may include cleaning or spacing. The silvicultural ground rules will be designed for each stand according to the desired future conditions put in place, the chosen treatments may have an impact on the success of the stand.

Summarized data collected by the Ministry of Natural Resources and Forestry (MNRF) from the silvicultural effectiveness monitoring program includes a detailed description of each stand. Information appropriate for this study includes each stand's renewal treatment, method of site preparation (if any), and tending operations (if any), along with each stand's status. Stands were deemed a silvicultural success, a regeneration success, or not satisfactorily regenerated. However, explanations as to the reasoning behind successes or failures were missing, or very little. This study will aim to understand what makes a stand considered to be a success or failure, based on the treatments chosen for renewal. Many years' worth of SEM data derived from the Hearst district will be analyzed (2014-2018). This study comprises of four null hypotheses: that 1) regeneration method, 2) site preparation, and 3) vegetation management, and their interactions, do not have a statistically significant effect on the status and WSFG stems/ha of a stand. The fourth hypothesis being that year of assessment does not significantly influence the status designation of a stand.

LITERATURE REVIEW

The Canadian Encyclopedia states that the practice of silviculture requires the knowledge of how various tree species grow under conditions of soil, climate, and spacing (silvics). It defines a silvicultural system to be a planned program of vegetation treatment during the life of a stand, including the blend of harvesting, regeneration and tending (Painter and Cooligan 2006). These treatments are generally used to reduce competition for resources (light, water, soil nutrients) between desired crop trees and competing plants (Wagner et al 2006). Since there is little literature on how silviculture treatments directly influence the regeneration status of a stand, this literature review will look at the effectiveness of the renewal method and how treatments may influence the health, growth, and survival of the stand. The health of a stand can influence the mean well-spaced free-growing stems in a stand, ultimately influencing the final status designation. The review will be focused on renewal methods (planting, artificial), site preparation (chemical and mechanical), and vegetation management (chemical), on boreal species as they are relevant to the study area.

RENEWAL METHOD

Planting, seeding, and natural regeneration are the main forest regeneration techniques used. Natural regeneration is known as the renewal of tree species by seed, vegetative reproduction, or advance growth. Whether or not a site will naturally regenerate depends on several factors such as the type of disturbance, site conditions, method of crop reproduction (suckering/seed tree), and species silvics (competitive ability). Therefore, natural regeneration can be variable. Although planting is considered a costly method of regeneration, in some cases the biological or physical characteristics of sites (productive, competitive, degraded) or characteristics of the species make panting a viable option. Planting is the most dependable method for regenerating black or white spruce in deep mineral soils. Direct seeding is the application of seeds by aircraft, machine, or hand. This method is considered a low-cost strategy that can be effective when site conditions are favourable, especially effective in areas with little competition. Direct seeding is occasionally used as a supplementary technique for tolerant hardwoods when seed crops fail or if natural regeneration is inadequate. Overall, planting is costly and labour intensive but can be the most suitable method for some productive, highly competitive sites. Direct seeding is generally not as effective as planting but is often used for jack pine regeneration. The natural regeneration method is more economical and less labour-intensive than other methods, however, less predictable (Hayes 2001). Each method was compared in an 11-year field trial in northern boreal Sweden. The trial found that natural regeneration produced the greatest number of total as well as main crop plants. However, found that planted seedlings had a height lead corresponding to 4.9 years compared with seeding, and 5.6 years compared with naturally regenerated crop trees (Ackzell 1993). A study observing the growth and development of jack pine in natural stands and planted stands discovered that mortality was highest in natural stands and lowest in planted stands with wide spacing. They also found that periodic diameter increment was higher in planted stands than natural, as well as the merchantable volume. However, it also indicated that better quality was achieved in the natural stand, at the expense of lower total volume compared to plantations (James and Brand 1988).

SITE PREPARATION

Site preparation can be accomplished through mechanical or chemical means. Mechanical site preparation can include mounding, plowing, mixing, trenching, and scarification. Overall, this method manipulates the forest floor and mineral layers. The objectives of mechanical site preparation involve reducing vegetative competition, improve planter access, and create favourable planting microsites (Wood and Althen 1993). A study found that after 20 years, spruce height and dimeter were larger in all mounding treatments than an untreated control site (Boateng et al 2006). Although the main objective of mechanical site preparation is to improve nutrient availability, this method is also associated with some negative impacts on site nutrient relations (Macdonald et al 1998). According to a study conducted by Sutherland and Foreman (2000), black spruce stem volume was highest on plots treated with mixed-mound site preparation. However, they also concluded that mechanical site preparation promotes nutrient depletion and threatens long-term soil productivity. A study by Macdonald et al (1998) also found that mechanical site preparation was associated with reduced total nitrogen and found no significant effect on foliar nutrients in white spruce. Chemical site preparation is commonly used to reduce competing vegetation on a site by applying herbicide. It is also commonly used along with mechanical site preparation methods. A study conducted to observe the development of planted black spruce and pine after treatments found that herbicide reduced competition and dramatically increased early growth all species, and scarification interacted with herbicide to further increase growth. The mean tree volume of jack pine increased greatly after scarification and intensive herbicide. Black spruce increased dramatically with intensive herbicide application (Burgess et al 2010). Also, foliar nutrient contents were generally higher in spruce and pine following herbicide application. The study also suggested that to obtain a more profitable allocation of regeneration resources herbicide such as glyphosate, should be applied immediately after planting. Another study (Powelson et al 2016) found that chemical site preparation resulted in 3-fold gains in stem volume relative to the untreated controls. A separate study that focused on the responses of black spruce to chemical and mechanical site preparation on a boreal site concluded that sites treated with liquid hexazinone produced the largest stem volume increase for black spruce, as well as the lowest vegetation indices for competing trees and shrubs (Sutherland and Foreman 2000). Chemical site preparation can greatly reduce the competition of shrubs and herbaceous vegetation. Wood and von Althen (1993) presented findings concluding that chemical site preparation reduced the percentage cover of woody sprouts, shrubs, and herbaceous vegetation by 95% at the time of planting. Also noticed was an improved height increment and stem diameter.

