# RESIDUAL DAMAGE IN MIXED HARDWOOD STANDS AFTER MECHANIZED LOGGING

by

Winter Lamont

An Undergraduate Thesis Submitted in Partial Fulfillment of the

Requirements for the Degree of Honours Bachelor of Science in Forestry

Faculty of Natural Resources Management

Lakehead University

April 2019

Reino Pulkki

Major Advisor

Jian Wang

Second Read

# LIBRARY RIGHTS STATEMENT



Signature: ________________________________

Date: ___________________________________

# A CAUTION TO THE READER

This HBSCF thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of either the thesis supervisor, the Faculty or Lakehead University.

# MAJOR ADVISOR COMMENTS

# ABSTRACT

Lamont, W. 2019. Residual damage in mixed hardwood stands after mechanized logging. Major Advisor: Dr. R.E. Pulkki.

Key Words: mechanical, residual damage, selection cutting, wounding, feller buncher, chainsaw, cable skidders, mixed hardwood stands.

Research and data collection on the issues surrounding mechanized harvesting in mixed hardwood stands was gathered within the Great Lakes-St. Lawrence forest region. The silviculture prescription for the stands studied was single tree selection. Harvesting was done by two different systems; 1) Timbco T-425c feller buncher with motor manual delimbing and one 240 Timberjack cable skidder and 2) harvested by motor manual chainsaw with motor manual delimbing and 225 Timberjack cable skidder. The objective of the study is to assess residual damage as a result of certain harvesting methods, equipment choices and seasonal harvest periods. Issues regarding logging damage done by different types of machinery used on stands with high-value timber needs to be recognized. The results of the study prove to show high significance in promoting careful logging practices that will lower the rate of logging damage on Southern Ontario stands.

# CONTENTS

`

Page

# TABLES

# FIGURES

# ACKNOWLEDGEMENT

I would like to acknowledge and thank my major advisor Dr. Reino Pulkki and second reader Dr. Jian Wang for their support through all stages of creating such a thesis. A thank-you also goes towards R and J Tree Farms for their knowledge and help in forming data collection sites. Lastly, a very special thank-you goes out to my grandfather who helped with collaboration efforts with Rand J Tree Farms so such a thesis could be conducted.

# INTRODUCTION

Central Ontario is heavily dominated by mixed hardwood stands, stands of which single tree selection practices are most commonly used. Single tree selection harvest is a silvicultural practice that involves the removal of individual trees of all age and size classes. Harvesting in such a way requires finesse in picking and choosing which stems should be taken and which will be left, in a way that not only benefits economically in the present but in the future forest as well. Such a system relies heavily on skilled markers as well as equipment operators that will ensure tree health and quality does not decline after harvest but rather leave the stand with vigorous high-quality stems of all ages and sizes (MNR 2003).

Throughout the years, forestry practices have evolved, and with it, the evolution has advanced from hand tools, motor manual machines to computer controlled machinery. Today's upgraded machinery has given the industry something to look forward to, from high volumes of removal, steep slope agility and a sense of ease not known in generations before. However, with the high rates of machinery in practice comes a higher risk for forests and their ecosystems. Harvesting equipment brings forth ease for workers yet if not used in a skilled and respectful manner machinery can be a leading cause of damage done to residual trees (FRP 2008). Machines come in a variety of models and sizes throughout central Ontario as local logging companies and farmers use different machinery. With this, it is imperative that no matter the size or machinery used, operators need to know how to apply them and care about the forests being harvested. Central Ontario is known to have high rates of felling performed with either a feller buncher or chainsaw. This is due to the high cost of machinery and smaller harvest blocks not needing large machines. Careful logging practices and known use of particular machinery can help protect future forests. Damage is inevitable but there are ways to prevent residual wounds and die back from occurring.

Careful logging practices hold many different variations, among the many is the use of; proper tree marking, observation walks, adequate machinery usage and time of harvest. In order to prove the techniques can work to prevent overall residual damage, observations of two different harvest systems were conducted. Research has examined the time of harvest and wound scaring found post harvest. There are two hypotheses within the study the first being winter harvest periods will show low rates of recorded damage compared to the other seasonal periods. The second hypothesis being that the chainsaw and small cable skidder will be determined as the best suited machine combination. It is thought that with smaller machinery and decreased rates of machine use by just having the cable skidder and a feller present on site will lead to lower rates of scaring present during harvest.

The objective of this thesis is to determine the overall extent of residual tree wounding when using different harvesting equipment in single tree selection cuts within Southern Ontario tolerant hardwood stands. The second objective is to observe whether or not the time of harvest affects how severe wound damage can occur.

# LITERATURE REVIEW

## Silviculture

Silviculture systems are planned programs of treatments carried out during the entire life of a stand for the main objective of controlling the establishment, composition, and growth of a forest (Anderson and Rice 1993). Selection cutting systems are controlled by a periodic time frame in which partial cuttings of the stand occur through many different cutting cycles. The system is controlled by basal area, tree vigor, and risk associated with cuts. This is dependent on the silvics, stand condition and products being managed for firewood or veneer and non-timber values (Straughan 2003). Removal of 1/3 of the basal area ensures the cut does not dramatically alter the stand structure thus producing a self-sustaining un-even aged stand (Caspersen 2006). The vigor of a forest can be seen after proper removal in single tree selection as the residual trees suffer less stress following harvest. Changes in "light, temperature, humidity, soil, moisture and wind" (Caspersen 2006) are not as severe if the single tree selection method is followed accurately. As single-tree selection reaches multiple cuttings, it leaves room for equipment and less risk of experiencing open face scars. The objective of harvest is to produce high-quality stems of which are represented by a variety of diameter classes that are free of damage and disease (Anderson and Rice 1993).

A tool that helps to regulate single tree selection system is tree-marking. The job of a tree marker is to first remove stems of poor quality and of high risk. Tree markers assess the trees based on vigor and value within the present and future cutting cycle.

Tree-marking is a highly sought after course and profession as before any harvest can commence a licensed tree marker must go in and analyze the stand (OMNR 2004).

