A CASE STUDY OF MOISTURE REGIME ON

Pinus banksiana ACROSS ONTARIO.

by

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Mr. Ryan Wilkie — Major Adviser

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A CAUTION TO THE READER

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ABSTRACT

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Keywords: Growth, Drought, Stresses, Moisture Regime, Soil type, Assisted Migration, Productivity.

With climate change affecting the boreal forest there are many consequences to plant species on different site types that can be detrimental to their longevity and productivity, affecting ecosystem health. In this study moisture regime effect on *Pinus banksiana* Lamb. (jack pine) productivity was explored. This study shows that mean annual increment on the moisture regimes 0-2 are the most productive annual with DBH growth and height growth. The introduced climatic stressors such as raised temperature can negatively impact these sites and allow for a major amount of drought stress to take place, which will hinder the productivity of this widely used commercial species. There will also be a shift in moisture regime for the regimes 3-7 causing these to become drier. This could allow for the fresh (3) and the moist sites (4-7) to become more productive as they dry out.

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INTRODUCTION

One of the largest forest biomes on Earth is the boreal forest and it approximately covers 1.9 billion hectares of the forested area globally (Government of Canada 2020). Canada has 28% of the worlds boreal zone which is 552 million hectares of the boreal forest (Government of Canada 2020). This forest is heavily dominated by different conifer species such as jack pine (*Pinus banksiana* Lamb.). There are species being faced with fast changing climate conditions, which is introducing worsening climatic stressors on the boreal forest (Gauthier *et al.* 2015).

Climate change is an everchanging challenge that the forests globally are being faced with. The southern limit of the boreal forest is privy to many of these implications creating a warm adapted species composition in the boreal (Boulanger *et al.* 2017). With temperatures warming in some areas, it is causing stresses on the environment and plant life found within it (Boulanger *et al.* 2017). These stresses can include temperature and precipitation changes that can cause drought stress from the decreased water availability (Boulanger *et al.* 2017). With the rapidly changing temperatures, individual tree productivity will be majorly impacted which will allow for more competition from other tree species with will change the forest composition, especially along the southern limit of the boreal forest (Boulanger *et al.* 2017). This can be from the decrease in water availability on drier sites because of early snow melt because of higher temperatures (Ruiz-Perez and Vico 2020). This positive feedback loop causes less snow cover because of warming and introduces more thermal heat onto the soil that causes warm and dry out over winter (Ruiz-Perez and Vico 2020). With a decreased water availability for species in dry sites they will have to adapt to a more drought prone area and conserve water (Ruiz-Perez and Vico 2020). Climate change potentially help with an increase in productivity because of the warmer weather, but this could also lead to more areas being challenged with more heat and water stresses happening (Ruiz-Perez and Vico 2020). With rapid change of temperature in the environment there is a large amount of variability that it can have environment, in dryer areas there can be a large impact on plat growth (Aber *et al*. 2001). In the drier sites with effects of higher temperatures and a longer growing season this could mean that plant respiration could outlast plant photosynthesis which will result in a decline of plant productivity (Aber *et al*. 2001). Fire disturbance is a primary driver of ecology in the boreal that is also being affected by climate change by causing shifting patterns in fire weather, fire behaviour, and carbon emissions (Groot *et al*. 2013). Groot *et al*. (2013) found through their predictions from three different global climate models (GCMs) and three different climate change scenarios for Russia and Canada (containing most of the world's boreal forests), the impacts on fire in 2091-2100 will cause the severity of fire weather to increase, with an extreme increase in the Canadian study area. With increasing drier areas in the boreal, fire disturbance will most likely be altered to have larger burn areas, a higher frequency of fire, increased fire intensity, and a longer fire season (Weber and Flannigan 1997).

The purpose of this paper was to look at the effect of different moisture regimes on jack pine productivity. The data being examined was from the Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) collected from across the province. Metrics used included moisture regimes (MR's) and microsite variables of Jack pine stands from a drought stressed state to normal growth period. This thesis will attempt to give insight on the growth of Jack pine in a changing environment and show what it might imply about the future of this species in the boreal forest biome from the effects of climatic change.

OBJECTIVE:

The purpose of this paper was to study data from the NDMNRF and model potential effects of climate variable shifts on moisture regimes and productivity of jack pine.

NULL HYPOTHESIS:

There is no difference of productivity of Jack pine on different moisture regimes.

ALTERNATIVE HYPOTHESIS:

There is a difference of productivity of jack pine on different moisture regimes.

LITERATURE REVIEW

PHYSIOLOGY OF TREE

Jack pine (*Pinus banksiana* Lamb.) are trees that grow up to 20m tall and roughly 30cmin diameter (Farrar 2017), but occasionally can grow larger and live longer than 150 years. This species also occurs in pure stands or with other shade-intolerant species such as trembling aspen (*Populus tremuloides* Michx.) (Farrar 2017). Beland and Bergeron (1996) found that site index or the height of Jack pine is influenced by soil depth and coarse fragments more so than precipitation. Jack pine have high water use efficiency but a low demand for soil fertility, this suggests a wet moisture regime for Jack pine is a growth limiting factor (Beland and Bergeron 1996). The height growth of jack pine was graphed and placed into two different categories, the first group consists of trees found on clays and deep tills (Beland and Bergeron 1996). This group showed small differences between the height of jack pine at 50 years old, the second group was composed of low productivity sites such as sands, which had the curves showing more of a variable height growth pattern, shown in figure 1 (Beland and Bergeron 1996). This could be because of the growth delay that the Jack pine on sandy soils have at younger ages that Beland and Bergeron (1996) observed.

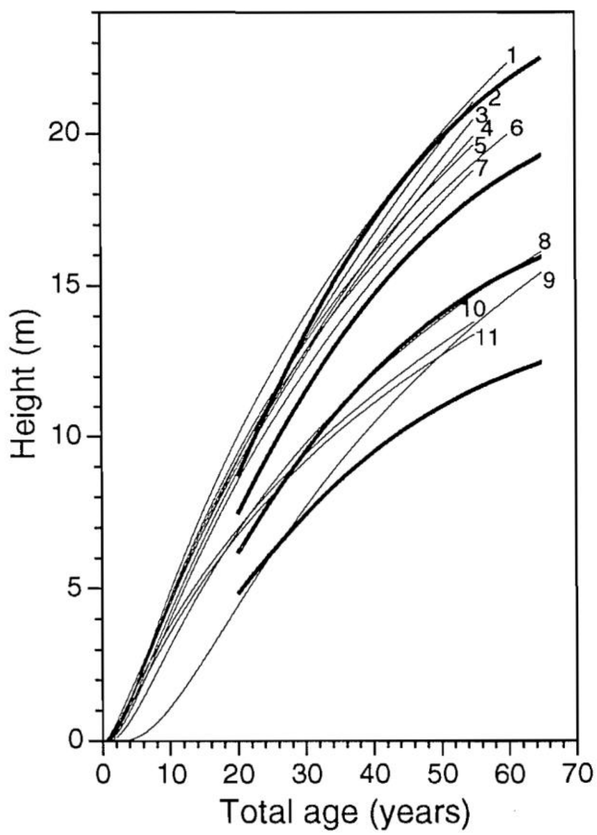

Figure 1. Beland and Bergeron's average jack pine height growth curves for the 11 sites studied, the darker lines show the limits of the three site classes of Plonski (1974).

Figure 1 shows the height growth of jack pine on different types of soils with the grey lines, the black lines show the limits of the three site classes of Plonski (Beland and Bergeron 1996; Plonski 1974). This figure shows slight deviations of height growth from the Plonski (1974) curves, with the soil type moderately dry clay (1) having the tallest trees (Beland and Bergeron 1996).

Jack pine's growth is the most productive in wetter sites, because of its water use efficiency, and it exhibits growth delay at younger ages on sandy soil sites because of the deeper rooting depth (Beland and Bergeron 1996). On deeper sandy soils there is a growth lag of jack pine that is exhibited because of the time that it takes for the taproot to reach available water in the site (Beland and Bergeron 1996). The growth of the species on sandy sites will have longer sustaining growth than those on wetter areas (Beland and Bergeron 1996).

CLIMATE

Jack Pine (*Pinus banksiana* Lamb.) are found in areas that are characterized by warm to cool summers that are usually short, with harsh long winters, with low rainfall (Rudolph and Laidly 1990). The average temperature ranges from January and July that jack pine can be found in are -29°C - -4°C in January and from 13°C - 22°C in July (Rudolph and Laidly 1990). Jack pine can be found on very dry sandy soils or on gravely soils so the moisture requirement for this species is low (Rudolph and Laidly 1990). Pj growing days range depending on their location, but the average growing days range found by Subedi and Sharma (2021) is 1077-1454. *Pinus banksiana* Lamb. is one of the most shade intolerant species and need sunlight immediately after establishing in the site for optimal survival (Rudolph and Laidly 1990).

MOISTURE REGIMES IN THE BOREAL

Soils throughout the Boreal Forest the moisture regimes (MRs); dry (0), fresh (1-3), moist (4-6), wet (7-9) (Sims *et al*. 1996; Ontario Institute of Pedology 1985; Sims *et al*. 1989).

COMMON FOREST SOILS THAT JACK PINE ARE ON

Jack pine (*Pinus banksiana* Lamb.) dominate forest sites that are on mesic to xeric soils (Dietrich *et al.* 2016). Jack Pine is commonly found on poor quality sites such as coarse sands, rock outcrops, and shallow soils in the forest, and sometimes even on permafrost sites (Farrar 2017). The most common occurrence of jack pine is on different variations of sandy soils found throughout the forest scape, but it can also be found in wetter sites such as clay (Donald 1981; Fowells 1965). Soil landscapes of Canada interactive map was used to determine soil orders that are currently suitable for Pj, the main soil orders suitable are brunisolic, podzolic, luvisolic, organic, and gleysolic (Government of Canada 2021). Brunisolic soils are classified as soils that are poorly developed and do not have well-defined horizons of podsol or luvisol, podzolic soils have found in coniferous forests throughout Canada and they have a well-developed A and B horizons (Earl 2015). Luvisolic soils are characterised by a clay rich B horizon, organic soils are defined as soils that are dominated by organic matter with mineral horizons that are usually absent (Earl 2015). Jack pine most commonly establishes on sites that range from 0-2 SMRs, were the peak amount of the species are normally found (Sims *et al.* 1996). These SMRs show that Jack Pine prefers dry to fresh sites, but most commonly occur in dry to moderately dry soil sites (Sims *et al.* 1996). It is extremely rare to find jack pine on organic soils in the forest scape, this is most likely due to competition from other species on these sights (Sims *et al*. 1996). These soil moisture gradients show the extremes that this species inhabits which range from extremely dry to waterlogged bogs (McCollum and Ibanez 2020).

CLIMATE CHANGE

With rising CO_2 levels in the atmosphere there are direct consequences for plant growth (Dietrich *et al.* 2016). With increased atmospheric CO_2 trees are likely to have increased productivity but will be limited by drought responses from trees (Dietrich *et al.* 2016; Huang *et al.* 2007). Dietrich *et al*. (2016) found that with increased drought stresses from climate change there are likely to be deviations from the expected growth increase caused by the abundance of atmospheric CO_2. Marchand *et al*. (2021) predict that there will a warming of three degrees Celsius by the end of the 21st century, which will in turn cause increase in evaporative demand over large parts of the Earth's surface (Dai 2013). The current biomes and ranges of Ontario are depicted in the figure 2. This map allows for insight on the current state of the forest ranges of Ontario, with warming of the northern soils there will a be a northern movement of these forest regions.

Figure 2. Biome map of Ontario (NDMNRF 2014).

This figure shows the biomes that are found in Ontario, and their different limits. With the effects of climate change on the Boreal there is potential for the Canadian boreal zone to be 4-5°C warmer by 2100 (Price *et al*. 2013). This will promote biome shifts and encroachment of the great lakes-St. Lawrence Forest

(GLSL) and the deciduous forest on the boreal forest. With the predictions of warming of 4-5°C on the boreal, future conditions will become more suitable for the GLSL forest and the deciduous forest species (Price *et al*. 2013). In figure 3, we see the mean annual summer temperatures for Canada and with a 4-5°C is shows us that the boreal can be changed to 22°C which is more viable for both the GLSL forest and deciduous forest.