VEGETATION MANAGEMENT

For this study, the chemical release associated with vegetation management will be reviewed, as it is most relevant to the study area and operations. In Canada, the application of aerial, broadcast spraying of glyphosate is the most common technique of conifer release and is crucial during the first few years following planting (Burgess et al 2010). A study mentioned earlier by Powelson et al. (2016) concluded that by age 25, planted spruce on a treated site, on average, had approximately nine times the individual tree volumes compared to the control, overtopped site. According to a different study (Wagner et al 2006), results indicated that spruce stem volume was from 53%-93% greater with vegetation control than without treatment. Also, among 14 herbicide treatments, softwood composition was 74% in herbicide treated plots, and 23% in untreated plots. Annual vegetation control significantly improved height growth, ground-level stem diameter, and health of planted seedlings, according to Wood and von Althen (1993). However, in 2001 Quebec banned the use of chemical herbicides on Crown Forest Lands, following public hearing processes. Instead, release is accomplished through mechanical treatments. A review on the vegetation management in Quebec described how the use of mechanical release can increase stand structural diversity as this method is not likely to affect understory plant diversity or composition. It stated that in black spruce stands with moderate competition, the manual release strategy can produce a growth response similar to the response under a chemical release. However, the review also noted that on sites with intense vegetative reproduction of northern hardwoods and herbaceous competition, the rapid closure of vegetative cover can harm crop-tree growth. Also, the costs associated with mechanical release are approximately double the cost of chemical treatments. Therefore, the review concluded that without intensive early control of herbaceous species, the herbicide-free approach may not yield maximum crop growth response (Thiffault and Roy 2010).

MATERIALS AND METHODS

STUDY AREA

The Gordon Cosens Forest (GCF) is located in the Ontario Ministry of Natural Resources and Forestry (MNRF) Northeast Region. The boundary of the forest overlaps three MNRF district boundaries including Chapleau, Hearst, and Timmins and is adjacent to Cochrane and Wawa District. The Gordon Consens Forest is shown in Figure 1.

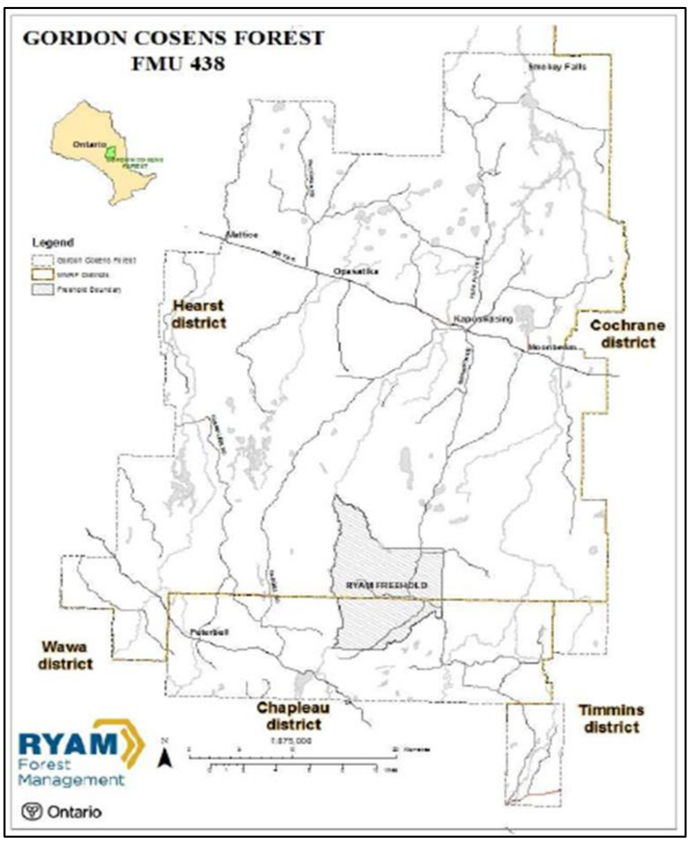

Figure 1. Visual representation of the map of the Gordon Cosens Forest taken from the annual report of 2016. Source: OMNR 2016

Hearst District is the lead district in administering the GCF, with one field office situated in Kapuskasing to carry out activities on the GCF. Communities located within the GCF include

Strickland, Fauquier, Moonbeam, Kapuskasing, Val Rita-Harty, Opasatika, and Mattice. The forest falls within the Treaty #9 area, with several First Nations communities near the GCF. The Sustainable Forestry Licensee and primary user of wood fibre on the GCF is Rayonier Advanced Materials (RYAM) forest management. The forest encompasses a total area of 1,818,581 hectares of Crown land, 1,808,346 hectares (99%) of this being forested land and 1, 631, 202 hectares is productive, the remaining are classified as either non-forested (water, agricultural land) or non-productive (open muskeg). Most of the timber is processed in Kapuskasing and Hearst. The GCF is located primarily on the Northern Clay Belt of the boreal forest, typically flat with muskeg and clay over bedrock with few gravel and sand ridges, making the forest one of the most poorly drained in Canada. The predominant tree species on the forest is black spruce which covers the poorly drained lowlands as well as the gently rising uplands. During the development of the management strategy, habitat for 10 wildlife species are considered; Black-backed Woodpecker, Black Bear Denning/foraging, Lynx, Red-Breasted Nuthatch, Moose winter habitat, Moose summer habitat, Marten, Deer Mouse, Black bear summer habitat, and the Woodland Caribou. Nine forest units were formulated for the 2010-2020 Forest Management Plan (FMP) including PJ1 (Jack Pine), SF1 (Spruce/Fir upland), SB1 (black spruce lowland), SP1 (spruce/pine upland), LC1 (lowland conifer), MW2 (mixedwood), PO1 (poplar), BW1 (white birch), and BOG (OMNR 2016). The proportions of the forest units can be observed in Figure 2.