Classifying trees under the single tree selection system are based off two properties, one being AGS acceptable growing stock and UGS unacceptable growing stock. Stems classified as AGS are of commercial value. AGS stems can be suitable for retention of one cutting cycle so as to produce a viable future log. UGS stems are those which have damage or disease resulting in low-quality timber. When done properly selection can reduce the level of poor quality timber within hardwood forests. This is due to the fact that when marking it is important to take out UGS species in higher volumes than AGS in order to help produce a future forest with little UGS trees. In some cases, the removal of UGS can leave stands basal area too low and introduce wind or light damage, with this it is imperative a good tree marker is placed in the forest to appropriately call if some UGS needs to be left in order to protect other stems (OMNR 2004). There are biological, ecological and management implications of logging damage as said by Anderson (1994) that must be minimized in order to protect residuals for future harvest.

<u>Forest Harvesting Operations</u>

Harvest of forests have long been witnessed as a construed element of Canada and remains a crucial operation for economic, social and environmental importance. Forest operations throughout the years have changed drastically. It was only in the late 1940s when a change in practices, tools, and techniques were dramatically altered by the rapid rate of forest mechanization (Silversides 1997). Since 1990 the push towards mechanized approaches for harvesting has increased due to shortages of workers wanting to partake in fieldwork and the decline of qualified workers (McNarma 1997;

Meek 1997). As said by Oscar Wilde "On mechanical slavery, on the slavery of the machine, the future of the world depends"(Wilde 1891). As society brings the need to compete in the growing forestry market, the dexterity of having mechanical machinery that produces high volumes of timber in a short time span is crucial to keeping up with the market demand.

The increased drive for mechanized harvesting equipment comes adaption to use machinery in the most careful way possible. During harvest, damage is inevitable when stands are treated as single-tree selection (Nyland 1991). Working with uneven-aged stand structures and densities the felling of large woody stems will almost always lead to damage of small or large standing trees. Likewise, skidding can have the same impact. Large trees on their way out will scrape or land on smaller stems causing wound damage and in some cases cause tree mortality (Nyland 1991).  The use of smaller lightweight machines has been seen to reduce rutting and scrapping damage caused by skidders.

Careful Logging Practices

Careful logging practices (CLP) are those which include a range of practices that can be used by private landowners and logging companies. These practices help protect and maintain forest health as well as overall productivity by decreasing site impacts and harvesting damage to residual trees. CLP’s help to protect forest values such as wildlife habitat and watershed characteristics, all while helping to increase a forests ecological function (OWA 2009). Careful logging practices are not only important to private landowners on a small scale but rather quite important to contractor's practicing any type of harvesting.

Damage to residuals can occur within partial cuttings in a variety of ways; crown, root, bole damage, soil compaction and termination of stems if not careful. Damages done to the bole of a tree can stimulate epicormic branches thus producing future inequalities of tree value and health as well produce open faced scars which devalue the bole qualities (Meadows 1993). Such a system as single tree selection is often deemed a benign method as the harvest does not dramatically change a stands structure (Caspersen 2006). Residual trees within single tree selection systems experience less stress following felling as changes are not as abrupt towards; light percentage, temperature, soil, moisture, and wind when compared to clear-cutting. Injuries obtained by harvest on trees of 10cm in diameter and above suffer a 5% immediate death ratio and prior studies shown by Caspersen (2006) show overall damages of 15 to 35% occur after harvest. Damage can be reduced but not completely avoided.

Practicing careful felling and skidding techniques within partial cut stands are not the only prevention techniques available. Site compaction can have a huge influence on tree health and growth. Smeltzer *et al.* (1986) conveyed a study on ecosystem response towards artificial soil compaction and a plants process after compaction has occurred. Smeltzer *et al.* (1986) concluded that with severe compaction, reduction of site productivity occurs through the changing of certain soil properties. Changes in the soil can influence soil microorganism populations which are involved in tree growth and development. Certain soil microorganisms found within the soil are made up of plant pathogens. The ubiquity and plenitude of such pathogens are dependent on soil properties altered by compaction (Smeltzer *et al.* 1986). Bulk density of soil has influential impacts on a trees rooting system. The increased bulk density and soil strength increase disadvantageous effects within root growth (Nambiar and Sands 1992).

Soils are much easily affected when traveling through the forest floor during wet periods when using heavy weight machinery and practicing poor operating techniques. The reality of harvesting is that even with limiting damage factors damage can still occur. Operators during harvest have the ability to limit the damage through careful logging practices by using light machinery, partaking in harvest during winter months and having skilled operators to run the machinery (Anderson 1991).

<u>Wound Damage</u>

Wound damage has adverse effects depending on the time of year, placement of damage and how large the wound is. Year dependency is related to the processes trees go through each year to prepare for each of the four seasons. During the spring months, trees emerge from dormancy. During this stage, the cambial cells are highly active in preparation for cell division with the beginning of new xylem and phloem cells. Cells during this stage are thin in nature and are far more susceptible to damage. Bond strength is very high during the fall and winter seasons as the bark is readying itself for dormancy. The strength weakens around April and will stay in this form until late July where the strength content begins to increase again. The final stages of the bark peeling phase in July are affiliated with the trees completed growth period (Anderson 1991).

Once any tissue of wood is uncovered and exposed to infectious content by microorganisms, rot is neither quick nor simple. Early invading organisms are incapable of introducing heart rot yet but are capable of chemically altering substrates that make a tree vulnerable to other destructive fungi (Andersen 1991). Andersen (1991) explains that phenols oxidize to form dark-colored polyphenols creating a term known as protection wood. The formed protection wood plugs cell cavities which creates a barrier against moisture giving little preferred area for fungi to thrive (Anderson 1991).