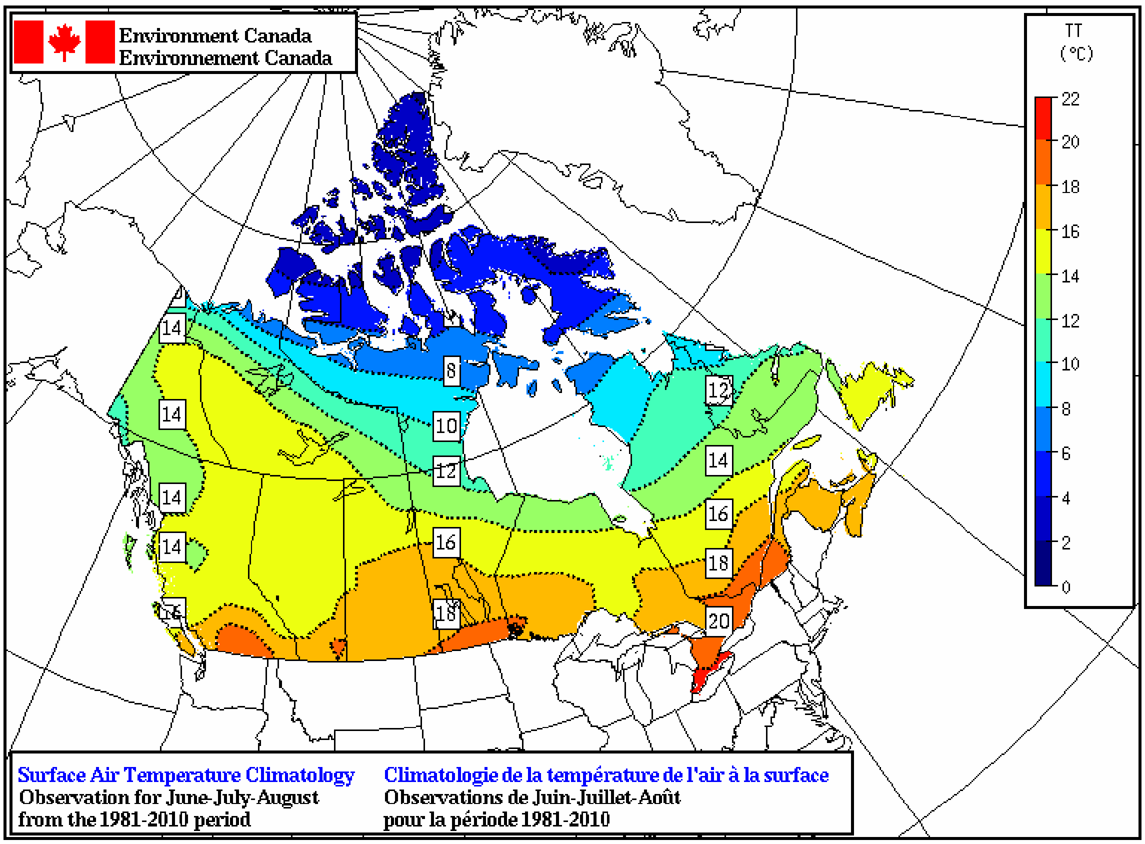

Figure 3. Mean annual summer temperature for Canada (Government of Canada 2022).

Climate change can also cause shifts in ecosystem state in sensitive areas that are exposed to increasing changes of climate (Price *et al.* 2013). Price *et al.* (2013) found through their predictions that in the time 2071-2100 there is a decrease in climate moisture index for the boreal. This decrease in moisture availability can cause major impacts on different sites, with warming and a moisture decrease this can cause rapidly draining dry soils, such as sandy sites to become inhospitable for tree species because of the lack of nutrients and water availability (Price *et al*. 2013).

EFFECTS ON BOREAL FOREST HEALTH

The boreal found in Canada is expected to face the largest impacts of climate change (Nelson *et al.* 2013). Some of the major changes that the boreal is facing are changes in fire regime such as increase in, fire intensity, severity, area burned, and time since last fire (Groot *et al.* 2013). With variations of ambient temperature in the Boreal this can increase growing days during the year, as well as seasonal changes in CO_2 that are amplified (Kauppi *et al.* 2014). Kauppi *et al*. (2014) found that in the Finish Boreal Forest more than half of the response to climatic change has been positive, from this there is a large change in the ecological and economic performance of the forest. In this area, growing season temperature is the main factor that causes variations of growth in the forest (Kauppi *et al.* 2014).

Another effect that climate change has on the boreal is all moisture regimes are moving towards a drier overall regime (Wang *et al*. 2014). There are a wide range of impacts from favourable to adverse that can happen to this landscape (Wang *et al.* 2014). Through the predictions done by Wang *et al.* (2014) in all four GCMs (general circulation models) there is a general warming trend across the Canadian boreal zone during the 21st century. With these implications on the boreal, there is a need for new management strategies to be put in place because of the rapidness of climate change, using historic management strategies will no longer work (Wang *et al*. 2014).

NORTHERN MOVEMENT OF SPECIES

With the temperature increasing there will warming in the northern areas of the boreal that have discontinuous permafrost, this will allow for a migration of conifer species into these new areas (Soja *et al.* 2007; Rizzo and Wilken 1992; Smith and Shugart 1993). With this northern movement of species, there will be a biome shift along the southern limit of the boreal forest causing it to shift into more of a temperature forest (Soja *et al.* 2007; Rizzo and Wilken 1992; Smith and Shugart 1993). These changes will become the most apparent in areas along the boarders of the forest biomes, the current composition of these areas will be forced northward and to higher latitudes (Evans and Brown 2017). These trends are becoming more commonly observed in many systems, but species' responses are complex and uneven with regional changes (Evans and Brown 2017; Walther *et al.* 2005; Chen *et al.* 2011; Boisvert-Marsh *et al.* 2014). These are also called biome shifts which is the landscape's transition over geological time scales to a different vegetation make up (Brecka *et al*. 2018; Donoghue and Edwards 2014). High latitude areas are expected to have the largest amounts of change in temperatures and have many shifts in precipitation regimes (Brecka *et al.* 2018; Diffenbaugh and Field 2013; Gautheir *et al.* 2015; Reyer *et al*. 2015). This is extremely important because of the shrinking suitable habits that these high altitude areas are causing immobile forest plant species to be trapped and have no way out (Brecka *et al.* 2018). Climate has a key role in the species composition of these higher latitudinal sites, with warmer average temperatures it can cause a die back of cold-adapted conifer species and replacement by deciduous species will happen (Brecka *et al*. 2018).

EFFECTS ON FOREST HEALTH

The energy within the forest structure will be altered along with moisture balances, productivity, and many other basics that make up the ecosystems will be altered with minimal temperature increases in the environment (Rizzo and Wiken 1992; Davis 1989). There is potential for a time lag before vegetation and soils reflect new a climate (Rizzo and Wiken 1992), this is because of permafrost melting from the soil, which leaves poor soils that limits potential growth in this newer environment (Soja *et al.* 2007; Heinselman 1978; Viereck and Schandelmeier 1980; West *et al.* 1981; Bonan 1989; Bonan and Shugart 1989).

There are indirect and direct effects that climate change will have on forest health in the boreal (Price *et al.* 2013). There is chance for photosynthesis, transpiration, and respiration to all be affected by climate change, and affect overall forest health (Price *et al*. 2013). Also, with climate change there is a negative effect on snow cover and water availability in the boreal that can be detrimental to the forest stands (Price *et al.* 2013). With less snow cover in the boreal due to the warming, forest soils are exposed earlier in the year, increasing solar heating of the soils, increasing soil temperature which could lead to there being less water availability on different sites (Price *et al*. 2013). On drier sites in the boreal such as a moisture regime 0 site, not having this available water can majorly affect the species composition and be devastating to the current species that occupy the area. While the MR sites that are wetter such as 4-7, the drying effect in these stands will allow for higher productivity of jack pine. With less water availability in these soils, it could allow for an increase in productivity for jack pine currently on wetter moisture regimes (Price *et al.* 2013).

JACK PINE RESPONSE TO DROUGHT

Under climatic stresses Jack pine on different sites have been affected positively depending on the weather effects in the environment (McCollum and Ibanez 2020). With increasing spring temperatures in April growth rates increase by 15% in bogs and 18.7% to 19.6% in the dryer sites but in drought years growth declines the most in bog sites (McCollum and Ibanez 2020). When spring temperatures are 5 °C and the PDSI (Palmer Drought Severity Index) is equal to negative -5 growth rates in the boggy areas that Jack pine is found on decrease by 17% (McCollum and Ibanez 2020). While in the dryer areas the growth rates are less affected and decrease <10% in these areas (McCollum and Ibanez 2020). Another factor that McCollum and Ibanez (2020) explore was when the sites are under drought and warm conditions from the start of the growing season, they found that both dry sites have an increase in growth rates by 11% and 3% respectively. While the bog site has a decrease in growth rates by 8%, as shown in figure 2.

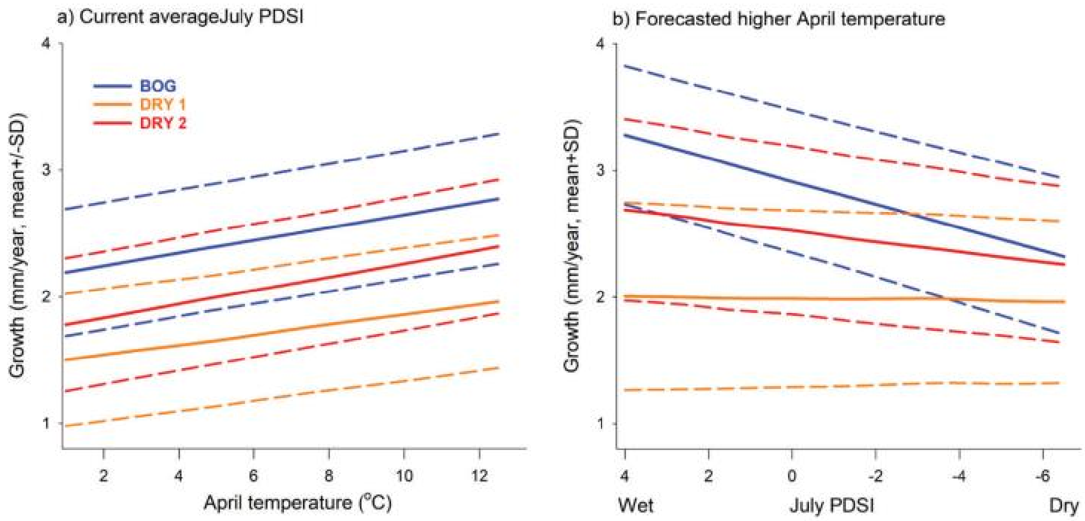

Figure 4. Radial growth predictions of *Pinus banksiana* Lamb. (a) Predicted growth with July PDSI of 0, for April's mean temperature. (b) Growth predictions under April's highest temperature in response to PDSI of July. Solid lines show mean growth, and the dotted shows ±2 standard deviations (McCollum and Ibanez).

As shown in figure 4, on the left side it shows that the bog site has the highest growth possibility with the warmer spring temperatures in April and no drought stresses throughout the summer (McCollum and Ibanez 2020). On these sites the jack pine all has positive responses to the higher spring temperatures in April, but the bog site has the best response to these temperatures (McCollum and Ibanez 2020). Shown on the right side of figure 4, there is a negative response to drought in the environment, but the bog is the most susceptible to this climate stressor (McCollum and Ibanez 2020). None of the sites shown above increase in growth as drier temperatures occur, but Dry 1 and Dry 2, are affected less than that of the big site (McCollum and Ibanez 2020).

METHODS AND MATERIALS

SPECIES STUDIED

Pinus banksiana Lamb. was the focal species of this study to help determine the effects from climate change on its productivity in the forest landscape. This was accompanied by height, dbh and other metrics through data collection of each tree within the plot areas studied. The data was collected through different types of sampling plots such as, permeant growth plots (PGP), and permeant sample plots (PSP). The stands studied were selected bas on different conditions that they represent, such as *Pinus banksiana* Lamb. dominated and the plots were located (semi) randomly within selected stand conditions. The data was collected by the Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) and ranges from 1983-2018.

STUDY AREA

The study was conducted in the province of Ontario throughout the boreal forest areas, from the western side of the province to Sudbury and surrounding areas. All the plots assessed by the Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) had GPS locations to go with them, so a point map was created in ArcGIS Pro (Figure 3).

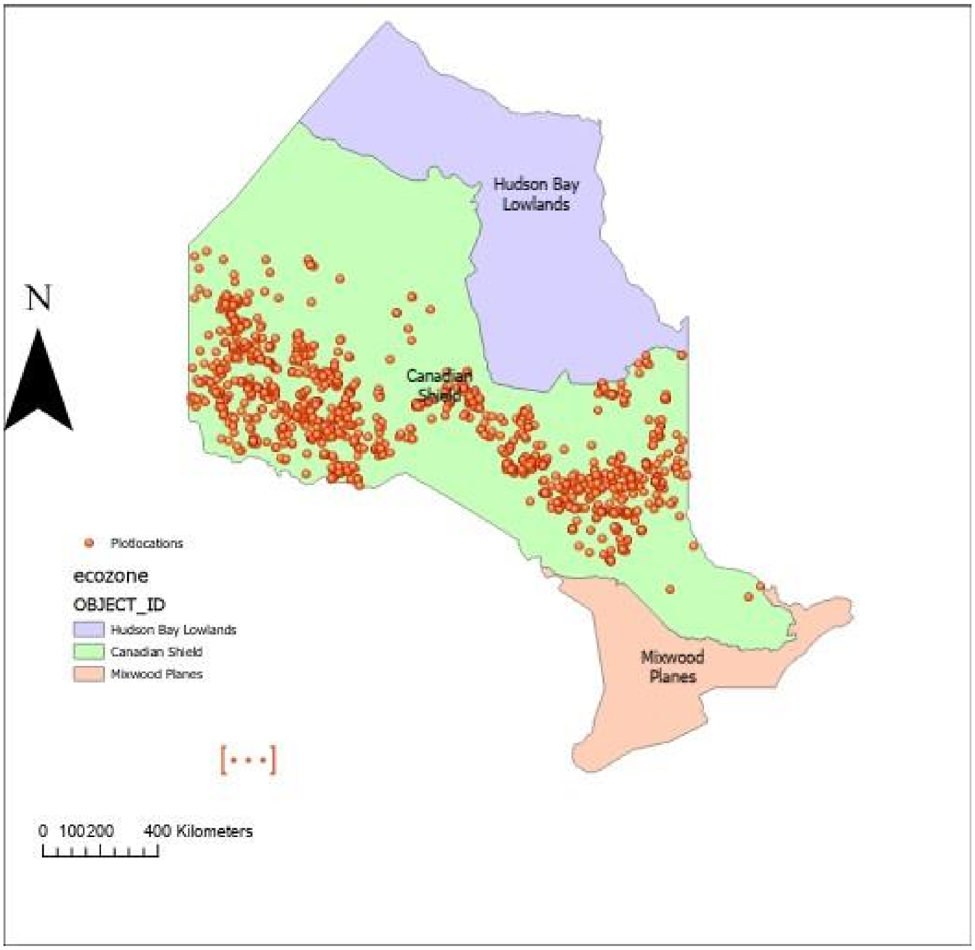

Figure 5. Plot locations in the ecozones of Ontario.