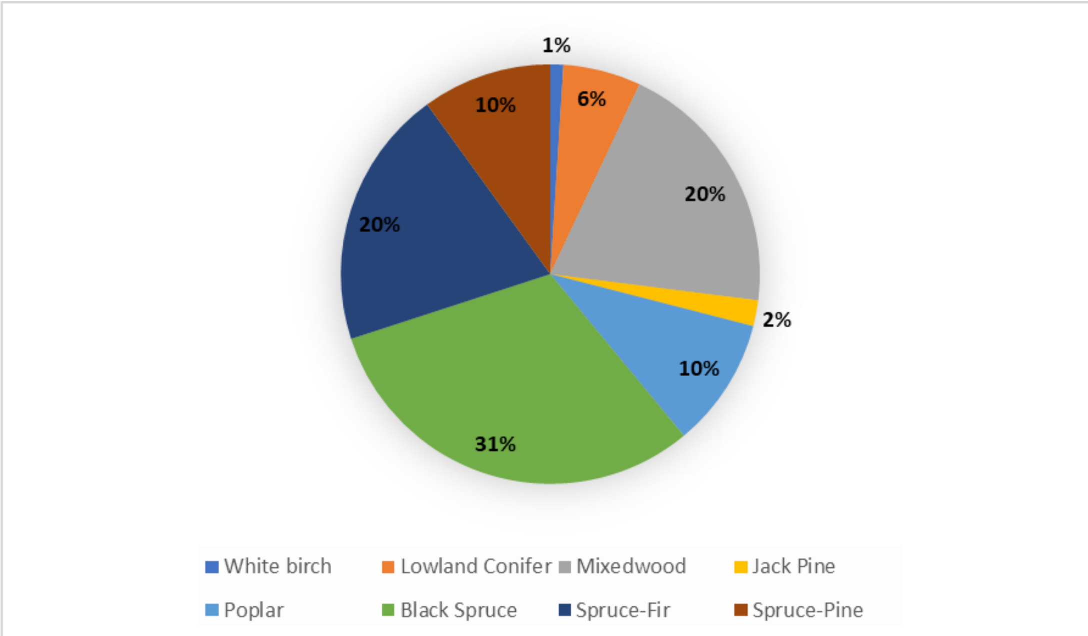

Figure 2. A pie graph demonstrating the average proportions of forest units within the GCF.

OPERATION TECHNIQUES

The predominance of wet organic soils on the GCF has led to the development of special operational techniques (winter harvesting) and specialized types of equipment (high floatation equipment) to overcome difficulties. Some upland areas can also be difficult to operate during the non-forest season, most companies therefore only harvest 7-8 months a year and most hauling occurs during the winter. The conventional clear-cut method is used on the forest, which involves the removal of overstorey trees from a large contiguous area in one operation. Careful logging around advanced growth (CLAAG) can be applied. The logging method most employed on the forest is the full-tree method, involving the removal of the entire tree to the roadside where delimbing and topping occurs, and occasionally the cut-to-length method. The harvested stands are renewed by either natural regeneration, planting, or seeding. Natural regeneration on the GCF includes a group seed tree harvesting (GST), and harvest and regeneration protection

(HARP). Artificial regeneration is recommended for the upland conifer forest units by seeding or planting. Planting can be done at the Basic 1, Basic 2, and Intensive treatment intensities on the forest. Planting of 1,500 to 1,800 stems per hectare is standard for the Basic 2 intensity, and 2,200 stems per hectare with intensive treatments. Aerial seeding is performed on the GCF at a rate of approximately 100,000 seeds per hectare. Site preparation is done either mechanically or chemically on the forest. Mechanical techniques include using a combination of D6 and D8 tractors fitted with shear blades to create corridors of suitable planting sites. Chemical site preparation involves the aerial application of herbicide to control competing vegetation prior to renewal. Cleaning on the GCF is primarily accomplished by chemical means, using a fixed-wing and rotary aircraft for the aerial application of herbicides, generally an application of 1.96 kilograms per hectare for glyphosate (OMNR 2016).

FIELD METHODOLOGY

The silvicultural effectiveness monitoring system relies on an efficient, transparent, and robust regeneration assessment procedure. The Free-Growing Regeneration Assessment is intended for application to all species/stands managed under the clear-cut system. Holders of the Sustainable Forest License (SFL) are required to carry out a monitoring program and assess regeneration. They are responsible for providing the required information to the MNRF. Responsibilities of the MNRF include spot checks of the areas required, using WSFG methodologies (OMNR 2001). The Well-spaced Free-growing regeneration assessment (WSFG) procedure is an intensive, ground-based method that provides a description of the stand and a basis for forecasting future stand development. The survey is conducted near the end of the renewal phase and can be used to identify the need for additional silvicultural treatments (White et al 2005). A series of well-distributed single, circular plots across a regeneration stratum is used for the assessment and accommodates targets of 625 well-spaced trees/ha (one well-spaced tree/plot) to 2,500 well-spaced trees/ha (four well-spaced trees/plot). The first few steps of the procedure involve office tasks which include stratifying the area, determining sample size, and to map the sampling grid and survey lines. Areas to be assessed are grouped into homogeneous units (strata) and the number of plots (sample size) is determined based on the stratum size (a minimum of 31 plots is used for a size of 10 ha). All parts of the stratum must have equal opportunity to be sampled, the use of the grid-based sampling design ensures this. In the field, the first step is to establish plots at the predetermined sampling points. The plots are fixed at an area of 16 m2 (radius of 2.26 m), the centre of each plot is marked with flagging tape to determine the plot boundary. The view of the plot can be seen in Figure 3.

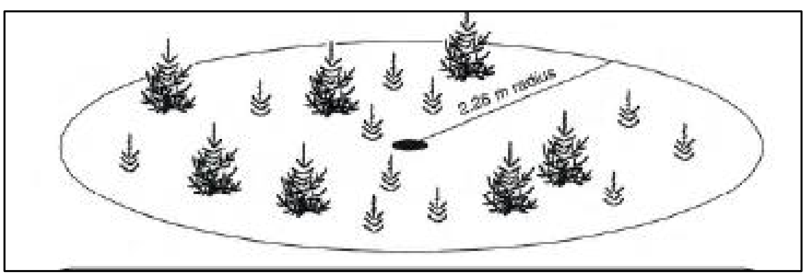

Figure 3. Representation of the plot to be assessed under the well-spaced free-growing procedure. Source: White et al 2005.

Next, all trees greater than 30 cm in height are tallied into appropriate height classes by species. Therefore, the total number of stems (both crop and non-crop) is tallied by height. The well-spaced criteria is applied next to crop trees. If the crop tree under consideration is healthy, has no other crop trees closer than 1.8 m, it is classed as well-spaced. A maximum of four well-spaced trees can be tallied. Next, the free-growing criterion is applied to trees tallied as well-spaced. This assessment is carried out within a 1.2 m radius cylinder around each well-spaced tree. A well-spaced tree is free growing if; it is not located underneath a closed canopy or overtopped, competing stems are less than one-half the height of the well-spaced tree, competing stems are greater than one-half the height but is confined to only one quadrant, and/or the crop tree has a height growth rate equal to or faster than the competitor species with equal height and all competition occurs in a maximum of two quadrants. The free-growing criterion is represented in Figure 4. With this information, the regeneration status is determined by comparing the results from the assessment to the minimum standards set out by the silvicultural ground rules (SGR). If the regeneration standard is less than the mean WSFG stems/ha calculated, the area is a success (White et al 2005).