Damage to the crown in the form of broken branches larger than 8cm in diameter has the ability to trap and retain moisture posing decay hazards. Crown loss can also reduce photosynthesis of which slows down the rate of callus growth. Bark damage to the bole of hardwood species greater then 18cm has a fifty/ fifty chance of experiencing defect within the next 20 to 25 years (Nyland 1991). Damage to roots exposing more than 25 % is classified as severe and any future conditions will result in rot. Many trees within a block may not be harvested for several cutting cycles giving time for decaying fungi to infect wounds caused by logging (Dey 1993). Dey (1993) states that sugar maple experience rot within the first ten years after injury. The injury size is dependent on the machine size, skidding intensity and driver's skill level (Dey 1993).

# METHODS AND MATERIALS

In order to determine the extent of damage over the seven different sites, two square plots 14ft by 14ft were randomly placed within each stand. The creation of plots better represents the ratio of damaged to undamaged trees. Within the plots close collection of a few details is crucial:

Type of damage- None, root, bole, crown, multiple or destroyed

Crown Class- Dominant, Co-dominant, Intermediate and Suppressed

Wound Characteristics- the number of wounds, position, size, depth, root damage and diameter (dbh) of the stem.

Trees with wounds present are picked at random to record detailed information on wound characteristics present. In order to duplicate such a study, one would need a DBH tape, ruler, Basal area Prism and clipboard. Data collection consisted of a tally system recording the type of damage, crown class, and wound characteristics while having a section to write extra information on; site composition, soil content, stand characteristics and which seasonal time period harvest took place.

## Study Area Description

The study area is located among the County of Bruce and County of Huron in Southern Ontario (Figures 1 and 2). The seven study sites fell within the two counties, which were bordered mainly by farmer's fields and roadways.

*Site one*

The first site was located on the edge of the Teeswater River off of highway 9. The stand 4 acres in size sloped down towards the Teeswater River. Soils on site were determined to be characterized a sandy loam soil type. The stand borders the river and can be found to flood throughout the spring and early summer. Harvest took place in the late summer by chainsaw felling and a 225 Timberjack cable skidder. The stand composition was made up of red maple (*Acer rubrum*) and black ash (*Fraxinus nigra)*. Knowledge of the stand prior to harvest indicated that the stand already low in basal area had decreased immensely.

*Site two*

The second study was found nestled in amongst farm fields off of Bruce Road 20. The study site was 6 acres of flat sandy loam soils. Harvest occurred in the early summer months with a chainsaw and 225 Timber Jack cable skidder. The stand was filled with young black ash (*Fraxinus nigra*), as well as larger diameter stems of ; black cherry (*Prunus serotina*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*) and black ash (*Fraxinus nigra*). Before harvest, the stand had a high basal area creating stress on fellers to drop trees with ease and the least amount of damage. It should also be noted that the harvest of the stand occurred during wet and rainy periods but the operators let the area dry out so as to prevent any rut damage.

*Site three*

The third study site was found amongst farm fields on the 10th concession of Kinloss. Six acres in size the site sat on flat sandy loam soils. Harvest occurred within the winter month using a 1998 Timbco model of feller buncher (T-425c) and a 240 Timber Jack cable skidder. The stand composition was made up of black ash with little sugar maple content. Opportunity to view before and after harvest was given for this particular site.

*Site four*

Site four located on the10th concession of Kinloss was 10 acres in size, 5 of which was harvested.  The stand was cut with a 1998 Timbco model of feller buncher (T-425c) and a 240 Timber Jack cable skidder in the late fall. Composition of the stand consisted of black ash and red maple. Past knowledge of the stand before harvest stated that there were large volumes of black ash content. The spot was found to be a considerably wet site. Due to the stand being wet the use of chain placement on the skidder's wheels were used in order to prevent any extra rutting disturbance.

*Site five*

Site five was located on highway 6. This stand had a 4% slope ratio which made manoeuvring within the stand difficult, however no rut damage was found. The stand of 10 acres was harvested 4 years ago during the winter months using a1998 Timbco model feller buncher (T-425c) and a 240 Timber Jack cable skidder. The stand composition was recorded to have species of ironwood (*Ostrya virginiana*), American beech (*Fagus grandifolia*), Eastern hemlock (*Tsuga canadensis*) and black ash (*Fraxinus nigra*). There was evidence of previous logging damage from the landowner prior to the most recent harvest.

*Site six*

The sixth site was located on Concession 14. The stand was placed on a 2% slope of which contained 5 acres of forested land. The harvest took place in the winter months using a 1998 Timbco model of feller buncher (T-425c) and a 240 Timberjack cable skidder. Stand composition contained species of ironwood (*Ostrya virginiana*), Eastern Hemlock (*Tsuga canadensis*) and black ash (*Fraxinus nigra*).

*Site seven*

The last study site was located on highway 6 containing 6 acres of forested land. The stand was harvested in the spring months using a chainsaw and 225 Timber Jack cable skidder. Stand seven had a 6% slope present proving to cause trouble for skid equipment during wet periods however no major rut damage was recorded. The logs on this particular site were cut in half before skidding commenced to prevent damage to residual trees. The species composition on site was recorded to have small amounts of Eastern hemlock (*Tsuga canadensis*) and the rest being a mix of red maple, sugar maple, and black ash.