DATA METRICS

There were many different metrics examined at each plot; height, ecosite, dbh, age (field and office age), soil type name, moisture regime, tree status (alive or dead), species code and abbreviation. Within this data some was not recorded or was irrelevant due to difference in species, this was excluded and taken out of during interpretation of the data. The base data given had 452,555 different trees that were studied throughout all the plots. After filtering out species to only study Pj, clearing out any missing data in age, soil type, moisture regime, any dead trees, and any missing DBHs and heights. The remaining amount of data is 196,105 different trees.

SPSS

The statistical software SPSS made by IBM, was used for all data analysis during this project. It was used for a bivariate correlation test, multiple ANOVA tests and multiple Tukey's Post hoc tests for the ANOVA tests. All these tests were done to determine significance of the data and find similarities and variance within the data. All the ANOVA tests used a confidence level of 95% or 0.05 confidence level.

EXCEL

Microsoft excel was used to filter and format the data before going into SPSS for analysis. It was also used to make graphs to visualize the filtered data, such as dbh and height distributions for different data points throughout the moisture regimes. Average dbh and height data for each plot were calculated as well, so that they could be brought into ArcGIS Pro for mapping. Estimated total volume was done by using two different calculations, one for the volume of the stump and then for the stem a taper equation was used. These two volumes were then added together to find the estimated total volume of each tree, they then were averaged per moisture regime. Mean annual increment was also calculated by using the DBH and field age of each tree and dividing them to gain cm/year, these where then also averaged per moisture regime. Mean annual increment and estimate total volume were also used for ANOVA testing in SPSS.

STATISICAL ASSUMPTIONS

For each test there are statistical assumptions that happen while conducting the test. Before testing began, some statistical assumptions that were made is that all the data collected is correct, the data is normally distributed throughout the data set. For Pearson's correlation coefficient (PCC) there are four main assumptions made, (1) each variable is continuous and not ordinal, (2) each single piece of data has a secondary related piece of data, for every field age (VAR00003) it has a corresponding office age (VAR00004). (3) Absence of outliers for either variable, and lastly (4) Linearity, which means that the shape of the data on a scatter plot has a straight relationship, and the trend line does not curve.

ANOVA tests have three main assumptions that are made for testing, (1) the data is normally distributed, (2) The cases being tested are independent of each other, and lastly (3) the variance among the groups should be approximately equal.

Assumptions made for the box and whisker plots made are that all number of points in each moisture regime as well as soil type are of equal size. Some other assumptions made for the bar graphs of mean annual increment and average total estimated volume per moisture regime, has the same number of trees in each moisture regime being tested.

RESULTS

DATA ANALYSIS

The first test that was done was a bivariate correlation between field age data and the office age data (Table 1), other preliminary tests that were conducted were two ANOVA tests for field age and dbh (Table 2) and field age and height (Table 3). These tests were conducted for the basis of other testing and allow for basic knowledge of as the tree gets older the taller it grows in height, and the dbh increases while aging to test for anomalies.

Table 1. Bivariate Pearson correlation for field age and office age.

Correlations

		VAR00003	VAR00004
VAR00003	Pearson Correlation	1	.985**
	Sig. (2-tailed)		.000
	N	1472	1472
VAR00004	Pearson Correlation	.985**	1
	Sig. (2-tailed)	.000	
	N	1472	1472

**. Correlation is significant at the 0.01 level (2-tailed).

This test was used to determine if the field age can be used instead of the office age. This was done because of missing data in both fields, the field age data was the most complete out of the two. From this test since VAR00004’s (Office Age) correlation value is .985 it is almost perfectly correlated which means the Field Age can be used in place of the office age. This is also further confirmed by the significance value of < 0.001 because this test is significant at the 0.01 level. This data set follows the statistical assumptions that are set by using PCC, which can be confirmed by coefficient values of 0.985 which is a very strong positive linear relationship between the values analyzed. It also follows the statistical assumption (2) because as shown above, the number of data points tested for in each variable is the same, 1472.

Table 2. ANOVA test results for field age and dbh.

Tests of Between-Subjects Effects

Dependent Variable: DBH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2558525.153[a]	115	22248.045	1226.294	.000
Intercept	2531751.257	1	2531751.257	139548.069	.000
FieldAge	2558525.153	115	22248.045	1226.294	.000
Error	3555731.027	195989	18.143		
Total	28657559.160	196105			
Corrected Total	6114256.180	196104			

a. R Squared = .418 (Adjusted R Squared = .418)

This test was conducted to observe the significance between field age and dbh of the tree. It is proven to be significant because of the reported significance value of <0.001. A post hoc test was also completed as well to look for similarities and differences within the different ages found throughout the plots but could not be exported due to processing limitations. This ANOVA test also shows a large F-value which means there is a high amount of variation sample means that is relative to the variation within the sample. This is good because the higher the F-value of 1226.294 the lower the corresponding significance value of <0.001, which is shown in table 2 above and further confirms that DBH of the tree is dependant on the age of the tree. The mean square error (MSE) for this test shows a value of 18.143 which is a low value and shows a close relation in the data.

Table 3. ANOVA test results from field age and height.

Tests of Between-Subjects Effects

Dependent Variable: HtTot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3749317.238[a]	115	32602.759	6965.292	.000
Intercept	2355966.270	1	2355966.270	503331.453	.000
FieldAge	3749317.238	115	32602.759	6965.292	.000
Error	917374.567	195989	4.681		
Total	27748794.370	196105			
Corrected Total	4666691.805	196104			

a. R Squared = .803 (Adjusted R Squared = .803)

This test was done to find if there is significance between the height of the tree and the age. With the reported significance value of <0.001 height is dependant on the age of the tree. A post hoc test was also conducted to look at which ages differ or are similar with height as the dependant factor but could not be exported due to program and processing limitations. These ANOVA test results also shows a large F-value of 6,965.292 and a low significance value of <0.001 which further shows that age is a statistically significant parameter for height estimation. The MSE value of 4.681 which is extremely low, showing an extremely small amount of error in the data, this means that height and age are corelated and the height is dependant on the age of the tree.

Table 4. ANOVA test results from plot and dbh interaction

Tests of Between-Subjects Effects

Dependent Variable: DBH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3966497.320[a]	1147	3458.149	313.904	.000	.649
Intercept	11428407.091	1	11428407.091	1037382.735	.000	.842
PlotName	3966497.320	1147	3458.149	313.904	.000	.649
Error	2147758.861	194957	11.017			
Total	28657559.160	196105				
Corrected Total	6114256.180	196104				

a. R Squared = .649 (Adjusted R Squared = .647)

This ANOVA was conducted to show if there was significance between the plots study and the DBH of the trees in them. The significance value determined of <0.001 for *Plot Name*, shows that *DBH* is dependant on location. A post hoc test was also conducted so show which plots are statistically different and statistically similar but could not be exported out of SPSS because of processing limitations and program limitations. Table 4 shows that there is a large amount of variance by the 0.649 partial Eta Squared value, but the data is still significant because of the reported significance value of <0.001 and a large F-value of 313.904. The MSE value of 11.017 shows a small amount of variance between the data and shows that the DBH and plot are corelated. This also further confirms the reported significance value of <0.001, and DBH being dependant on the plot.

Table 5. ANOVA test results for Plot and height interaction

Tests of Between-Subjects Effects

Dependent Variable: HtTot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4361862.097[a]	1077	4050.011	2591.157	.000
Intercept	9444514.341	1	9444514.341	6042505.871	.000
PlotName	4361862.097	1077	4050.011	2591.157	.000
Error	304829.708	195027	1.563		
Total	27748794.370	196105			
Corrected Total	4666691.805	196104			

a. R Squared = .935 (Adjusted R Squared = .934)

These test results report a significance value of <0.001, which shows that height is dependant on the plot. A post hoc test was also completed for this interaction showing the significance between and similarities between plots but could not be exported due to program and processing limitations. The MSE value of 1.563 shows that this ANOVA shows there is very minimal variance for the interaction between *height* and *plotname* variables. The significance value of <0.001 is further confirmed by the F-value of 2591.157.

SOIL TYPE TESTING

Table 6. ANOVA test results for DBH and Soil type.

Tests of Between-Subjects Effects

Dependent Variable: DBH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	123782.588[a]	9	13753.621	450.218	.000
Intercept	7123727.471	1	7123727.471	233191.469	.000
SoilTypeName	123782.588	9	13753.621	450.218	.000
Error	5990473.592	196095	30.549		
Total	28657559.160	196105			
Corrected Total	6114256.180	196104			

a. R Squared = .020 (Adjusted R Squared = .020)

This ANOVA test uses a confidence level of 95% or 0.05, and the results show a significance level of <0.001 which shows that DBH size is dependant on the type of soil in the site. A post hoc test was also conducted with these parameters using Tukey's HSD to show the variance and similarities within the plots (APPENDIX I). A box and whisker plot was made to visualize the productivity of DBH in the different soil types (Figure 4). The MSE value of 30.549 shows there is a fair amount of variance of DBH growth depending on the soil type.

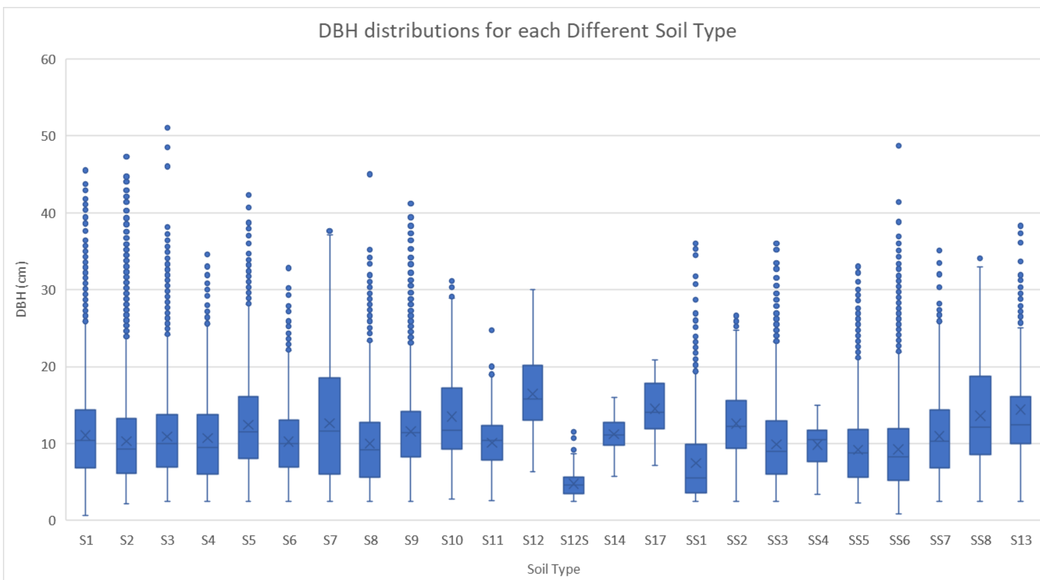

Figure 6. Box and Whisker plot for the DBH distributions for each soil type.

The soil type S12, has the highest mean DBH of 16.45 cm which means it is high of high productivity for Pj diameter growth. Soil type S17, SS2, S13, and SS8 have mean DBH's of 14.53cm, 12.6cm, 12.4cm, 12.1cm, respectively. These four sites are the next most productive for diameter growth of Pj. Soil type S12S and SS1 have the lowest productivity of 4.76cm and 5.5cm respectively for their mean DBH and are by far the least productive soils studied. Soils like

S12S and S14 likely have less amounts of trees that were found on them causing the data to be slightly skewed to having smaller distributions. S11 and SS4 also show the possibility of smaller sample sizes because of their smaller sized distributions.

Table 7. ANOVA test results for height and soil interaction.

Tests of Between-Subjects Effects

Dependent Variable: HtTot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	98010.916[a]	9	10890.102	467.420	.000
Intercept	7035616.465	1	7035616.465	301979.771	.000
SoilTypeName	98010.916	9	10890.102	467.420	.000
Error	4568680.888	196095	23.298		
Total	27748794.370	196105			
Corrected Total	4666691.805	196104			

a. R Squared = .021 (Adjusted R Squared = .021)

This ANOVA was done to test the statistical significance between the soil type and the heights of the trees. This test shows a significance level of <0.001 which means that the heights are dependant on the type of soil on the site. A Tukey's HSD post hoc test was also conducted to observe the soil type similarities and differences (APPENDIX II). These results show a MSE value of 23.298 which shows slight error in the data. The dependence of height on the soil type is further by the F-value of 467.420. A box and whisker plot was also made to visualize the productivity of height for the different soil types (Figure 5).