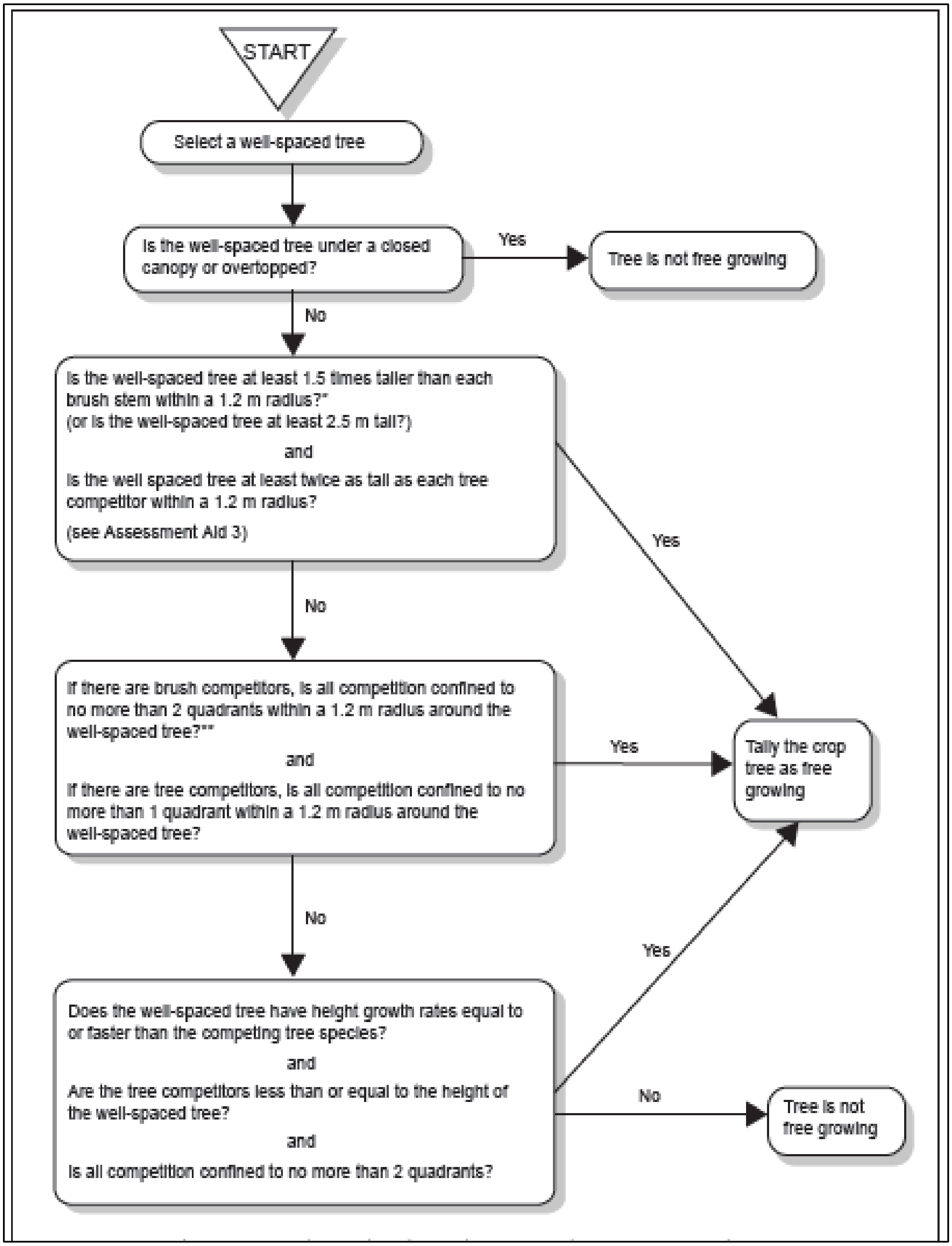

Figure 4. A framework model representing the criteria to decide whether a well-spaced tree is free-growing. Source: White et al 2005.

STATISTICAL ANALYSIS

Data collected over many years from the WSFG assessment procedure on the Gordon Consens Forest will be analyzed for this study, specifically years 2014, 2015, 2016, 2017, and 2018. Data taken from a total of 98 blocks (N=98) was utilized. Once the raw data is organized and categorized correctly, a statistical analysis can be properly performed. To test whether regeneration treatments influence the success of the stand, a three-way ANOVA will be performed. Site preparation includes two treatments: mechanical and chemical, as well as absent treatment. The regeneration method includes three treatments: natural, planting, and seeding. Vegetation management includes two treatments: either present or absent. To further analyze the dataset, an additional three-way ANOVA will be conducted to test the relation and significance between regeneration method, site preparation techniques, and vegetation methods on the average WSFG stems/ha. A one-way ANOVA is also completed to test significance the year of assessment has on silvicultural status. There is a significance if P values are less or equal to 0.05 (95% confidence). The silvicultural status, average WSFG stems/ha, and year of assessment are the dependent variables while regeneration method, vegetation management, site preparation are the independent variables. The ANOVA tests were performed using IBM SPSS Statistics software.

. To further prepare the data for analysis, all string values were transformed into numeric data types while maintaining ordinal measures. Under regeneration methods: natural (N) was transformed into “1”, plant (P) to “2”, and a “3” for seed (S). Vegetation management values were converted from present (Y) to “1”, and absent (A) to “0”. Site preparation received a value of “1” under mechanical (M), “2” under chemical (C), and “0” for absent (A). Silvicultural status was transformed to “1: for silvicultural success (SS), and a “2” for regeneration success (RS).

For statistically accurate results, blocks that were not satisfactorily regenerated (NSR) were removed from the analysis due to lack of data, only two blocks received this status. Therefore, a total of three blocks were removed from the original dataset (N=96). Excel software was also used to construct descriptive tables and figures to provide a basic analysis of the full dataset (N=98).

RESULTS

STATISTICAL ANALYSIS

The two-way ANOVA test results on silvicultural status vs regeneration method, site preparation, ang vegetation management can be observed in Table 1. The results show that there is no significant difference (P>0.05) in silvicultural status by regeneration method (0.26), site preparation (0.33) and vegetation management (0.17). The results also indicate that there is no significant interaction between regeneration method and vegetation management on silvicultural status (0.74). The interactions between site preparation ang vegetation management as well as the interaction between site preparation and regeneration method were not calculated in the ANOVA because there were no replicates to test on.

Table 1. Three-way ANOVA test results on silvicultural status

Tests of Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.
Regeneration_Method	0.64	2	0.32	1.39	0.26
Site_Preparation	0.51	2	0.26	1.11	0.33
Vegetation_Management	0.44	1	0.44	1.88	0.17
Regeneration_Method * Site_Preparation	0.00	0			
Regeneration_Method * Vegetation_Management	0.03	1	0.03	0.11	0.74
Site_Preparation * Vegetation_Management	0.00	0			
Regeneration_Method * Site_Preparation * Vegetation_Management	0.00	0			
Error	20.38	88	0.23		
Total	207.00	96			
Corrected Total	22.74	95			

a. R Squared = .104 (Adjusted R Squared = .032)

The two-way ANOVA results on the average WSFG stems/ha is represented by Table 2. The ANOVA test indicated that there was no significant difference (P>0.05) in the average WSFG stems/ha by regeneration method (0.15), site preparation (0.91) and vegetation management (0.05). Although the significance value of vegetation management is found to be 0.05, this does not indicate significance. There was no significance value calculated for all three interactions.