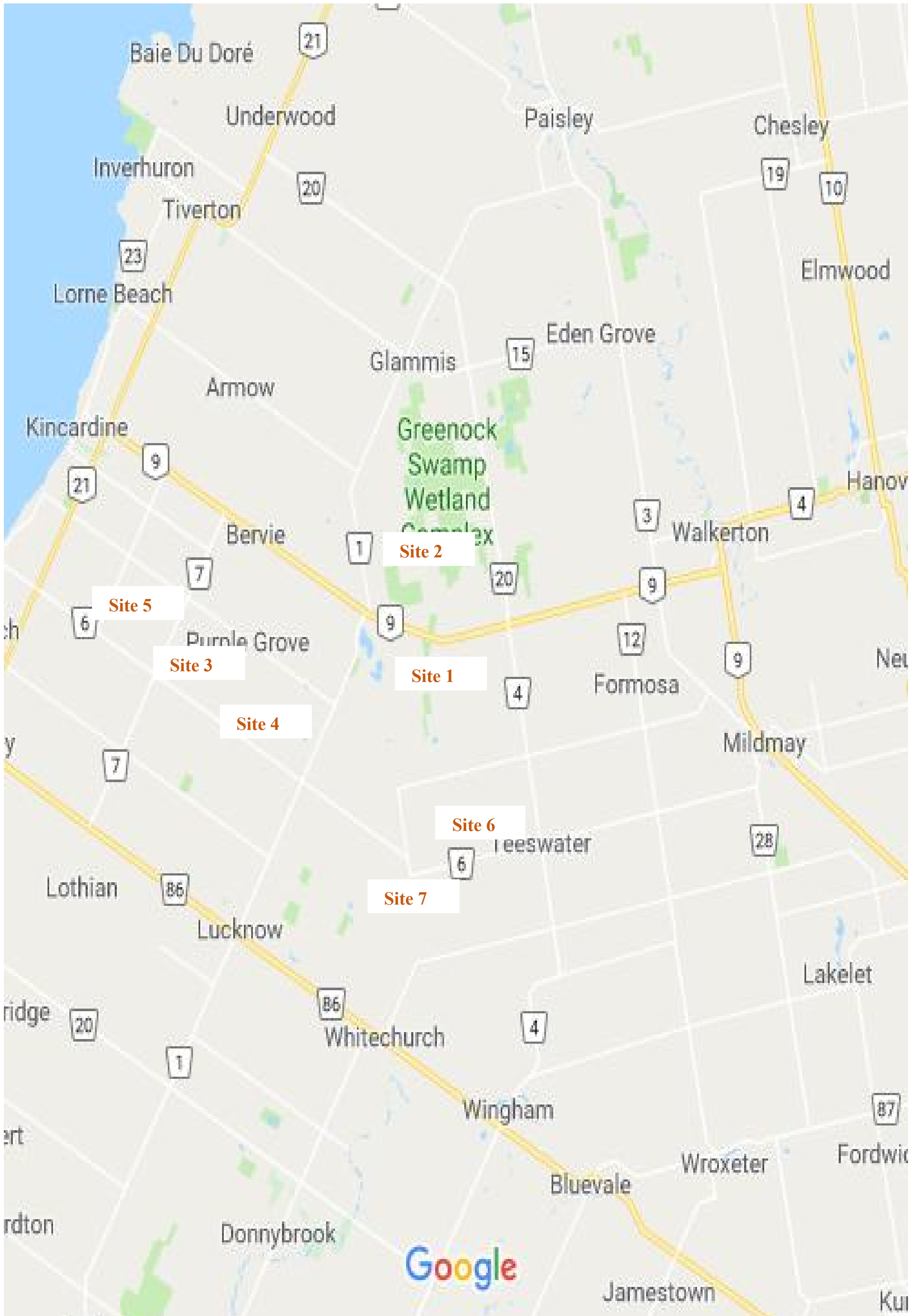


Figure 1. Map outlining the seven specific study site locations (Google Maps 2018).


Figure 2. Outline of Bruce and Huron County (Southwest health line, 2018).

# RESULTS

The results pertaining to the four seasonal periods and harvest machinery varied over the seven study sites. The data collected was correlated to represent which particular method of harvest from the feller buncher to the chainsaw is best suited to prevent residual stems from harvest damage, as well to show the time period best recommended to protect stems from increased volumes of disturbance. Wounding results were characterized by the species, diameter, size, and depth of wound in order to develop an understanding of what the future of the forest and stem can hold when a disturbance occurs.

The outcome of the collected data pertaining to the seasonal harvest periods demonstrated to support the hypothesis that the least damage would occur during the fall and winter harvest times. Due to the close relation and tree growth patterns, the fall and winter periods have been combined together to form a representation of disturbance found within the 4 seasonal study periods. Raw data collection can be found in the appendix for a further breakdown of specific plot tree counts.

Damage recorded during the fall and winter harvest covered a total of thirty-one acres of forested land. Eight plots had a recorded total of 69 trees within the four fall and winter sites. 15 of the 69 trees are recorded to have different variations of wound damage and destruction due to harvest. With a total of 67% damage being just on the bole of stems. Destroyed stems that were broken off were found to have affected 13% of the tallied trees. Trees experiencing multiple wounds from a mixture of bole, root and crown damage totaled out to 20% and stems experiencing multiple wounds had relatively small affected areas. As for the fall and winter seasonal period, no listed damage was observed on the roots of stems surveyed (Figure 3).