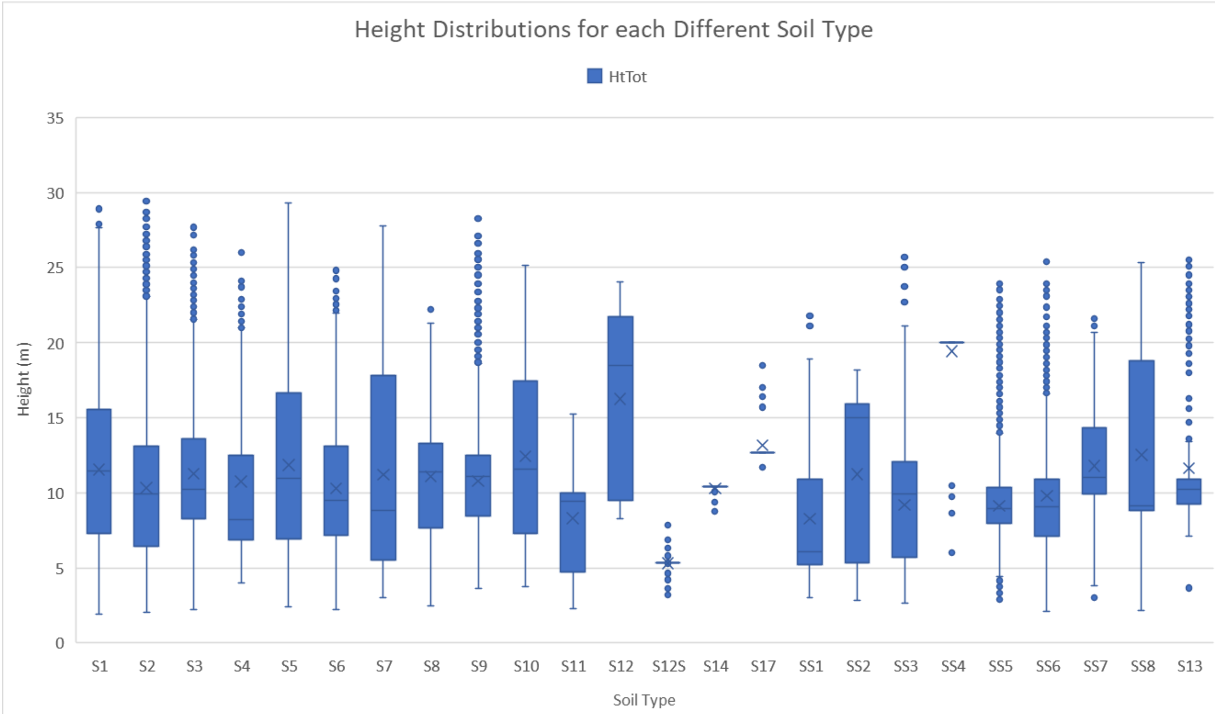

Figure 7. Box and Whisker plot for the height distribution for the different soil types studied.

Soil type S12 has the highest mean height of 18.51m, inferring this is the highest productivity site. Soil types S1, S5, S8, S10, and SS2 are the next closest in productivity with mean heights of, 11.47m, 10.98m, 11.09m, 11.6m, 14.97m, respectively. While the lowest production sites are S12S and SS1 with mean heights of 5.33m and 6.1m, respectively. For the soils S12s, S14, S17, SS4 shows that there are less trees that were surveyed on these soils. For soil types S2, S3, S9, SS5, SS6, S13, there are large amounts of outliers in data, which can explain the MSE value of 23.298.

MOISTURE REGIME TESTING

Table 8. ANOVA test results for dbh and moisture regime interaction.

Tests of Between-Subjects Effects

Dependent Variable: DBH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	73253.062[a]	7	10464.723	339.695	.000
Intercept	805969.652	1	805969.652	26162.581	.000
MoistRegimeCode	73253.062	7	10464.723	339.695	.000
Error	6041003.118	196097	30.806		
Total	28657559.160	196105			
Corrected Total	6114256.180	196104			

a. R Squared = .012 (Adjusted R Squared = .012)

This ANOVA shows that the DBH of the trees is dependent on the SMR they are on, because of the significance level of <0.001 observed from this test, this is further confirmed by the large F-value of 339.695. A Post Hoc test was also conducted for this to evaluate the statistical similarities and differences for each moisture regime (APPENDIX III). A box and whisker plot was created along with this ANOVA in excel to show the different distribution of DBH's and productivity of each moisture regime (Figure 6). The MSE value of 30.806 shows a fair amount error in the data which explains the outliers seen below.

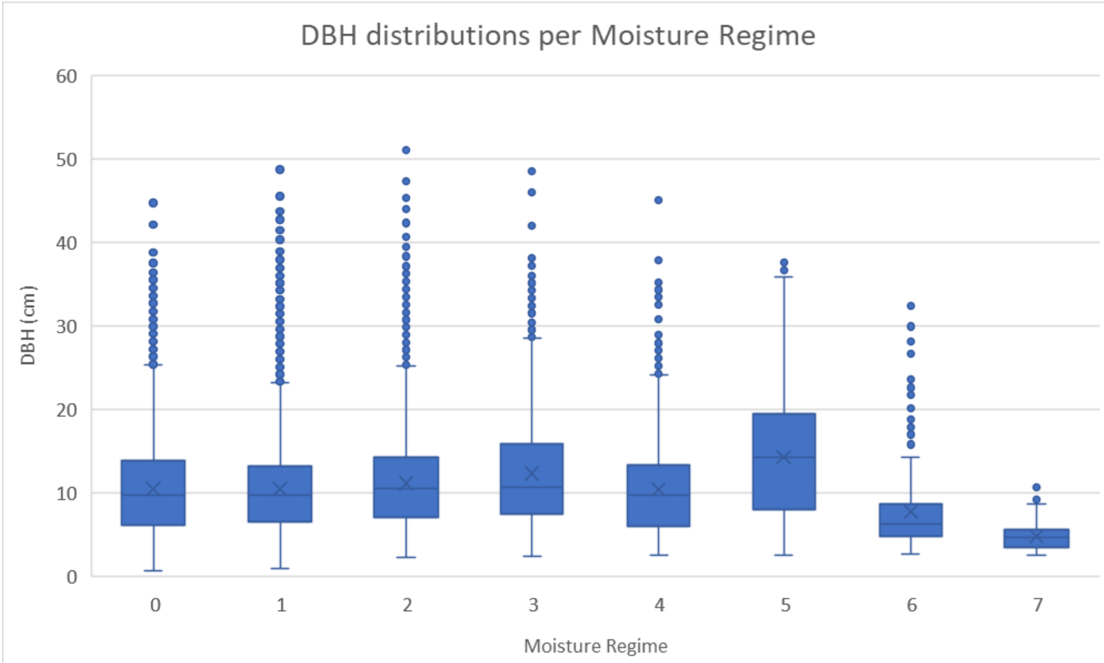

Figure 8. Box and whisker plot for DBH distributions for each moisture regime

This graph was made to see which moisture regime was the most productive for *Pinus banksiana* Lamb. As this graph shows the most productive on average moisture regime is MR 5 which is a moist site, it has an average dbh of 14.3 cm which is higher than the rest of the SMRs shown (Sims *et al.* 1996; Ontario Institute of Pedology 1985; Sims *et al.* 1989). Moisture regime 3 which is classified as a very fresh site, is the next most productive after moisture regime 5 (Sims *et al.* 1996; Ontario Institute of Pedology 1985; Sims *et al.* 1989). SMRs 0-2 which are dry, moderately fresh, and fresh respectively, are not as productive as the very fresh (3) and the moist (5) SMR (Sims *et al.* 1996; Ontario Institute of Pedology 1985; Sims *et al.* 1989). The soil moisture regime of 6 and 7, very moist and moderately wet respectively, are by far the least productive which the average DBH of 6 being 6.3cm and the average of 7 being

4.6cm (OMNRF 2021). This was also done for the heights of the trees studied to determine the most productive SMRs as well.

Table 9. Average age in each moisture regime.

Moisture Regime	Average of FieldAge
0	28.36
1	25.10
2	25.92
3	30.60
4	26.58
5	35.43
6	34.32
7	17.00

This table shows the average age per moisture regime, to show the differences between the ages in each moisture regime. This table shows that there is a 10-year age difference between moisture 5 and moisture 2 (25 years). This age difference can cause a large amount of variance in testing, which can be observed by the DBH sizes of the trees in the moisture regime.

Table 10. ANOVA test results for height and moisture regime.

Tests of Between-Subjects Effects

Dependent Variable: HtTot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	27736.835[a]	7	3962.405	167.498	<.001
Intercept	802145.806	1	802145.806	33908.151	.000
MoistRegimeCode	27736.835	7	3962.405	167.498	<.001
Error	4638954.970	196097	23.656		
Total	27748794.370	196105			
Corrected Total	4666691.805	196104			

a. R Squared = .006 (Adjusted R Squared = .006)

This ANOVA has a significance value of <0.001 which means the height of the trees is also dependant on the moisture regime of the site, which is further confirmed the F-value of 167.498. A post hoc test was also conducted to provide observations on the similarities and differences between each moisture regime with the height as the dependant variable (APPENDIX IV). A box and whisker plot was created as well to show the distributions and productivity of height in the different moisture regimes (Figure 9). The MSE value of 23.656 shows a small amount of error in the data, which can be seen below by looking at the outliers of each moisture regime.

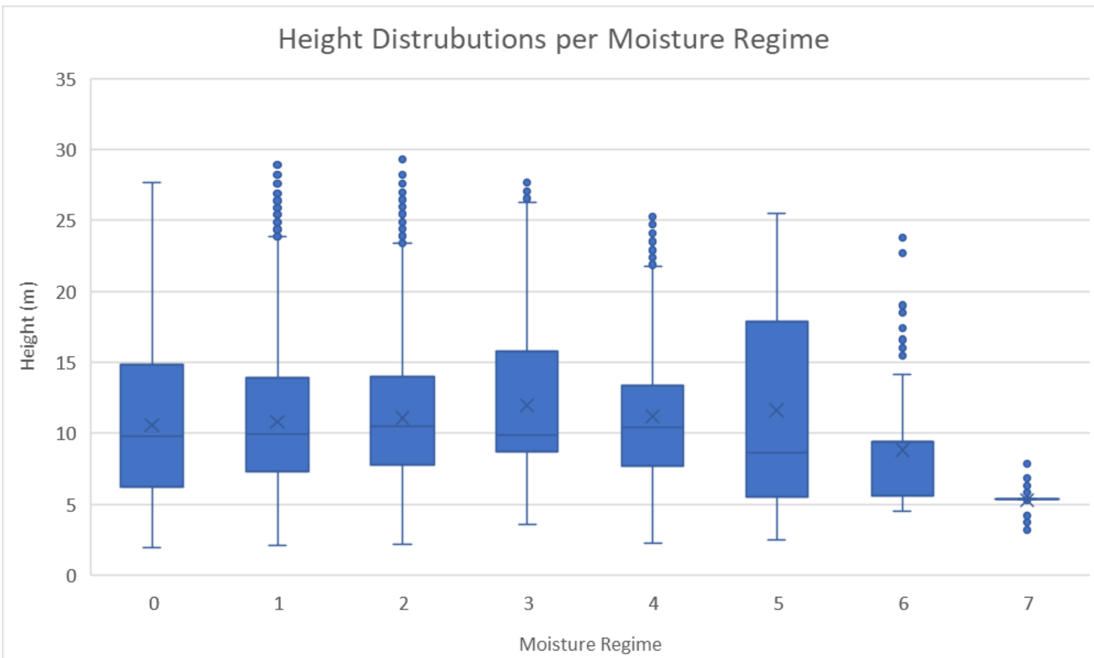

Figure 9. Box and Whisker plot for height distributions of each moisture regime.

Unlike the figure 4, SMR 5 has the lowest average height of 8.6m which is lower than SMRs 0-4, but a wider range of heights as well. SMR 6 and 7 also are the least productive for heights with their mean heights being under 10m tall. Moisture regimes 0 and 5 are the only regimes that do not have outliers, while moisture regimes 1, 2, and 7 have most of the outliers. Moisture regime 7 also shows a small standard deviation with a few outliers on the upper and lower limit. This can be because of the lack of trees left in this moisture regime. Figure 8 shows the average height and DBH for each plot, sorted west to east.

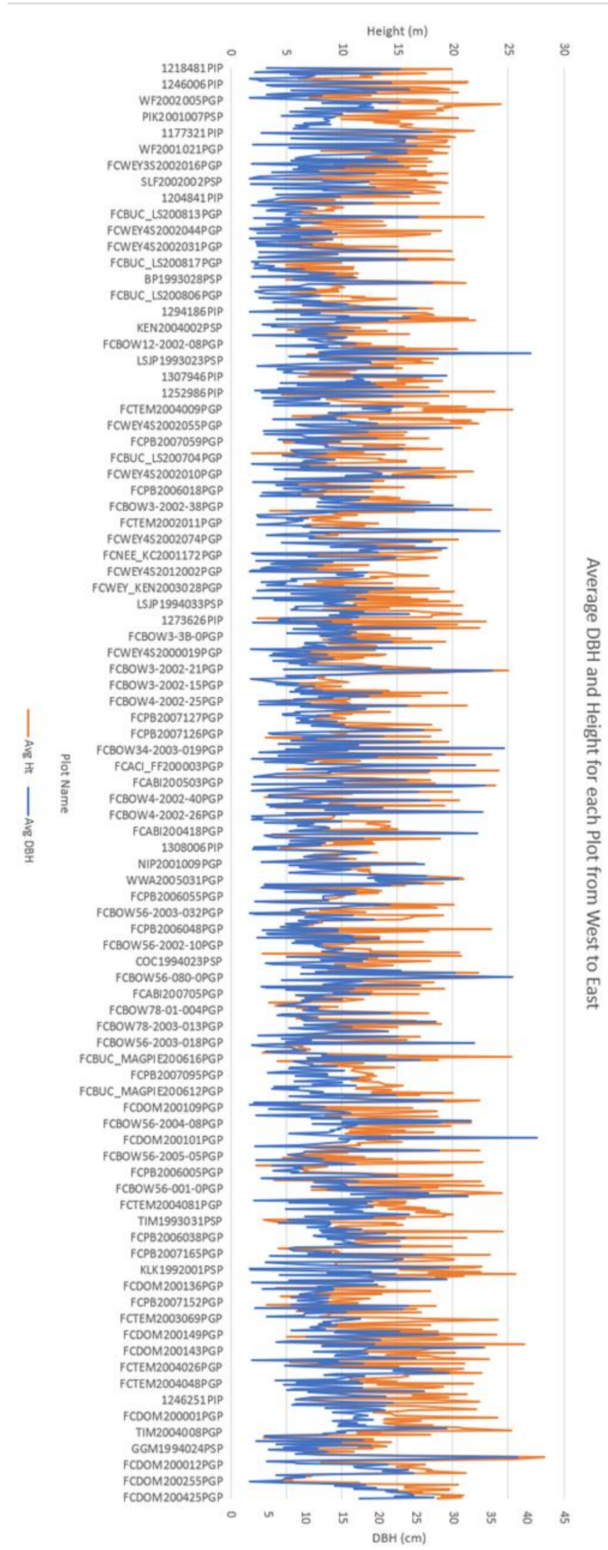

Figure 10. Average height and DBH line graph for each plot sorted from west to east.