Table 2. Two-way ANOVA test results on average WSFG stems/ha

Tests of Between-Subjects Effects					
Source	Sum of Squares	df	Mean Square	F	Sig.
Regeneration_Method	274516.37	2	137258.18	1.93	0.15
Site_Preparation	12840.43	2	6420.22	0.09	0.91
Vegetation_Management	279335.51	1	279335.51	3.92	0.05
Regeneration_Method * Site_Preparation	0.00	0			
Regeneration_Method * Vegetation_Management	0.00	0			
Site_Preparation * Vegetation_Management	0.00	0			
Regeneration_Method * Site_Preparation * Vegetation_Management	0.00	0			
Error	4347621.74	61	71272.49		
Total	178513014.00	68			
Corrected Total	5557591.88	67			
a. R Squared = .218 (Adjusted R Squared = .141)					

A one-way ANOVA was performed to test significance that year of assessment has on silvicultural status. The analysis found that there was a significance in the effect that year has on silvicultural status. Table 10 illustrates the significance of 0.00 (P<0.05).

Table 3. ANOVA results of silvicultural status vs year of assessment.

ANOVA					
Silvicultural_Status					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.07	4.00	1.02	5.01	0.00
Within Groups	18.29	90.00	0.20		
Total	22.36	94.00			

BASIC CALCULATIONS

Using the entire data set, several graphs were formulated to provide a visualization of the relationships between silvicultural status and regeneration method, vegetation management, and site preparation. With an additional graph for year versus silvicultural status. Graphs were also produced to represent the relationship between the average WSFG stems/ha and regeneration method, vegetation management, and site preparation as further analysis.

Figure 5 demonstrates the number of blocks that meet each criterion. There are 27 blocks that are naturally regenerated and a silvicultural success (SS), nine blocks were a regeneration success (RS), and one block was not satisfactorily regenerated (NSR). Under planting method 32 blocks were a silvicultural success, 27 a regeneration success, and one block was not satisfactorily regenerated. Only one block was seeded and received a regeneration success status.

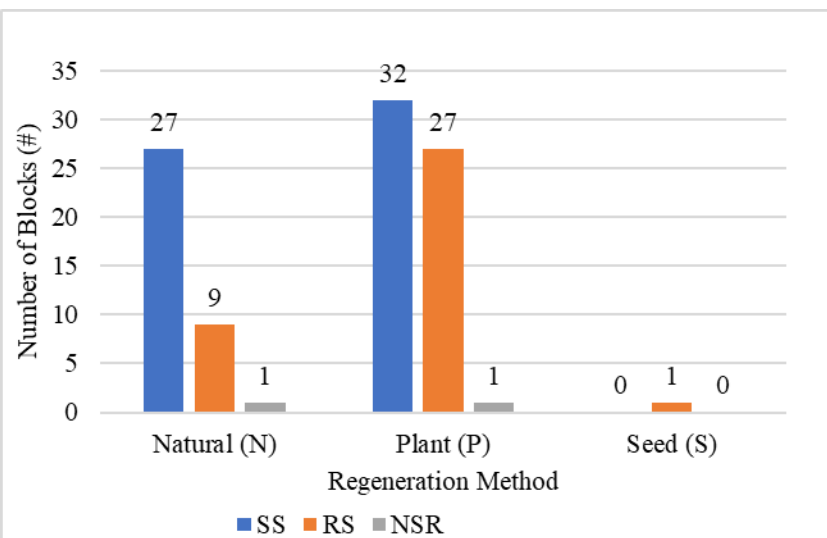

Figure 5. Bar graph representing the number of blocks that are designated as a silvicultural success (SS), regeneration success (RS) or not satisfactorily regenerated (NSR) under each regeneration method.

The average WSFG stems/ha for each regeneration method is displayed by Figure 6. There was an average of 1135 WSFG stems/ha under naturally regenerated blocks, 1408 WSFG stems/ha for planted blocks and the seeded block had 1907 WSFG stems/ha.

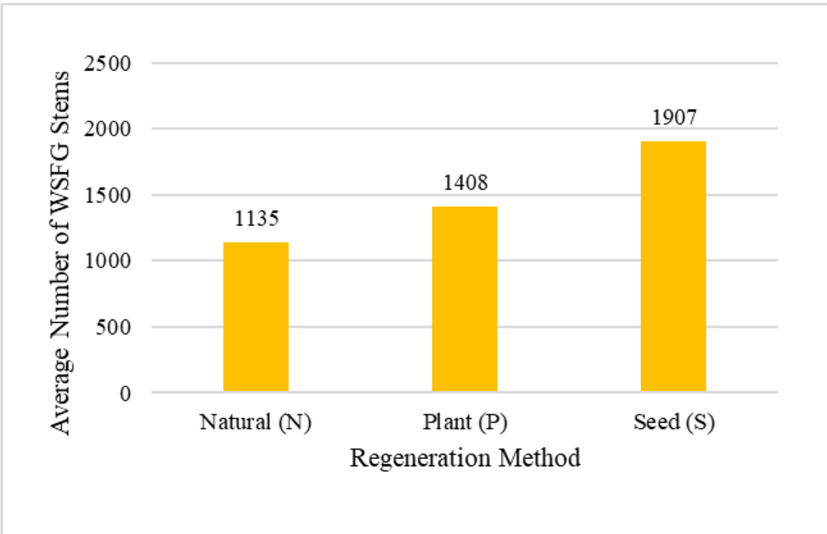

Figure 6.The average number of well-spaced free-growing stems per hectare under each regeneration method.

In the presence of vegetation management there were 33 blocks that were a silvicultural success, and 29 blocks that were a regeneration success. Without vegetation management there were 26 blocks that were a silvicultural success, eight a regeneration success, and two that were not satisfactorily regenerated (Figure 7).