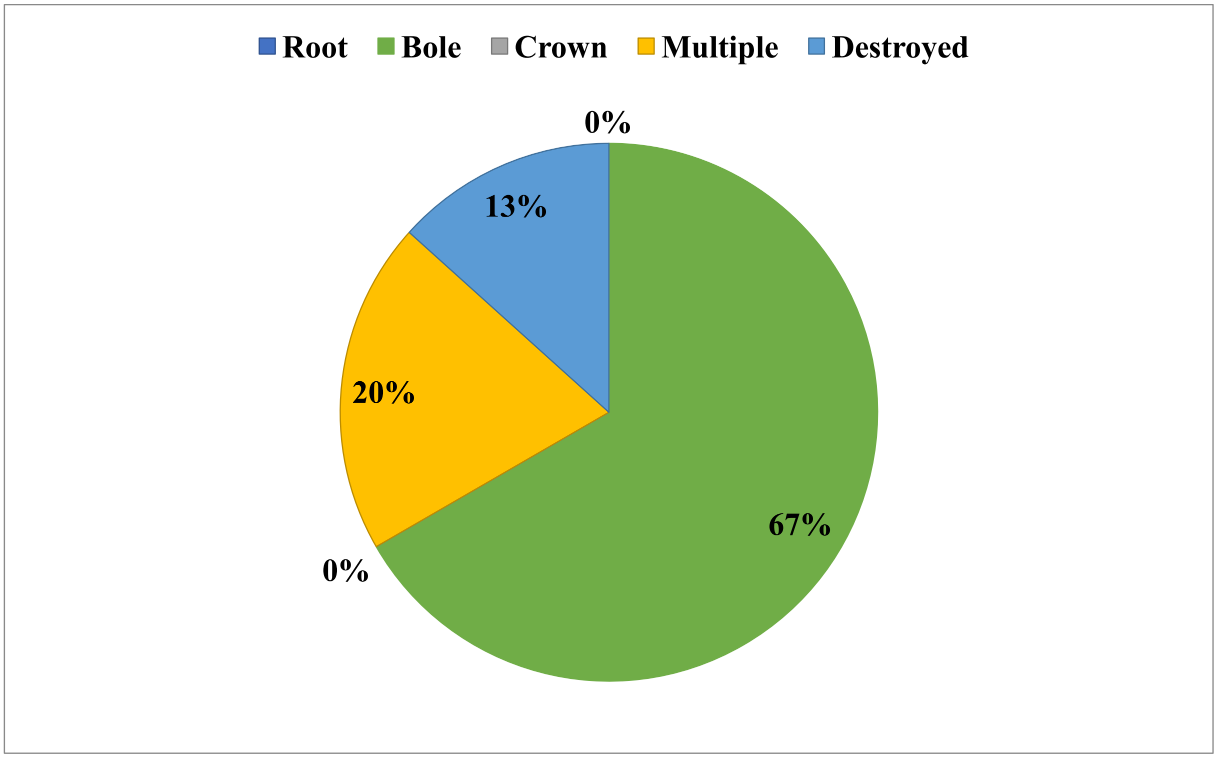


Figure 3. Recorded damage within the Fall and Winter study sites.

The spring harvest period demonstrated high rates of damage compared to undamaged as recorded in Figure 4. The damages observed occurred within both the felling and skidding harvest processes. The 2 plots observed resulted in a total of 23 damaged trees out of an overall count of 25 trees found within the plots. Damage on the bole (31%) and crown (30%) of stems received higher rates of disturbance and were seen to place severe disturbance on the tallied stems. A total of 13% was recorded to have damage directly to roots of stems. The remainder of damage occurred within the multiple wounds category (13%) of which included root and bole wounds that were significant in size.

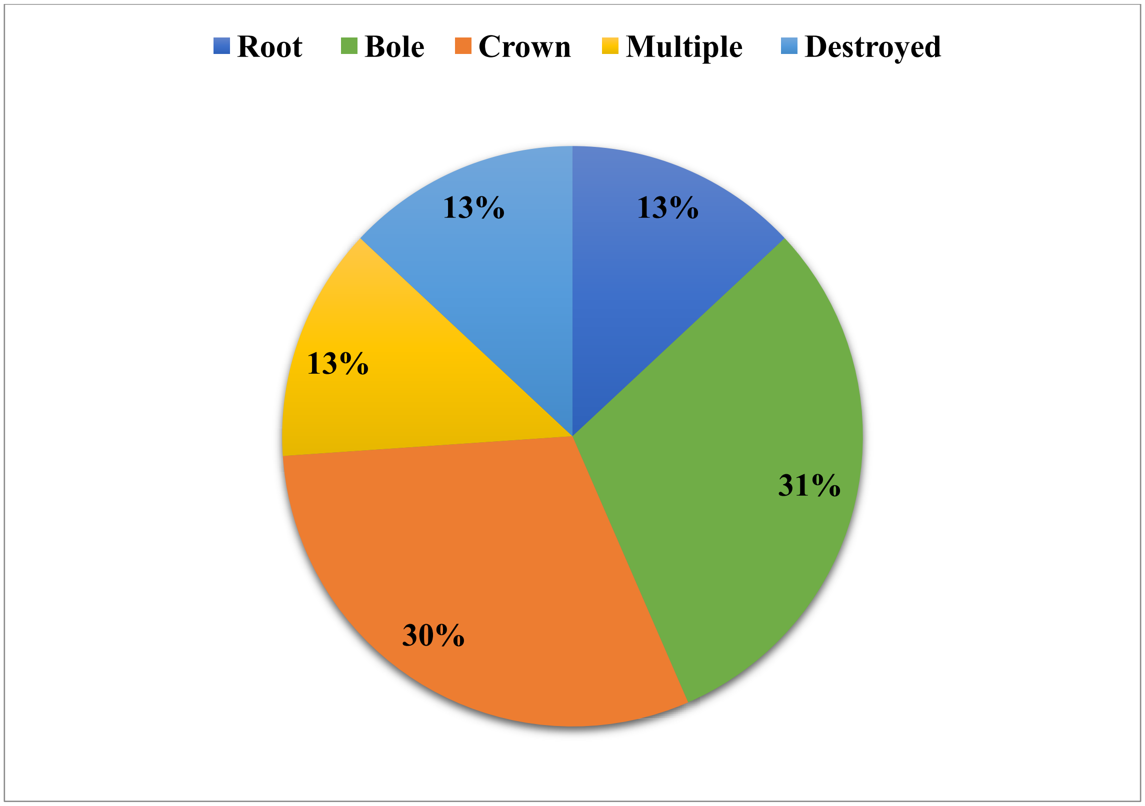


Figure 4. Damage to residual trees during the spring harvest period over 25 trees.

The two summer harvest sites showed high amounts of damaged trees. A total of 29 out of 48 trees tallied were affected by harvesting practices. The damaged summer harvest percentages among the five damage characteristic types are found below in Figure 5. Wounds occurring on the bole of trees were found to be 40% of the tallied trees found in the summer harvest plots. with 13% of the damage happening in the crown portion. Throughout the fall and winter sites, no recorded root damage was observed. Within the summer harvest period, a total of 22% was then recorded. This led to a higher ratio of predicted mortality for the harvest of the studied summer forested stands.