ARCGIS PRO MAPS

Figure 11 shows the average DBH classes map of Ontario made in ArcGIS pro; each plot has an associated colour depending on the DBH range.

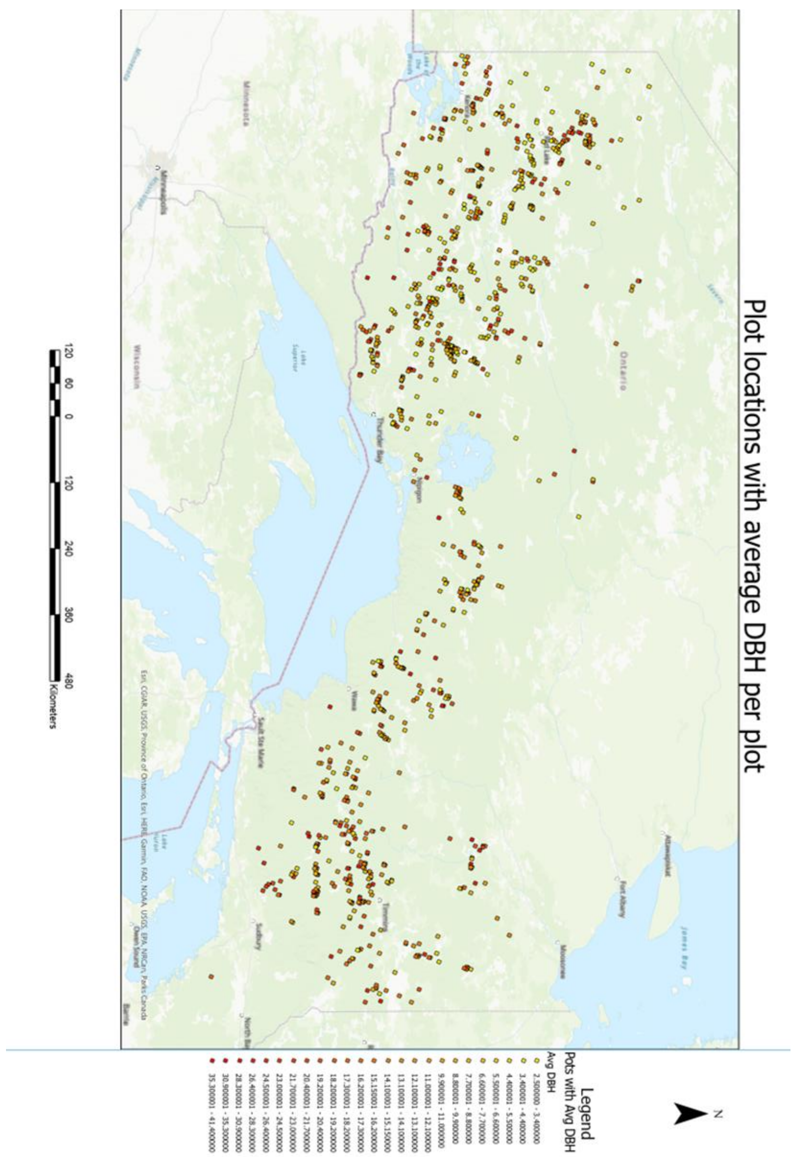

Figure 11. Map of Ontario showing average DBH classes as assorted colours for each plot.

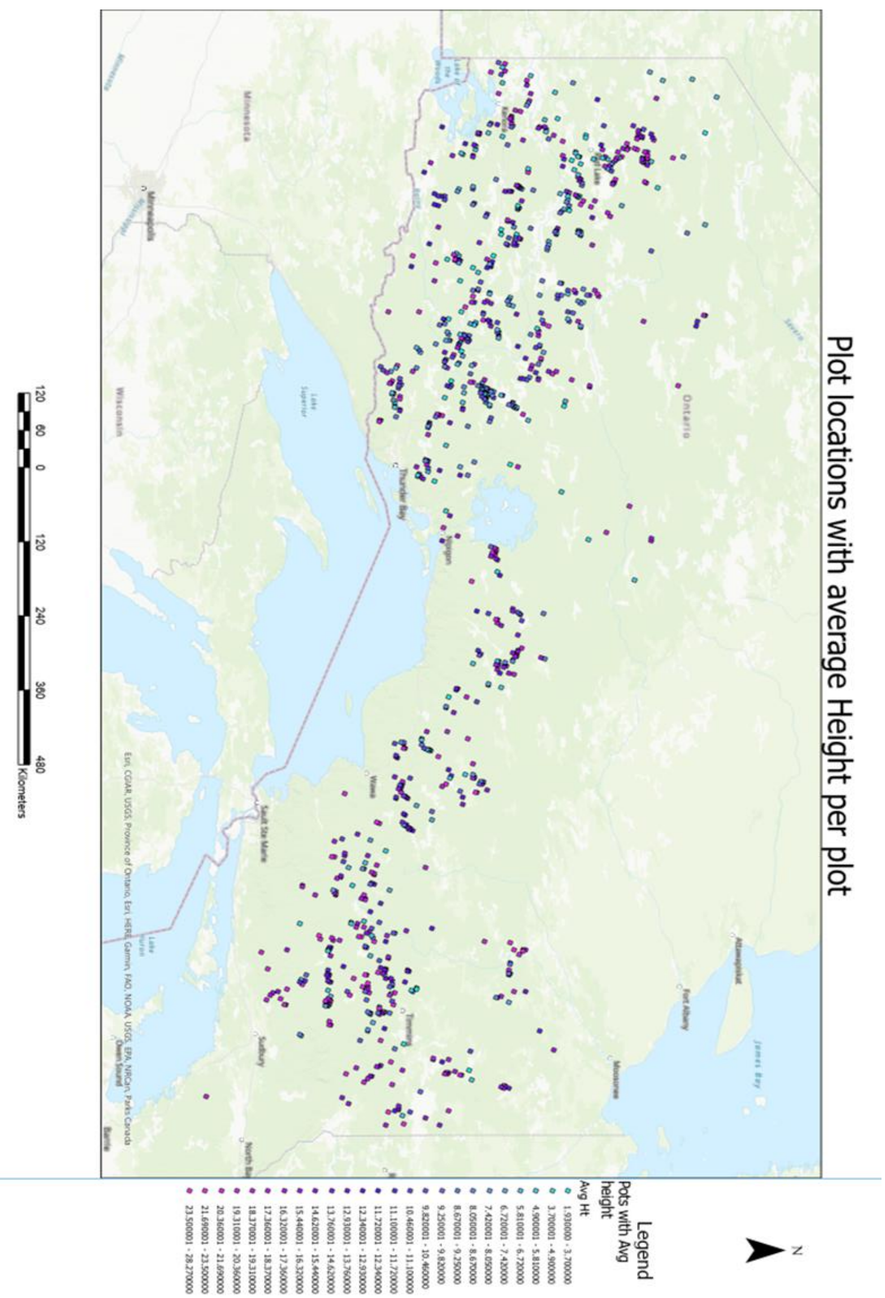

Figure 12. Map of Ontario showing average height classes as assorted colours, for each plot.

The tallest range for the trees on this map is shown by the brightest shade of pink, and the range is 23.5-28.27m tall.

VOLUME TESTING

Table 11. ANOVA test results for Total estimate volume (m3) and moisture regime

Tests of Between-Subjects Effects

Dependent Variable: Total estimate Volume (m3)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	18.608[a]	7	2.658	304.192	.000
Intercept	31.166	1	31.166	3566.468	.000
MoistRegimeCode	18.608	7	2.658	304.192	.000
Error	1713.640	196097	.009		
Total	2546.859	196105			
Corrected Total	1732.248	196104			

a. R Squared = .011 (Adjusted R Squared = .011)

This ANOVA test was conducted to determine the significance for the estimated total volume that was calculated to each moisture regime. With the significance value of <0.001, which proves that the volume of the trees is linked to the moisture regime of the site and is further confirmed by the large F-value of 304.192 shown above. Tukey’s post hoc test was also conducted for this test and can be found in the APPENDIX V. The MSE value of 0.009 shows that there is basically no error in the data, and that total estimate volume is a good indicator for productivity of each moisture regime. The average estimate volume for each moisture regime were complied into figure 13.

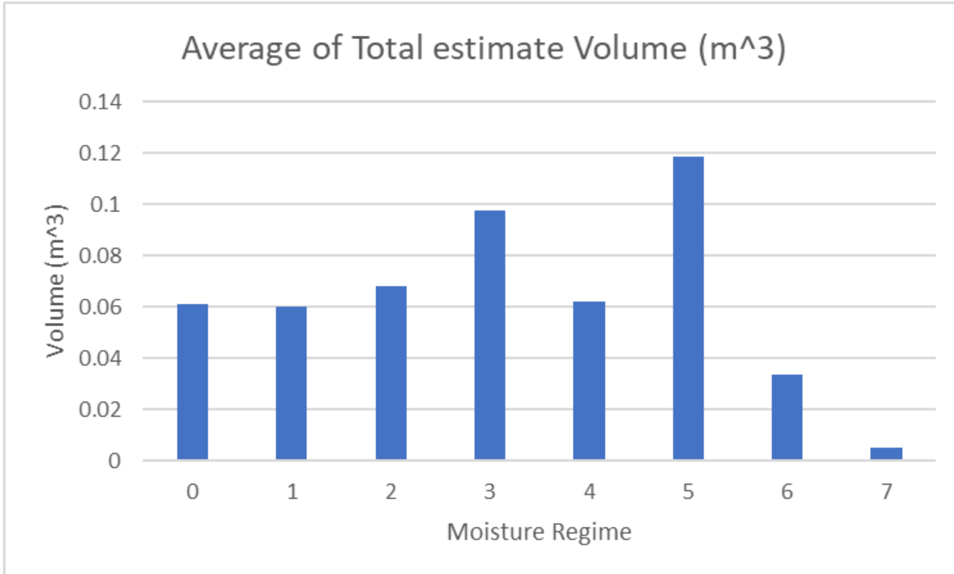

Figure 13. Bar graph of the different estimate total volume for each moisture regime.

This figure shows the average of estimated total volume per moisture regime, with moisture regime 5 and 3 having the highest estimated volume out of the 7 regimes. Moisture regime 5 has an average value of 0.12m^3 and moisture regime 3 has a reported value of 0.09m^3. While moisture regimes 6 and 7 have the lowest values of 0.03m^3 and 0.005m^{3,} respectively. Moisture regime 0 and 1 have almost the exact same average volumes of 0.061m^3 and 0.060m^3. Moisture regime 4 is also close to the volumes of moisture regimes 0-2 with the value of 0.062m^3.

MEAN ANNUAL INCREMENT

Table 12. ANOVA test results from mean annual increment and moisture regime.

Tests of Between-Subjects Effects

Dependent Variable: Mean Annual Increment (cm/year)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	68.420[a]	7	9.774	85.695	<.001
Intercept	1652.523	1	1652.523	14488.354	.000
MoistRegimeCode	68.420	7	9.774	85.695	<.001
Error	22366.576	196097	.114		
Total	77371.925	196105			
Corrected Total	22434.996	196104			

a. R Squared = .003 (Adjusted R Squared = .003)

This ANOVA test was conducted to observe the significance between mean annual increment and moisture regime. The reported significance level of <0.001 shows that there is significance between these two variables, which means that yearly growth is dependant on the moisture regime, which is further confirmed by the corresponding F-value of 85.695. The MSE value 0.114 is exceptionally low as well, which shows that there is an extremely small amount error in the data, this shows that this data set is a good indicator for productivity as well. The average mean annual increment was put into a bar chart to visually show the differences for each moisture regime (Figure 14). The post hoc test for this ANOVA test can be found in APPENDIX VI.