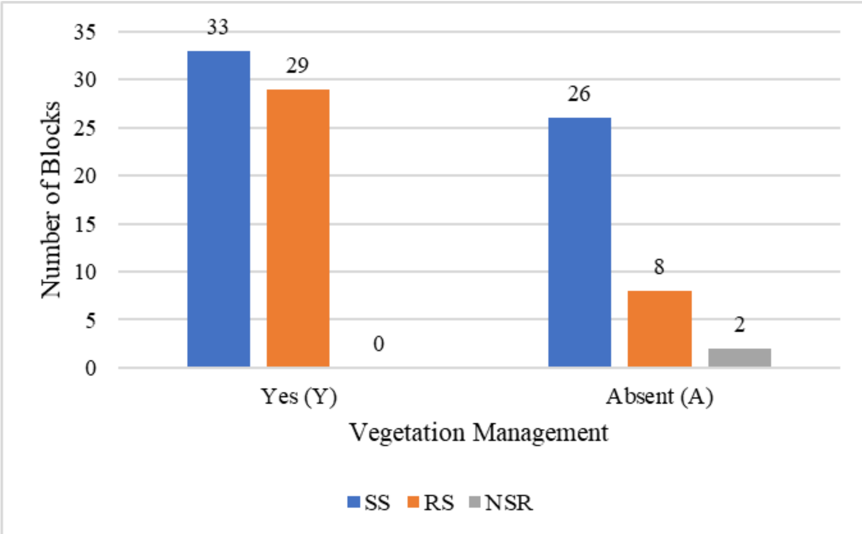

Figure 7. Bar graph representing the number of blocks that are designated as a silvicultural success (SS), regeneration success (RS) or not satisfactorily regenerated (NSR) in the presence (Y) or absence (A) of vegetation management.

An average of 1671 WSFG stems/ha was calculated for blocks with vegetation management, and 1156 WSFG stems/ha without vegetation management. This is shown in Figure 8.

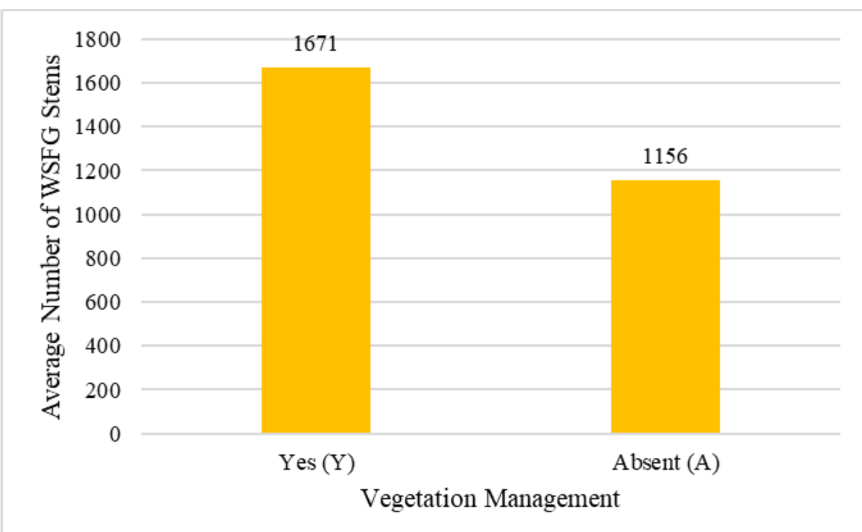

Figure 8. The average number of well-spaced free-growing stems per hectare with (Y) or without (A) vegetation management.

Under mechanical site preparation six blocks were a silvicultural success and five were a regeneration success. Two blocks under chemical site preparation were a silvicultural success. A total of 51 blocks were a silvicultural success, 32 a regeneration success, and two were not satisfactorily regenerated in the absence of site preparation (Figure 9).

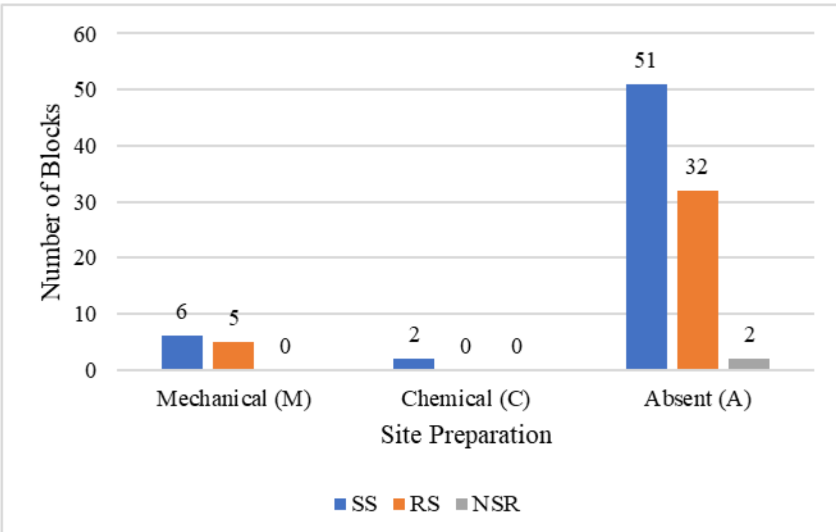

Figure 9. Bar graph representing the number of blocks that are designated as a silvicultural success (SS), regeneration success (RS) or not satisfactorily regenerated (NSR) under each site preparation method.

Figure 10 expresses the average WSFG stems/ha under each site preparation treatment. With mechanical site preparation, an average of 1586 WSFG stems/ha is achieved, 1553 WSFG stems/ha under chemical preparation, and 1307 WSFG stems/ha in the absence of site preparation.

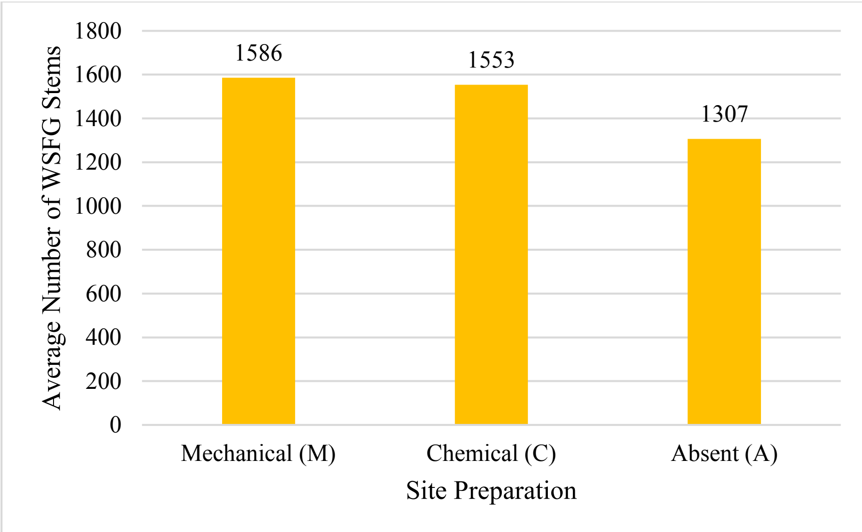

Figure 10. The average number of well-spaced free-growing stems per hectare under mechanical, chemical, or in absence of site preparation.