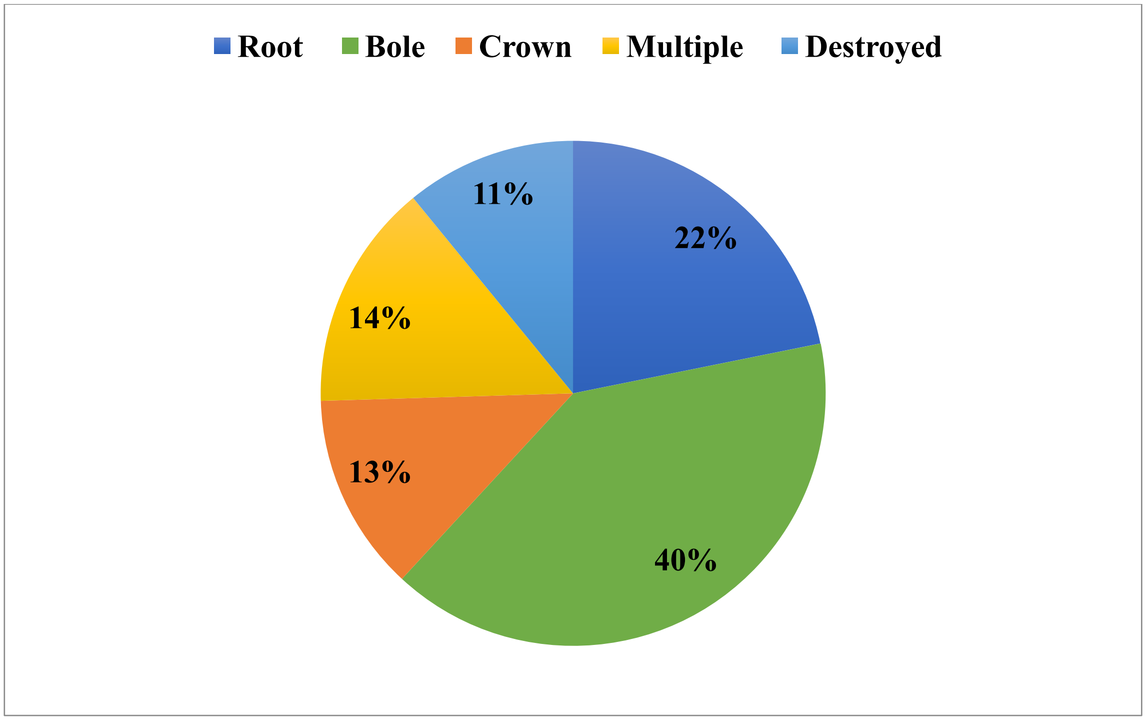


Figure 5. Damage to residual trees during the summer harvest period.

Wound Characteristics

The Table placed below (Table 1) outlines the collected data on trees found within the studied plots. The table was created for the observation of specific detail on the tree's; species, the quantity of wounds, the position of the wound, surface area and depth of the wound and lastly the diameter (DBH). Trees larger than 10 cm in diameter were tallied within all sections particularly within the wound characteristic tally. This diameter class was chosen to relate back to other studies research and conclusions of wounds and what the future holds for trees affected. Wounds found within the spring months seen long wound lengths, whereas summer wounds were found to be high in area. The overall disturbances had widths over 10 cm and lengths up to 70 cm. The wounds found in the winter and fall period were small in comparison to the spring and summer and affected trees of smaller diameter class.

Table 1. Collected details on scars found within all 7 sites over seasonal periods.

| | Winter and Fall | | | Spring | | Summer | | |
|---|---|---|---|---|---|---|---|---|
| Species | Sugar Maple | Sugar Maple | Sugar Maple | American Beech | Black Ash | Sugar Maple | Sugar Maple | Black Ash |
| Quantity | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 |
| Position | Bole | Bole | Bole | Bole | Root | Bole | Bole/ Root | Bole |
| Size (cm) | 6 x 8 | 4 x 50 | 5 x 40 | 3 x 60 | 5 x50 | 20x 30 | 15 x 70 | 10 x14 |
| Depth | Bark | 6cm | Bark | 2cm | Bark | Bark | Bark | Bark |
| DBH (cm) | 12 | 20 | 12 | 10 | 24 | 16 | 24 | 34 |

Comparison of Machinery

The study results do not support the proposed hypothesis that harvest with chainsaw and cable skidder would be the best method of harvest. The results favor the T-425c feller buncher and 240 Timberjack over the chainsaw fell and skid method as the system had the lowest percentage of damage. Out of the 69 tallied trees within the surveyed plots an overall damage percent of 21% was recorded. The collected data for harvest done using the T-425c feller buncher and 240 Timberjack skidder is displayed in Figure 6. The highest amount of recorded damage done on the stands using the feller buncher which showed a total of 14% (10 trees) damage on the bole of trees. Such damage was found due to skidding practices and wounded trees were classified as protection trees (bumper tree). As wounds are found inevitable bumper trees help to prevent increased rates of further wounds. The remaining damage had low counts of multiple wounds (3) and a low rate of destroyed trees at 2 stems overall.