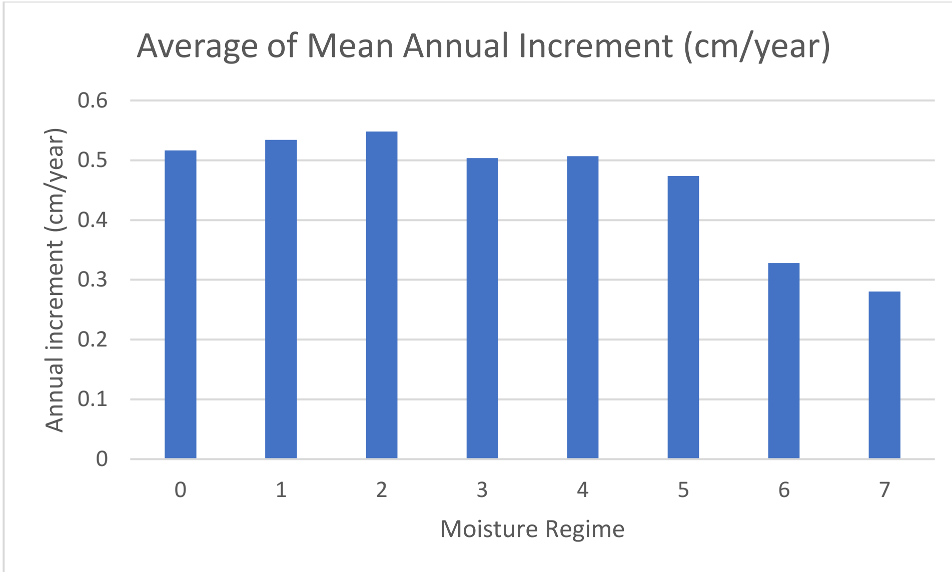

Figure 14. Bar graph showing the average mean annual increment for each moisture regime.

This graph shows the moisture regimes 0-2 have the highest mean annual increment out of all the moisture regimes with the amount of 0.52cm/year, 0.53 cm/year, and 0.54 cm/year, respectively. While moisture regimes 3 and 5 have preformed worse in radial growth per year with the values of 0.50cm/year and 0.47cm/year, respectively. Moisture 6 and 7 show the lowest mean annual growth of 0.33 and 0.28 cm/year. Moisture regime 4 has a reported mean annual increment of 0.51cm/year which is very close to moisture regime 3's mean annual increment.

DISCUSSION

SOIL TESTING

With Figure 4 and Figure 5 in mind, this shows that the most productive soil type for mean height and mean DBH is S12 which is a deep organic soil (Sims *et al.* 1989). This meaning if larger DBH and height and overall, more productive Pj is wanted, planting this species in this type of soil will let that happen. But it must be kept in mind that DBH size is dependent on density of the plot (Herbert *et al.* 2016). Herbert *et al.* (2016) found that spacing of the trees have a large effect on DBH sizes and allows for rapid and large DBHs and they also found that the spacing in a site does not have an impact on height. So, if the density of the sandy soils is higher than that of S12, or the other soils, DBH will be largely impacted by this (Herbert *et al.* 2016). Knowing that competition in Pj's preferred niche will be fierce in the drier and sandier soils, moving them to gain dominance in the soil type S12, may allow for a more productive tree. The trees found on the S1 soil type which is Dry/Coarse Sandy soil, has trees that are over 10m tall with a small amount variation and outliers, these heights can possibility be because of competition for these soils (Sims *et al.* 1989). The observed lower mean heights for the soil types SS1-SS4 which are classified as very shallow, and SS5-SS9, which are shallow to moderately deep soils have low mean heights. This is further confirmed by Beland and Bergeron (1996), who found that with shallow sites, and sites with heavy coarse fragments that jack pine responded poorly in height growth. The MSE error values shown in tables 6 and 7 can possibly be explained by the age variance of the trees found on the different soil types, because of the relationship that DBH and height have with age.

MOISTURE REGIME

The moisture regime results show that for DBH of jack pine it is most productive on SMR 5(moist) but once again this is influenced by spacing on the sites studied (Beland and Bergeron 1996). Figure 7 shows I much wider range but lower mean height in SMR 5, while 0(dry), 1(moderately fresh), 2(fresh), have higher mean heights and a closer grouping than that of SMR 5. Table 9 shows the average age on each moisture regime are relatively close, but there is a 10-year age gap between moisture regimes 1 (25 years) and 5 (35 years). This shows that the drier sites are more productive in height growth because of the ecology of the site. Figure 7 also shows that moisture regimes 6 and 7, which are very moist and moderately wet respectively, have extremely low mean heights on the site (Sims *et al.* 1996; Ontario Institute of Pedology 1985; Sims *et al.* 1989). This is because of water content in the soil for these regimes. The mean DBHs for moisture regimes 0-2 are close in size which could mean that these sites were planted with a relatively similar spacing because of this. The MSE values shown in table 8 and 10 are possible because of the age of trees found in different plots for the moisture regimes. As it is known DBH and height growth of trees is dependant on the age of the tree, so if there is a large variance in ages found on the same moisture regime there will be much taller trees which are shown by the outliers in figures 8 and 9.

ESTIMATE TOTAL VOLUME

For this testing estimated total volume of the tree was used because of lack of further measurements on the tree. There is a lack of measurements for taper and a measurement below ground, which did not allow for the exact merchantable volume of the trees to be found. The total estimated volume for each moisture in figure 11, shows that moisture 5 and 3 have the highest estimated volume. This follows suit with the results from looking at mean DBH's for each moisture regime, as shown in figure 6. With the spacing effect on DBH that was discussed above in the soil testing results portion of the discussion. Figure 11 also shows lower estimated total volume in moisture regimes 0-2, even though they had higher mean heights. This also coincides with Herbert *et al.* (2016), findings of tree spacing effect on DBH, causing smaller DBH's in dense stands and larger DBH's in sparse stands. The results from this test could also be from the age of the trees in the plot, as observed in the testing results from field age and DBH and height, and is commonly known, these measurements are related to the age. In table 10, it shows that there is only a seven-year age difference between moisture regime 5 and 0. This shows that the age difference between the trees doesn't account for the large gap in estimated volume between these two moisture regimes.

MEAN ANNUAL INCREMENT

Mean annual increment is a key indicator of productivity of a site, this proven by the small value of MSE shown in table 12. The results from the testing done for mean annual increment show that moisture regime 0-2 have the highest cm/year average, with moisture regime 2 having the largest growth per year. The values reported for these moisture regimes are extremely close in value, while moisture regimes 3-5 are close but less than the moisture regimes 0-2. While moisture regimes 6 and have the lowest mean annual increments which can be attributed to the wetness of the site, which is a growth limiting factor (Beland and Bergeron 1996). The results shown in figure 13, show that even though moisture regime 5 has a higher mean DBH than that of moisture regimes 0-2, the productivity on these drier sites is higher. Also, shown in figure 14 for moisture regimes 6 and 7 the productivity on these sites is extremely poor which can change as the sites become drier due to climate change.

CLIMATE CHANGE

With the climate in Ontario warming the available soils for jack pine, this can make suitable sites such as moisture regimes 0-2 unsuitable for productive growth. The results if figure 7 show high mean heights for the soil moisture regimes 0-2, which could have a significant impact if these soils are to get warmer and drier (Reich *et al*. 2018). Reich *et al.* (2018) found that climate change will affect photosynthesis of Boreal tree species through the change of the soil moisture regime. With climate change it is extending growing degree days in the Boreal for some sites, particularly the colder and wetter sites (Riech *et al*. 2018). The warming causes stimulation for photosynthesis in moist soils while in dry soils it shows the opposite and causing less productivity in photosynthesis (Riech *et al*. 2018). With climate change the boreal has become more vulnerable to effects such as temperature-induced drought stress, which in drier sites the productivity can be greatly impacted (Ruiz-Perez and Vico 2020; Barber *et al.* 2000; Beck and Goetz 2011). Price *et al.* (2013) also predicts that with climate change the growing season may be longer, but it will also be drier which can be devastating to future growth on dry sites such as ones studied in this paper on moisture regime 0. With the drying of wetter moisture regimes and increased growing degree days this is a possibility for an increasement of jack pine productivity through these moisture regimes shifts (Price *et al*. 2013)

FUTURE RECOMMENDATIONS

With the knowledge gained from this study assisted migration for jack pine can be a feasible option to help the longevity of the species in the boreal. I believe future studies for assisted migration of this species is warranted, especially to have the least environmental impact on the future areas that could sustain jack pine. Dry sites, or soon to become dry sites should be assessed with jack pine in mind for future migration of the species, because of the growth lag of sandy/drier sites, possibly finding a faster establishing site such as a fresh site for jack pine might be the most feasible to begin further migration trials.

I recommend for studies on the climate change impacts on sites with the moisture regime of 0, for a way to try rehabilitating these areas for further plant growth. With the drying in these sites there is cause for concern of them becoming completely inhospitable for different species.

For similar study in the future, I would recommend getting representative samples from each moisture regime and to start organizing data and test at the plot level for the influence of all factors. Doing this will allow for better insight into key ecosystem components that influence the growth of *Pinus banksiana* Lamb. I also believe testing by age class would be beneficial because it will allow more accurate testing for productivity with limited amount of variance based on age of the tree. Also, collecting water availability data would be beneficial to this because it will allow for more understanding of the productivity of the site. I also believe a team of analysts running the simulations would be extremely beneficial to keeping the testing results concise and organized. Also, if possible, to run global climate models in conjunction to get predications on the effects of climate change on the different age classes and moisture regimes, would be extremely because of the insight it would give to just how extensive the climate change effect will be on these different sites. Using a global climate model in conjunction with water availability will also allow for the futures of the different moisture regimes to be assessed, which will predict the future productivity of the regimes.

CONSIDERATIONS

The post hoc tests for DBH and plotname, as well as height and plotname could not be exported from SPSS due to limitations of the program and processing power. The post hoc tests for DBH and field age, as well as height and field could also not be exported due to processing power and program limitations. The data was also not tested for normalization before conducting the ANOVA tests used. Also, since the volume used to help determine moisture regime average volume was not merchantable volume, these values are only to be taken as estimates. With the measurements from the data, there was not enough information for exact merchantable volume of the species. Some of the data examined is almost 39 years old, so DBH, height, estimated total volume, and mean annual increment, will be much larger now if the plots were to be remeasured now.

CONCLUSION

From the testing that was conducted there is noticeable differences in moisture regime productivity which rejects the null hypothesis and accepts the alternative hypothesis that there are noticeable differences in productivity on different moisture regimes. The results show that the moisture regime 0-2 have the highest mean annual increment with moisture regime 2 having the largest amount of yearly growth. With the effects of climate change on these drier sites there is cause for concern for decreased productivity due to decreased water availability and more heat and water stress in these areas. The wetter moisture regimes, such as 6 and 7, will also become drier allowing for higher productivity of jack pine on sites that were previously unproductive. This will allow for better growth of already established species on these wetter MRs, and for migration of the species still within their natural range.

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APPENDICIES

APPENDIX I POST HOC TEST FOR DBH AND SOIL TYPE.

Multiple Comparisons

Dependent Variable: DBH
Tukey HSD

(I) SoilTypeName	(J) SoilTypeName	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
S1	S2	.7930*	.03559	<.001	.6804	.9056
	S3	.2188*	.05276	.001	.0519	.3858
	S4	.4141*	.12186	.024	.0286	.7997
	S5	-1.3245*	.05128	<.001	-1.4867	-1.1622
	S6	.8555*	.06282	<.001	.6568	1.0543
	S7	-1.5119*	.09520	<.001	-1.8130	-1.2107
	S8	1.0970*	.11477	<.001	.7339	1.4601
	S9	-.4762*	.07886	<.001	-.7257	-.2267
	SS	1.4430*	.03443	<.001	1.3340	1.5519
S2	S1	-.7930*	.03559	<.001	-.9056	-.6804
	S3	-.5742*	.05617	<.001	-.7519	-.3965
	S4	-.3789	.12338	.066	-.7692	.0114
	S5	-2.1175*	.05478	<.001	-2.2908	-1.9442
	S6	.0625	.06571	.995	-.1454	.2704
	S7	-2.3049*	.09713	<.001	-2.6122	-1.9976
	S8	.3040	.11637	.212	-.0642	.6721
	S9	-1.2692*	.08118	<.001	-1.5261	-1.0124
	SS	.6499*	.03945	<.001	.5251	.7748
S3	S1	-.2188*	.05276	.001	-.3858	-.0519
	S2	.5742*	.05617	<.001	.3965	.7519
	S4	.1953	.12938	.889	-.2141	.6046
	S5	-1.5433*	.06722	<.001	-1.7560	-1.3306
	S6	.6367*	.07639	<.001	.3950	.8783
	S7	-1.7307*	.10465	<.001	-2.0618	-1.3996
	S8	.8781*	.12272	<.001	.4899	1.2664
	S9	-.6950*	.09004	<.001	-.9799	-.4102
	SS	1.2241*	.05544	<.001	1.0487	1.3995
S4	S1	-.4141*	.12186	.024	-.7997	-.0286
	S2	.3789	.12338	.066	-.0114	.7692