Under each year (2014-2018), the percentage of occurrence for each silvicultural status was calculated and illustrated in Figure 11. The highest percentage of blocks that were a silvicultural success was in 2018 (82%) and the lowest in 2015 (26%). Regeneration success designation was highest in year 2015 (70%) and lowest in 2018 (18%). Two years, 2017 and 2015 received a not satisfactory regeneration status, five blocks for year 2017 and four for 2015.

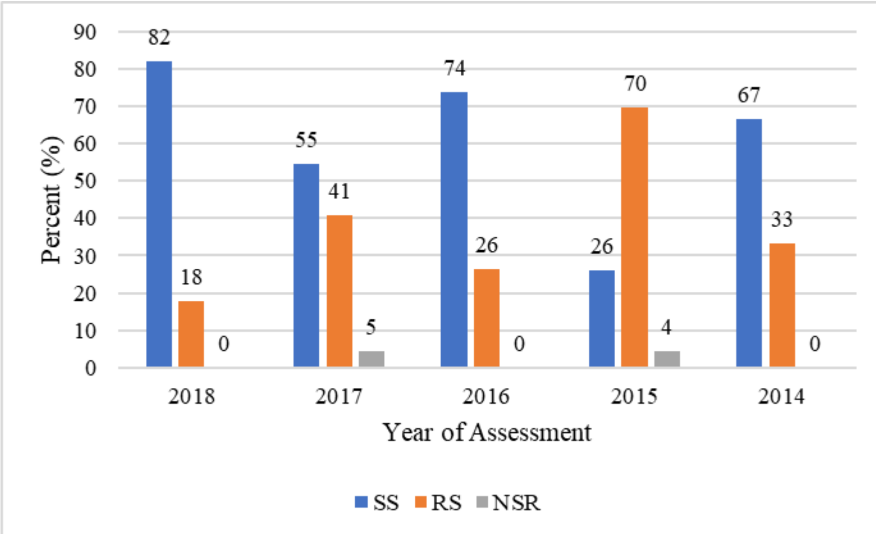

Figure 11. Bar graph illustrating the percentage of each status occurrence under each year of assessment.

DISCUSSION

Results from the three-way ANOVA testing the significant differences and interactions of regeneration method, vegetation management, and site preparation on silvicultural status fails to reject the first three null hypotheses. This means that method of regeneration (natural, plant, or seed), method of site preparation (mechanical, chemical, and absent), and vegetation management (absent or present) did not significantly influence the status designation of a stand. The two-way ANOVA testing the significant differences in the average WSFG stems/ha based on regeneration method, vegetation management, and site preparation also fails to reject all three null hypotheses. Vegetation management treatment significance value was calculated at 0.05, this is borderline not significant, indicating that this treatment may have more significance compared to the other two. Overall, this means that regeneration treatments do not have a significant effect in the average WSFG stems/ha. The lack of significant results discovered in the ANOVAs can be due to the lack of data that falls under each criterion. For example, in Figure 9, there is three categories that are missing data. Under chemical site preparation, there is missing data for both regeneration success and not satisfactorily regenerated criteria. Missing data like this can be found throughout the entirety of the dataset. This results in criterion that cannot be accurately tested against or between other criterion because there is no data to perform an analysis on. Therefore, if all criterions were occupied by sufficient data, then the statistics software can produce results for all interactions and compare means between regeneration treatments. Furthermore, there appears to be a lack of replicates that falls under each specific criterion, causing an uneven data set to be tested against each other. For example, there was 11 replicates of mechanical site preparation and only two replicates for chemical site preparation (Figure 9).

The one-way ANOVA, however, did find significance between year of assessment and silvicultural status designation (Table 3). This rejects the fourth null hypothesis and means that the year of assessment (2014-2018) results in significantly different status designations. This discovery can be either due to the individual assessments during each year or relating to the planting year, roughly 10 years prior to assessment. Determining which conclusion contributed to the significant difference is a challenging task, however, generalizations can be provided for each. There are many variables that can alter the success of a planting or seeding year, as well as the year natural regeneration took place. Budget, environmental conditions, as well as weather events can all potentially be causing factors. If there are strict budget constraints during one season, the effort invested in treatments may have been reduced. For example, sites may have experienced a lower level of site preparation and vegetation management compared to other sites during that year. Environment conditions prior to regeneration of the stand may also be essential. Suitable regeneration conditions may have been in more abundance in certain years compared to others. In some years, the region may have experienced either drier or wetter conditions based on average temperature and precipitation level, this can influence success of regeneration of certain species. Similarly, environmental conditions following regeneration, site preparation, and vegetation management could also alter results. Some years may have suffered through an earlier than usually frost event or a substantial strom. This could have an adverse impact on seed and seedling survival. A detailed analysis of the past environmental conditions of the region would need to be conducted to provide a better understanding. Silvicultural assessment monitoring (SEM) surveys can also experience variations between years and can also pay an important role in the results of this study. Assessment method over the years have been known to change often. For example, in earlier years, the primary method of recording was through pencil and paper tallying. However, this has shifted to the use of computerized software programs using tablets as the primary method of recording. In addition, despite the common parameters required under the SEM manual and the well-spaced free-growing regeneration assessment procedure, inputs into models have also changed through the years. For example, in earlier times with paper tallying, every tree in the plot is recorded and measured, however, recently this has changed to only tallying (on a tablet) a certain number based on size and species type. From here, the software generates an accurate projection of entire stand characteristics, omitting the need for additional data collected in previous years. There is also possible variation in individual or group performance. Although each person or group is expected to follow appropriate procedures and manuals, there is always the possibility of bias measurements. Bias can be found during measurements (ex. height) between surveyors as humans tend to either measure up or down unknowingly and creates bias in the dataset.