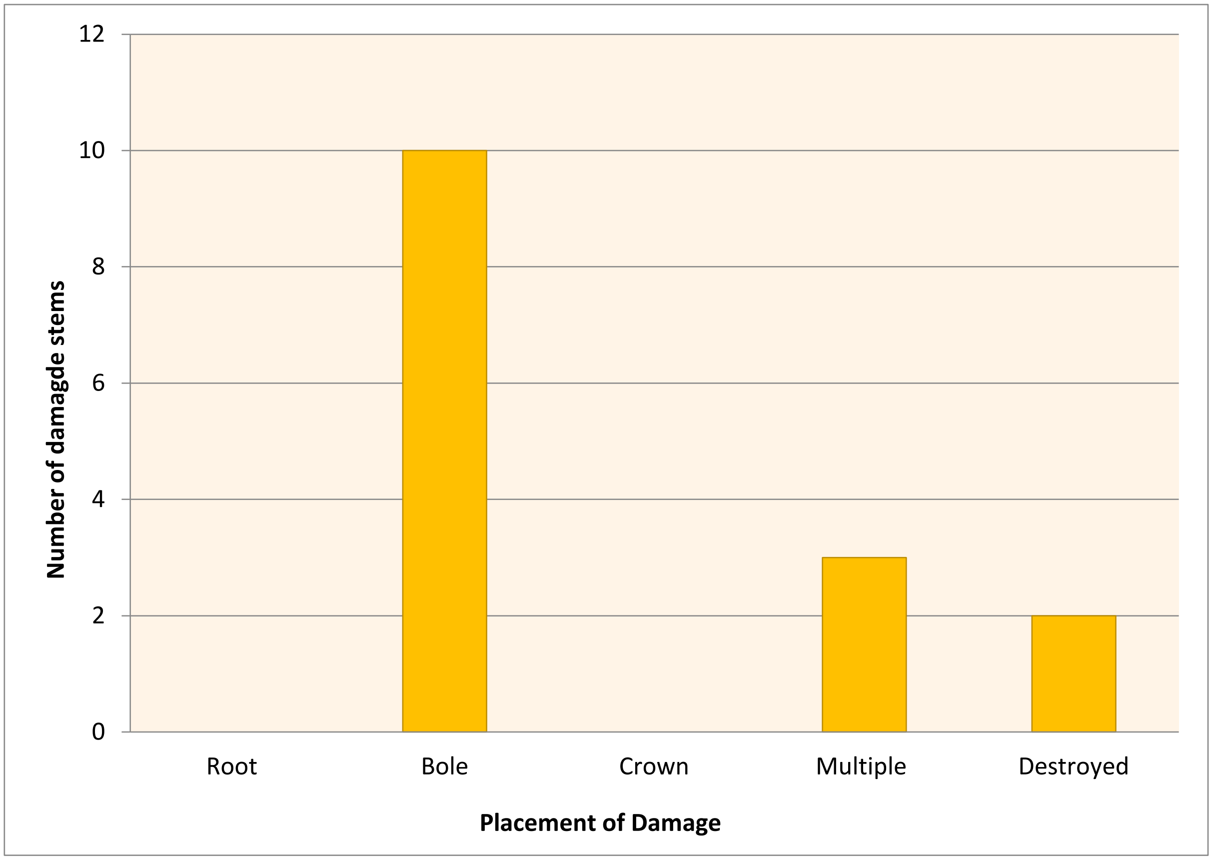


Figure 6. Damage to residuals after harvest by T-425c Feller Buncher and 240 Timberjack Cable Skidder.

The unfavoured method of harvest according to the results collected is the chainsaw and the 225 Timberjack cable skidder having a total of 3 recorded sites. Figure 7, proved to show higher rates of bole damage due to felling and skidding damage at a total of 18 trees. A higher rate of damage to the crowns was apparent with a total of 12 trees due to felling. Root damage had higher rates when compared to Figure 6, which was totaled out at 9 trees. This can partially be acquitted being the season of harvest the study sites took place during the summer and spring. Total damage percentage associated with such method of the harvest was 71% compared to 21% for feller buncher and 240 Timberjack cable skidder.

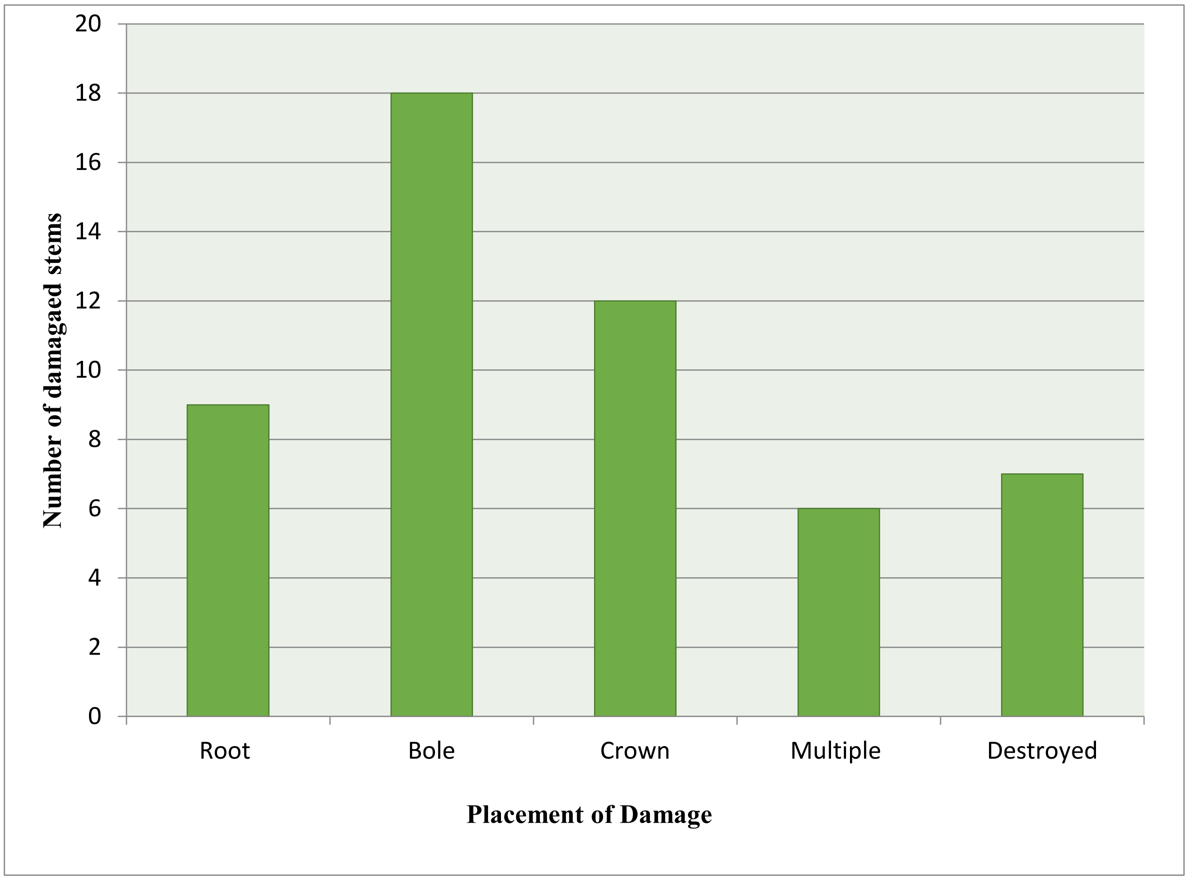


Figure 7. Damage to residuals after harvest by Chainsaw and 225 Timberjack Cable Skidder.