	S3	-.1953	.12938	.889	-.6046	.2141
	S5	-1.7386*	.12878	<.001	-2.1460	-1.3311
	S6	.4414*	.13380	.033	.0181	.8647
	S7	-1.9260*	.15172	<.001	-2.4060	-1.4460
	S8	.6829*	.16470	.001	.1618	1.2039
	S9	-.8903*	.14204	<.001	-1.3397	-.4409
	SS	1.0289*	.12305	<.001	.6396	1.4181
S5	S1	1.3245*	.05128	<.001	1.1622	1.4867
	S2	2.1175*	.05478	<.001	1.9442	2.2908
	S3	1.5433*	.06722	<.001	1.3306	1.7560
	S4	1.7386*	.12878	<.001	1.3311	2.1460
	S6	2.1800*	.07537	<.001	1.9415	2.4184
	S7	-.1874	.10391	.733	-.5162	.1413
	S8	2.4214*	.12209	<.001	2.0352	2.8077
	S9	.8483*	.08918	<.001	.5661	1.1304
	SS	2.7674*	.05403	<.001	2.5965	2.9384
S6	S1	-.8555*	.06282	<.001	-1.0543	-.6568
	S2	-.0625	.06571	.995	-.2704	.1454
	S3	-.6367*	.07639	<.001	-.8783	-.3950
	S4	-.4414*	.13380	.033	-.8647	-.0181
	S5	-2.1800*	.07537	<.001	-2.4184	-1.9415
	S7	-2.3674*	.11006	<.001	-2.7156	-2.0192
	S8	.2415	.12737	.672	-.1615	.6444
	S9	-1.3317*	.09628	<.001	-1.6363	-1.0271
	SS	.5874*	.06509	<.001	.3815	.7934
S7	S1	1.5119*	.09520	<.001	1.2107	1.8130
	S2	2.3049*	.09713	<.001	1.9976	2.6122
	S3	1.7307*	.10465	<.001	1.3996	2.0618
	S4	1.9260*	.15172	<.001	1.4460	2.4060
	S5	.1874	.10391	.733	-.1413	.5162
	S6	2.3674*	.11006	<.001	2.0192	2.7156
	S8	2.6088*	.14608	<.001	2.1467	3.0710
	S9	1.0357*	.11994	<.001	.6562	1.4151
	SS	2.9548*	.09671	<.001	2.6489	3.2608
S8	S1	-1.0970*	.11477	<.001	-1.4601	-.7339
	S2	-.3040	.11637	.212	-.6721	.0642
	S3	-.8781*	.12272	<.001	-1.2664	-.4899
	S4	-.6829*	.16470	.001	-1.2039	-.1618

	S5	-2.4214*	.12209	<.001	-2.8077	-2.0352
	S6	-.2415	.12737	.672	-.6444	.1615
	S7	-2.6088*	.14608	<.001	-3.0710	-2.1467
	S9	-1.5732*	.13600	<.001	-2.0034	-1.1429
	SS	.3460	.11602	.084	-.0211	.7131
S9	S1	.4762*	.07886	<.001	.2267	.7257
	S2	1.2692*	.08118	<.001	1.0124	1.5261
	S3	.6950*	.09004	<.001	.4102	.9799
	S4	.8903*	.14204	<.001	.4409	1.3397
	S5	-.8483*	.08918	<.001	-1.1304	-.5661
	S6	1.3317*	.09628	<.001	1.0271	1.6363
	S7	-1.0357*	.11994	<.001	-1.4151	-.6562
	S8	1.5732*	.13600	<.001	1.1429	2.0034
	SS	1.9192*	.08068	<.001	1.6639	2.1744
SS	S1	-1.4430*	.03443	<.001	-1.5519	-1.3340
	S2	-.6499*	.03945	<.001	-.7748	-.5251
	S3	-1.2241*	.05544	<.001	-1.3995	-1.0487
	S4	-1.0289*	.12305	<.001	-1.4181	-.6396
	S5	-2.7674*	.05403	<.001	-2.9384	-2.5965
	S6	-.5874*	.06509	<.001	-.7934	-.3815
	S7	-2.9548*	.09671	<.001	-3.2608	-2.6489
	S8	-.3460	.11602	.084	-.7131	.0211
	S9	-1.9192*	.08068	<.001	-2.1744	-1.6639

Based on observed means.

The error term is Mean Square(Error) = 30.549.

*. The mean difference is significant at the .05 level.

APPENDIX II POST HOC TEST FOR HEIGHT AND SOIL TYPE.

Multiple Comparisons

Dependent Variable: HtTot
Tukey HSD

(I) SoilTypeName	(J) SoilTypeName	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
S1	S2	1.1679*	.03108	<.001	1.0696	1.2662
	S3	.2206*	.04608	<.001	.0748	.3663
	S4	.7361*	.10642	<.001	.3994	1.0728
	S5	-.3560*	.04479	<.001	-.4977	-.2143
	S6	1.2077*	.05486	<.001	1.0341	1.3813
	S7	.2856*	.08314	.021	.0226	.5486
	S8	.4007*	.10023	.003	.0836	.7178
	S9	.7169*	.06887	<.001	.4990	.9348
	SS	1.6233*	.03007	<.001	1.5282	1.7184
S2	S1	-1.1679*	.03108	<.001	-1.2662	-1.0696
	S3	-.9473*	.04905	<.001	-1.1025	-.7921
	S4	-.4318*	.10774	.002	-.7727	-.0909
	S5	-1.5238*	.04784	<.001	-1.6752	-1.3725
	S6	.0398	.05738	1.000	-.1417	.2214
	S7	-.8823*	.08482	<.001	-1.1506	-.6139
	S8	-.7672*	.10163	<.001	-1.0887	-.4456
	S9	-.4510*	.07089	<.001	-.6753	-.2267
	SS	.4554*	.03445	<.001	.3464	.5644
S3	S1	-.2206*	.04608	<.001	-.3663	-.0748
	S2	.9473*	.04905	<.001	.7921	1.1025
	S4	.5155*	.11299	<.001	.1580	.8730
	S5	-.5765*	.05870	<.001	-.7622	-.3908
	S6	.9871*	.06671	<.001	.7761	1.1982
	S7	.0651	.09139	.999	-.2241	.3542
	S8	.1802	.10717	.806	-.1589	.5192
	S9	.4964*	.07863	<.001	.2476	.7451
	SS	1.4027*	.04842	<.001	1.2496	1.5559
S4	S1	-.7361*	.10642	<.001	-1.0728	-.3994
	S2	.4318*	.10774	.002	.0909	.7727

	S3	-.5155*	.11299	<.001	-.8730	-.1580
	S5	-1.0920*	.11247	<.001	-1.4478	-.7362
	S6	.4716*	.11685	.002	.1020	.8413
	S7	-.4504*	.13249	.024	-.8696	-.0313
	S8	-.3353	.14383	.368	-.7904	.1197
	S9	-.0191	.12404	1.000	-.4116	.3733
	SS	.8872*	.10746	<.001	.5473	1.2272
S5	S1	.3560*	.04479	<.001	.2143	.4977
	S2	1.5238*	.04784	<.001	1.3725	1.6752
	S3	.5765*	.05870	<.001	.3908	.7622
	S4	1.0920*	.11247	<.001	.7362	1.4478
	S6	1.5637*	.06582	<.001	1.3554	1.7719
	S7	.6416*	.09074	<.001	.3545	.9287
	S8	.7567*	.10662	<.001	.4194	1.0940
	S9	1.0729*	.07788	<.001	.8265	1.3193
	SS	1.9793*	.04719	<.001	1.8300	2.1285
S6	S1	-1.2077*	.05486	<.001	-1.3813	-1.0341
	S2	-.0398	.05738	1.000	-.2214	.1417
	S3	-.9871*	.06671	<.001	-1.1982	-.7761
	S4	-.4716*	.11685	.002	-.8413	-.1020
	S5	-1.5637*	.06582	<.001	-1.7719	-1.3554
	S7	-.9221*	.09612	<.001	-1.2262	-.6180
	S8	-.8070*	.11123	<.001	-1.1589	-.4551
	S9	-.4908*	.08408	<.001	-.7568	-.2248
	SS	.4156*	.05684	<.001	.2358	.5954
S7	S1	-.2856*	.08314	.021	-.5486	-.0226
	S2	.8823*	.08482	<.001	.6139	1.1506
	S3	-.0651	.09139	.999	-.3542	.2241
	S4	.4504*	.13249	.024	.0313	.8696
	S5	-.6416*	.09074	<.001	-.9287	-.3545
	S6	.9221*	.09612	<.001	.6180	1.2262
	S8	.1151	.12757	.996	-.2885	.5187
	S9	.4313*	.10475	.002	.0999	.7627
	SS	1.3377*	.08446	<.001	1.0705	1.6049
S8	S1	-.4007*	.10023	.003	-.7178	-.0836
	S2	.7672*	.10163	<.001	.4456	1.0887
	S3	-.1802	.10717	.806	-.5192	.1589
	S4	.3353	.14383	.368	-.1197	.7904

	S5	-.7567*	.10662	<.001	-1.0940	-.4194
	S6	.8070*	.11123	<.001	.4551	1.1589
	S7	-.1151	.12757	.996	-.5187	.2885
	S9	.3162	.11877	.189	-.0595	.6919
	SS	1.2226*	.10132	<.001	.9020	1.5431
S9	S1	-.7169*	.06887	<.001	-.9348	-.4990
	S2	.4510*	.07089	<.001	.2267	.6753
	S3	-.4964*	.07863	<.001	-.7451	-.2476
	S4	.0191	.12404	1.000	-.3733	.4116
	S5	-1.0729*	.07788	<.001	-1.3193	-.8265
	S6	.4908*	.08408	<.001	.2248	.7568
	S7	-.4313*	.10475	.002	-.7627	-.0999
	S8	-.3162	.11877	.189	-.6919	.0595
	SS	.9064*	.07046	<.001	.6835	1.1293
SS	S1	-1.6233*	.03007	<.001	-1.7184	-1.5282
	S2	-.4554*	.03445	<.001	-.5644	-.3464
	S3	-1.4027*	.04842	<.001	-1.5559	-1.2496
	S4	-.8872*	.10746	<.001	-1.2272	-.5473
	S5	-1.9793*	.04719	<.001	-2.1285	-1.8300
	S6	-.4156*	.05684	<.001	-.5954	-.2358
	S7	-1.3377*	.08446	<.001	-1.6049	-1.0705
	S8	-1.2226*	.10132	<.001	-1.5431	-.9020
	S9	-.9064*	.07046	<.001	-1.1293	-.6835

Based on observed means.
The error term is Mean Square(Error) = 23.298.
*. The mean difference is significant at the .05 level.

APPENDIX III POST HOC TEST FOR DBH AND MOISTURE REGIME

Multiple Comparisons

Dependent Variable: DBH
Tukey HSD

(I) MoistRegimeCode	(J) MoistRegimeCode	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
.00	1.00	.0495	.03075	.745	-.0437	.1427
	2.00	-.6456*	.03471	<.001	-.7508	-.5404
	3.00	-1.8494*	.06479	<.001	-2.0458	-1.6530
	4.00	.1299	.08467	.789	-.1267	.3866
	5.00	-3.7687*	.13341	<.001	-4.1730	-3.3643
	6.00	2.7384*	.29551	<.001	1.8427	3.6340
	7.00	5.7192*	.37241	<.001	4.5905	6.8480
1.00	.00	-.0495	.03075	.745	-.1427	.0437
	2.00	-.6951*	.03246	<.001	-.7934	-.5967
	3.00	-1.8989*	.06362	<.001	-2.0917	-1.7061
	4.00	.0804	.08377	.980	-.1735	.3344
	5.00	-3.8182*	.13284	<.001	-4.2208	-3.4155
	6.00	2.6889*	.29525	<.001	1.7940	3.5838
	7.00	5.6697*	.37221	<.001	4.5416	6.7979
2.00	.00	.6456*	.03471	<.001	.5404	.7508
	1.00	.6951*	.03246	<.001	.5967	.7934
	3.00	-1.2039*	.06562	<.001	-1.4028	-1.0050
	4.00	.7755*	.08531	<.001	.5170	1.0341
	5.00	-3.1231*	.13381	<.001	-3.5287	-2.7175
	6.00	3.3839*	.29569	<.001	2.4877	4.2802
	7.00	6.3648*	.37256	<.001	5.2356	7.4940
3.00	.00	1.8494*	.06479	<.001	1.6530	2.0458
	1.00	1.8989*	.06362	<.001	1.7061	2.0917
	2.00	1.2039*	.06562	<.001	1.0050	1.4028
	4.00	1.9794*	.10134	<.001	1.6722	2.2865
	5.00	-1.9192*	.14456	<.001	-2.3574	-1.4811
	6.00	4.5878*	.30071	<.001	3.6764	5.4992
	7.00	7.5687*	.37656	<.001	6.4273	8.7100
4.00	.00	-.1299	.08467	.789	-.3866	.1267

	1.00	-.0804	.08377	.980	-.3344	.1735
	2.00	-.7755*	.08531	<.001	-1.0341	-.5170
	3.00	-1.9794*	.10134	<.001	-2.2865	-1.6722
	5.00	-3.8986*	.15450	<.001	-4.3669	-3.4303
	6.00	2.6084*	.30561	<.001	1.6821	3.5347
	7.00	5.5893*	.38048	<.001	4.4361	6.7425
5.00	.00	3.7687*	.13341	<.001	3.3643	4.1730
	1.00	3.8182*	.13284	<.001	3.4155	4.2208
	2.00	3.1231*	.13381	<.001	2.7175	3.5287
	3.00	1.9192*	.14456	<.001	1.4811	2.3574
	4.00	3.8986*	.15450	<.001	3.4303	4.3669
	6.00	6.5070*	.32253	<.001	5.5295	7.4846
	7.00	9.4879*	.39420	<.001	8.2931	10.6827
6.00	.00	-2.7384*	.29551	<.001	-3.6340	-1.8427
	1.00	-2.6889*	.29525	<.001	-3.5838	-1.7940
	2.00	-3.3839*	.29569	<.001	-4.2802	-2.4877
	3.00	-4.5878*	.30071	<.001	-5.4992	-3.6764
	4.00	-2.6084*	.30561	<.001	-3.5347	-1.6821
	5.00	-6.5070*	.32253	<.001	-7.4846	-5.5295
	7.00	2.9809*	.47426	<.001	1.5434	4.4183
7.00	.00	-5.7192*	.37241	<.001	-6.8480	-4.5905
	1.00	-5.6697*	.37221	<.001	-6.7979	-4.5416
	2.00	-6.3648*	.37256	<.001	-7.4940	-5.2356
	3.00	-7.5687*	.37656	<.001	-8.7100	-6.4273
	4.00	-5.5893*	.38048	<.001	-6.7425	-4.4361
	5.00	-9.4879*	.39420	<.001	-10.6827	-8.2931
	6.00	-2.9809*	.47426	<.001	-4.4183	-1.5434

Based on observed means.