Although regeneration method, site preparation, and vegetation management did not significantly influence the status of a stand, general trends can be observed in Figures 5 to 11. According to Figure 5, regeneration method achieved the most silvicultural success designated stands under planting. This may suggest that planting (greater effort) can produce more successful stands. However, more data is obtained under planted stands compared to the other two regeneration methods. The average WSFG stems/ha on the other hand, appear to have a trend where the average WSFG stems/ha increase from natural regeneration, to planting, to seeding method. Under seeding, an additional 772 average WSFG stems/ha is obtained compared to natural regeneration, and approximately 499 average WSFG stems/ha over planted trees. Therefore, seeding method can produce more WSFG stems/ha than natural regeneration and planting regeneration method. Though, this generalization is conducted based on just one block that comprised of seeding. There is a strong correlation noticeable between the presence of vegetation management and the success of the stand. Looking at Figure 7, there are both more blocks classed as a silvicultural success and regeneration success compared to the absence of vegetation management. Also, two not satisfactorily regenerated blocks received no vegetation management. This is similar in Figure 8 regarding the average WSFG stem/ha. There is a decline of average WSFG stems/ha from blocks with vegetation management to blocks without. Under vegetation management, there is an average of 515 WSFG stems/ha more compared to no vegetation management. This implies that to increase the success of the stand, vegetation management should be conducted. Generalizations is difficult to formulate for site preparation due to lack of data. However, according to Figure 9, two NSR blocks appeared to experience no site preparation. In Figure 10, the average WSFG stems/ha appears to experience a slight decline from mechanical site preparation, to chemical site preparation, to no site preparation. These observations possibly suggest that areas that receive some form of site preparation will be more successful than areas without. It is also worth examining the blocks that have received an NSR status designation. Both blocks received no vegetation management and no site preparation, one was naturally regenerated and the other planted. This may indicate that success of a stand can exceptionally decrease in the absence of both vegetation management and site preparation of the block.

Further data may be required to obtain results that are more significant. Both an increase in overall data samples as well as an increase in the replicates that fall under each criterion will be essential. This will provide a more accurate and enhanced dataset to undergo statistical analysis. For this to occur, data from many more forest management units would be considered an asset.

CONCLUSION

It is well understood that in many cases, silvicultural treatments can have profound positive effects on the regeneration of a stand. The combination of treatments can result in a stand to be designated as a silvicultural success (SS), regeneration success (RS), or not satisfactorily regenerated (NSR). These designations are produced through the silvicultural effectiveness monitoring program along with the well-spaced free growing assessment procedure in Ontario. These assessments are extremely valuable to understand how well the stand is regenerating, and whether supplemental treatments are required. Overall, this study did not find any significant influence that regeneration method, site preparation, or vegetation management has on status designation (SS, RS, NSR) of a block within the Gorden Cosens Forest. Year of assessment, however, was found to have a significant influence on the silvicultural status of a stand. Despite lack of significant results, trends were observed of the general calculations. These results support the idea that with increasing silvicultural treatment efforts, an increase in either the silvicultural success or average WSFG stems/ha can be achieved. With no vegetation management or site preparation there is a risk that blocks become not satisfactorily regenerated. Also, to achieve the highest possibility of being a silvicultural success, it is recommended that blocks undergo either seeding or planting, mechanical site preparation, and vegetation management is conducted. However, lack of sufficient data should not be ignored within this dataset and to obtain higher quality results, more information is required. In the end, silviculture is an important tool in forestry in that it gives foresters the opportunity to manipulate the structure, composition, or health of the forest to achieve various goals and objectives.

LITERATURE CITED

Ackzell, L. 1993. A comparison of planting, sowing, and natural regeneration for Pinus Sylvestris (L.) in boreal Sweden. Forest Ecology and Management. Vol 61 (3-4). 229-245 pp.

Boateng, J., J.L. Heineman, J. Mclarnon, and L. Bedford. 2006. Twenty year responses of white spruce to mechanical site preparation and early chemical release in the boreal region of northeastern British Columbia. Canadian journal of forest research. Vol 36(10): 2386-2399 pp.

Burgess, D., G. Adams, T. Needham, C. Robinson, and R. Gagnon. 2010. Early development of planted spruce and pine after scarification, fertilization, and herbicide treatments in New Brunswick. The forestry chronicle. Vol 86. 444-454 pp.

Hayes, A. 2001. Regeneration strategies as a proactive approach to vegetation management. Northwest Sci & Technol. Technical notes TN-46. A guide to opportunities. 8 pp.

James P.S., and D.G. Brand. 1988. Comparative growth and development of planted and natural stands of jack pine. The forestry chronicle. https://pubs.cif-ifc.org/doi/pdfplus/10.5558/tfc64320-4. (online).

Nyland, R. D. 2016. Silviculture: concepts and applications, third edition. Waveland Press. 680 pp.

Macdonald, S., M. Schmidt, and R.L. Rothwell. 1998. Impacts of mechanical site preparation on foliar nutrients of planted white spruce seedlings on mixed-wood boreal forest sites in Alberta. Forest ecology and management. 35-48 pp.

Ministry of Natural Resources and Forestry. 2016. Gordon cosens forest annual report. Hearst district. Northeast Region. http://www.efmp.lrc.gov.on.ca/eFMP/home.do. (online).

Ontario Ministry of Natural Resources and Forestry. 2001. Silvicultural effectiveness monitoring manual for Ontario. Queen’s printer for Ontario. 42pp.

Ontario Ministry of Natural Resources and Forestry. 2015. Forest Management guide to Silviculture in the Great Lakes-St. Lawrence and Boreal Forests of Ontario. Queens Printer for Ontario. 394 pp.

Painter, M.F and D. Cooligan. 2006. Silviculture. The Canadian Encylopedia. https://www.thecanadianencyclopedia.ca/en/article/silviculture (online).

Powelson, R., J. L. Heineman, L. Bedford, J. McClarnon, A. F. Linnell Nemec, and J. O. Boateng. 2016. White spruce responses to mechanical site preparation, chemical site preparation, and post-planting vegetation control over three decades in the boreal white and black spruce zone of British Columbia. Technical report. British Columbia. https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR103.pdf. (online).

Sutherland, B., and F.F. Foreman. 2000. Black spruce and vegetation response to chemical and mechanical site preparation on a boreal mixedwood site. The Canadian journal of forest research. Vol 30. 1561-1570 pp.

Thiffault, N. and V. Roy. 2010. Living without herbicides in Quebec (Canada): historical context, current strategy, research and challenges in forest vegetation management. European journal of forest research. Vol 130 (1): 117-133 pp.

Wagner, R., K.M. Little, B. Richardson, and K. Mcnabb. 2006. The role of vegetation management for enhancing productivity of the world's forests. Forestry: An international journal of forest research. Vol 9(1). 57-79 pp.

White, R., C. Bowling, W. Parton and W. Towill. 2005. Well-spaced Free-growing Regeneration Assessment Procedure for Ontario: NWSI Technical Manual TM-007. 41 pp.

Wood J. E., and F. W. von Althen. 1993. Establishment of white spruce and black spruce in Boreal Ontario: effects of chemical site preparation and post-planting weed control. The forestry chronicle. Vol 69(5): 554-560 pp.