The error term is Mean Square(Error) = 30.806.

*. The mean difference is significant at the .05 level.

APPENDIX IV POST HOC TEST FOR HEIGHT AND MOISTURE REGIME

Multiple Comparisons

Dependent Variable: HtTot
Tukey HSD

(I) MoistRegimeCode	(J) MoistRegimeCode	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
.00	1.00	-.2155*	.02695	<.001	-.2971	-.1338
	2.00	-.4979*	.03041	<.001	-.5901	-.4057
	3.00	-1.4145*	.05678	<.001	-1.5865	-1.2424
	4.00	-.6286*	.07420	<.001	-.8535	-.4037
	5.00	-1.0406*	.11690	<.001	-1.3949	-.6862
	6.00	1.7473*	.25896	<.001	.9624	2.5321
	7.00	5.2667*	.32635	<.001	4.2776	6.2558
1.00	.00	.2155*	.02695	<.001	.1338	.2971
	2.00	-.2824*	.02845	<.001	-.3686	-.1962
	3.00	-1.1990*	.05575	<.001	-1.3680	-1.0300
	4.00	-.4132*	.07341	<.001	-.6357	-.1907
	5.00	-.8251*	.11641	<.001	-1.1779	-.4723
	6.00	1.9627*	.25873	<.001	1.1785	2.7469
	7.00	5.4822*	.32617	<.001	4.4936	6.4708
2.00	.00	.4979*	.03041	<.001	.4057	.5901
	1.00	.2824*	.02845	<.001	.1962	.3686
	3.00	-.9166*	.05751	<.001	-1.0909	-.7423
	4.00	-.1307	.07475	.655	-.3573	.0958
	5.00	-.5427*	.11726	<.001	-.8981	-.1873
	6.00	2.2451*	.25912	<.001	1.4598	3.0305
	7.00	5.7646*	.32648	<.001	4.7751	6.7541
3.00	.00	1.4145*	.05678	<.001	1.2424	1.5865
	1.00	1.1990*	.05575	<.001	1.0300	1.3680
	2.00	.9166*	.05751	<.001	.7423	1.0909
	4.00	.7858*	.08881	<.001	.5167	1.0550
	5.00	.3739	.12668	.063	-.0101	.7578
	6.00	3.1617*	.26352	<.001	2.3630	3.9604
	7.00	6.6812*	.32998	<.001	5.6810	7.6813
4.00	.00	.6286*	.07420	<.001	.4037	.8535

	1.00	.4132*	.07341	<.001	.1907	.6357
	2.00	.1307	.07475	.655	-.0958	.3573
	3.00	-.7858*	.08881	<.001	-1.0550	-.5167
	5.00	-.4119*	.13539	.048	-.8223	-.0016
	6.00	2.3759*	.26781	<.001	1.5642	3.1876
	7.00	5.8953*	.33342	<.001	4.8848	6.9059
5.00	.00	1.0406*	.11690	<.001	.6862	1.3949
	1.00	.8251*	.11641	<.001	.4723	1.1779
	2.00	.5427*	.11726	<.001	.1873	.8981
	3.00	-.3739	.12668	.063	-.7578	.0101
	4.00	.4119*	.13539	.048	.0016	.8223
	6.00	2.7878*	.28264	<.001	1.9312	3.6445
	7.00	6.3073*	.34544	<.001	5.2603	7.3543
6.00	.00	-1.7473*	.25896	<.001	-2.5321	-.9624
	1.00	-1.9627*	.25873	<.001	-2.7469	-1.1785
	2.00	-2.2451*	.25912	<.001	-3.0305	-1.4598
	3.00	-3.1617*	.26352	<.001	-3.9604	-2.3630
	4.00	-2.3759*	.26781	<.001	-3.1876	-1.5642
	5.00	-2.7878*	.28264	<.001	-3.6445	-1.9312
	7.00	3.5195*	.41560	<.001	2.2598	4.7791
7.00	.00	-5.2667*	.32635	<.001	-6.2558	-4.2776
	1.00	-5.4822*	.32617	<.001	-6.4708	-4.4936
	2.00	-5.7646*	.32648	<.001	-6.7541	-4.7751
	3.00	-6.6812*	.32998	<.001	-7.6813	-5.6810
	4.00	-5.8953*	.33342	<.001	-6.9059	-4.8848
	5.00	-6.3073*	.34544	<.001	-7.3543	-5.2603
	6.00	-3.5195*	.41560	<.001	-4.7791	-2.2598

Based on observed means.

The error term is Mean Square(Error) = 23.656.

*. The mean difference is significant at the .05 level.

APPENDIX V POST HOC TEST FOR TOTAL ESTIMATE VOLUME AND

MOISTURE REGIME.

Multiple Comparisons

Dependent Variable: Total estimate Volume (m3)

Tukey HSD

(I) MoistRegimeCode	(J) MoistRegimeCode	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
.00	1.00	.0012	.00052	.321	-.0004	.0027
	2.00	-.0072*	.00058	<.001	-.0089	-.0054
	3.00	-.0365*	.00109	<.001	-.0398	-.0332
	4.00	-.0008	.00143	.999	-.0051	.0035
	5.00	-.0577*	.00225	<.001	-.0645	-.0508
	6.00	.0277*	.00498	<.001	.0126	.0428
	7.00	.0559*	.00627	<.001	.0368	.0749
1.00	.00	-.0012	.00052	.321	-.0027	.0004
	2.00	-.0083*	.00055	<.001	-.0100	-.0067
	3.00	-.0377*	.00107	<.001	-.0409	-.0344
	4.00	-.0019	.00141	.869	-.0062	.0023
	5.00	-.0588*	.00224	<.001	-.0656	-.0520
	6.00	.0265*	.00497	<.001	.0114	.0416
	7.00	.0547*	.00627	<.001	.0357	.0737
2.00	.00	.0072*	.00058	<.001	.0054	.0089
	1.00	.0083*	.00055	<.001	.0067	.0100
	3.00	-.0293*	.00111	<.001	-.0327	-.0260
	4.00	.0064*	.00144	<.001	.0020	.0108
	5.00	-.0505*	.00225	<.001	-.0573	-.0436
	6.00	.0349*	.00498	<.001	.0198	.0499
	7.00	.0630*	.00627	<.001	.0440	.0821
3.00	.00	.0365*	.00109	<.001	.0332	.0398
	1.00	.0377*	.00107	<.001	.0344	.0409
	2.00	.0293*	.00111	<.001	.0260	.0327
	4.00	.0358*	.00171	<.001	.0306	.0409
	5.00	-.0211*	.00243	<.001	-.0285	-.0137
	6.00	.0642*	.00506	<.001	.0488	.0796
	7.00	.0924*	.00634	<.001	.0732	.1116

4.00	.00	.0008	.00143	.999	-.0035	.0051
	1.00	.0019	.00141	.869	-.0023	.0062
	2.00	-.0064*	.00144	<.001	-.0108	-.0020
	3.00	-.0358*	.00171	<.001	-.0409	-.0306
	5.00	-.0569*	.00260	<.001	-.0648	-.0490
	6.00	.0284*	.00515	<.001	.0128	.0440
	7.00	.0566*	.00641	<.001	.0372	.0761
5.00	.00	.0577*	.00225	<.001	.0508	.0645
	1.00	.0588*	.00224	<.001	.0520	.0656
	2.00	.0505*	.00225	<.001	.0436	.0573
	3.00	.0211*	.00243	<.001	.0137	.0285
	4.00	.0569*	.00260	<.001	.0490	.0648
	6.00	.0853*	.00543	<.001	.0689	.1018
	7.00	.1135*	.00664	<.001	.0934	.1336
6.00	.00	-.0277*	.00498	<.001	-.0428	-.0126
	1.00	-.0265*	.00497	<.001	-.0416	-.0114
	2.00	-.0349*	.00498	<.001	-.0499	-.0198
	3.00	-.0642*	.00506	<.001	-.0796	-.0488
	4.00	-.0284*	.00515	<.001	-.0440	-.0128
	5.00	-.0853*	.00543	<.001	-.1018	-.0689
	7.00	.0282*	.00799	.010	.0040	.0524
7.00	.00	-.0559*	.00627	<.001	-.0749	-.0368
	1.00	-.0547*	.00627	<.001	-.0737	-.0357
	2.00	-.0630*	.00627	<.001	-.0821	-.0440
	3.00	-.0924*	.00634	<.001	-.1116	-.0732
	4.00	-.0566*	.00641	<.001	-.0761	-.0372
	5.00	-.1135*	.00664	<.001	-.1336	-.0934
	6.00	-.0282*	.00799	.010	-.0524	-.0040

Based on observed means.
The error term is Mean Square(Error) = .009.
*. The mean difference is significant at the 0.05 level.

APPENDIX VI POST HOC TEST FOR MEAN ANNUAL INCREMENT AND MOISTURE REGIME.

Multiple Comparisons

Dependent Variable: Mean Annual Increment (cm/year)
Tukey HSD

(I) MoistRegimeCode	(J) MoistRegimeCode	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
.00	1.00	-.0175*	.00187	<.001	-.0232	-.0118
	2.00	-.0310*	.00211	<.001	-.0374	-.0246
	3.00	.0132*	.00394	.018	.0013	.0252
	4.00	.0099	.00515	.532	-.0057	.0255
	5.00	.0430*	.00812	<.001	.0184	.0676
	6.00	.1885*	.01798	<.001	.1340	.2430
	7.00	.2362*	.02266	<.001	.1676	.3049
1.00	.00	.0175*	.00187	<.001	.0118	.0232
	2.00	-.0135*	.00198	<.001	-.0195	-.0076
	3.00	.0307*	.00387	<.001	.0190	.0424
	4.00	.0274*	.00510	<.001	.0120	.0429
	5.00	.0605*	.00808	<.001	.0360	.0850
	6.00	.2060*	.01797	<.001	.1515	.2604
	7.00	.2537*	.02265	<.001	.1851	.3224
2.00	.00	.0310*	.00211	<.001	.0246	.0374
	1.00	.0135*	.00198	<.001	.0076	.0195
	3.00	.0442*	.00399	<.001	.0321	.0563
	4.00	.0410*	.00519	<.001	.0252	.0567
	5.00	.0741*	.00814	<.001	.0494	.0988
	6.00	.2195*	.01799	<.001	.1650	.2741
	7.00	.2673*	.02267	<.001	.1986	.3360
3.00	.00	-.0132*	.00394	.018	-.0252	-.0013
	1.00	-.0307*	.00387	<.001	-.0424	-.0190
	2.00	-.0442*	.00399	<.001	-.0563	-.0321
	4.00	-.0033	.00617	1.000	-.0220	.0154
	5.00	.0298*	.00880	.016	.0032	.0565
	6.00	.1753*	.01830	<.001	.1198	.2307
	7.00	.2230*	.02291	<.001	.1536	.2925

4.00	.00	-.0099	.00515	.532	-.0255	.0057
	1.00	-.0274*	.00510	<.001	-.0429	-.0120
	2.00	-.0410*	.00519	<.001	-.0567	-.0252
	3.00	.0033	.00617	1.000	-.0154	.0220
	5.00	.0331*	.00940	.010	.0046	.0616
	6.00	.1786*	.01860	<.001	.1222	.2349
	7.00	.2263*	.02315	<.001	.1561	.2965
5.00	.00	-.0430*	.00812	<.001	-.0676	-.0184
	1.00	-.0605*	.00808	<.001	-.0850	-.0360
	2.00	-.0741*	.00814	<.001	-.0988	-.0494
	3.00	-.0298*	.00880	.016	-.0565	-.0032
	4.00	-.0331*	.00940	.010	-.0616	-.0046
	6.00	.1454*	.01963	<.001	.0860	.2049
	7.00	.1932*	.02399	<.001	.1205	.2659
6.00	.00	-.1885*	.01798	<.001	-.2430	-.1340
	1.00	-.2060*	.01797	<.001	-.2604	-.1515
	2.00	-.2195*	.01799	<.001	-.2741	-.1650
	3.00	-.1753*	.01830	<.001	-.2307	-.1198
	4.00	-.1786*	.01860	<.001	-.2349	-.1222
	5.00	-.1454*	.01963	<.001	-.2049	-.0860
	7.00	.0478	.02886	.717	-.0397	.1352
7.00	.00	-.2362*	.02266	<.001	-.3049	-.1676
	1.00	-.2537*	.02265	<.001	-.3224	-.1851
	2.00	-.2673*	.02267	<.001	-.3360	-.1986
	3.00	-.2230*	.02291	<.001	-.2925	-.1536
	4.00	-.2263*	.02315	<.001	-.2965	-.1561
	5.00	-.1932*	.02399	<.001	-.2659	-.1205
	6.00	-.0478	.02886	.717	-.1352	.0397

Based on observed means.

The error term is Mean Square (Error) = .114.

*. The mean difference is significant at the 0.05 level.