The results overall have an alarming ratio of damaged to undamaged stems found within blocks. The stands observed were cut by a team of careful loggers and tree markers, of which brings forth the question on what else could have been implemented in order to prevent damage or damage just inevitable as Nyland (1991) states.

# DISCUSSION

Determining the overall extent of residual damage when using two different methods of harvesting equipment proved to give way to an adequate source of information and results. This information helped gain the recommended machinery, time of harvest and preventative measures as to not damage residual trees. Through the collection of data regarding recorded wounds and details regarding each site, a considerable representation of why careful logging is a crucial practice needing to be implemented. It should be noted that other studies showed a steady increase in growth and vitality post-harvest, giving great hope that if harvest is done in a conscientious manner the future of a forest will not only have strong growth and exuberance but could be capable of holding great economic value.

Accomplishing harvest in a conscientious manner can also mean the use of careful logging techniques within harvests. Caspersen (2006) stated within his research that "It is commonly believed that collateral damage to residual trees can also be minimized if careful logging practices are employed". In acknowledging Caspersen's work, the concept of CLP's is incredibly beneficial for hardwood harvests as any drastic changes to the silvics or significant damages to stems can lead to decline in overall health and productivity of a forested stand. While walking through the seven stands it is apparent that the pre-walk through of the potential harvest involving a skilled tree marker and logger is key to ensure harvest is done as carefully as possible. Tree marking is given a high level of responsibility to those practicing as it is the wish that a marker wants to give a forested stand the best viably sustainable future possible. If tree marking is not done in an attentive manner the stands analysis and written prescriptions could be incorrect. It is not just the analysis and prescription that could be incorrect but the stands overall future could be in jeopardy (OMNR 2004). This particular study looked over stands marked by a worker that has worked within the forestry industry for roughly 10 years. The skill gathered by the marker over the years showed while collecting data. Damage was recorded in high damage percentages throughout the observed stands nonetheless it should be stated that without the skilled tree marker present the stands that had high initial basal area and high valued stems present could have had higher rates of damage rates that could have occurred in higher volumes. Skilled markers are highly interested in the present value of stems. They acknowledge the future a stand holds in terms of recognizing the values of residual stems for the next harvest cycle through close observation on crown position, crown size, and bark characteristics when marking. In holding high standards towards the management of present and future harvest cycles, tree markers have the ability to alter stands into a healthy and sustainable outcome.

Steps taken before harvest can also involve the development of a plan of action involving specific machinery suited for the stand and where each tree will be directionally felled and hauled out of stands. The marker on the stands observed within the study ensured careful felling routes were placed when marking stems.

When working with a chainsaw only a portion of the work is done by the feller and the other is done by the tree itself. An experienced feller can direct the tree where they wish it to go in a manner that is safe and won't damage other trees around. However, even in the case of an experienced feller, some issues can arise. For the study two chainsaw fellers one with roughly 20 years’ experience and the other having 10 years, problems did arise. As discussed with one of the fellers, it was stated that " you can have years of experience but error can still occur because at the end of the day that tree is going to do what it wants." Results collected within the chainsaw felling portion had higher rates of felling damages of which occurred to the crown and bole of trees. A discussion on why the damage occurred with the fellers resulted in high winds and sites where a high initial basal area was a limiting fell factor. An example of one of the chainsaw sites is below in Figure 8, being this particular study site had high initial basal area. The site also showed a high crown cover percentage before and after harvest. This stand saw large outcomes of fell damage towards the crown and bole of trees due to the high densities and large healthy crown structures. Sites like this can be difficult to fell in for any skill level.

Figure 8. Site 2: Chainsaw and 240 Timberjack Cable Skidder site with a high basal area. Lamont 2018.

The feller buncher's relation to fell damage had little recorded disturbances. Mechanical properties found on the head of a feller buncher has the ability to cut and control the felling of trees so as to help prevent scaring caused by felling (USDA 2019). Be that as it may, it is still recognized that an operator with a high skill level is paramount when working on mixed hardwood forests.

In terms of having an operator with experience in the use of proper machinery, stress on residual trees can be condensed to a minimum (Sist and Nguyen-The 2002). In Canada, forest operations provide crucial economic, social and environmental importance. If forested stands are not managed in a means to protect and promote growth, operations can affect not only the environmental components but the Canadian economy. Currently, Southern Ontario has seen several acres of forested stands being converted to farmland or urban centre's. In acknowledging the decreased forested stand regions, forestry workers are inaudibly inclined to take care of remaining stands through close perception on the machines and methods used during harvest on single tree selective stands.

There are lower rates of harvesting within the Southern region of Ontario in comparison to Northern Ontario as well the land characteristics vary among the two regions. Different machinery and methods of harvest are used within the Southern region with manual felling being most common from farmers to small ran logging companies. Companies owning felling machines have a great advantage in terms of felling large volumes of timber in a safe manner. The comparison of manual felling and machine felling techniques give a close representation of just how imperative it is to choose the right equipment for each harvest site. A larger model of skidder (240 Timberjack) was paired with the Timbco feller buncher of which had higher recorded rates of skid damage compared to the smaller model of skidder (225 Timberjack) within the manual felling operations.

From less residual damage to a lower initial cost, small skidders are the preferred machine for thinning and selective cuts. Unfortunately to achieve higher machine efficiency rates the bigger the machine the better (Robe 1988). Although the bigger the better can lead to higher residual damages rates, observations recorded prove the smaller machinery is preferred when wanting to manage for lower damage rates. The decision of big or small is all dependent on site characteristics and the operator’s skill level.

As both skidders studied are cable skidders (Figure 9 and 10) it is relevant to state that some of the skid damage is associated with the logs being hauled behind the machinery. Logs of which are normally in full tree length form. This method can prove to have maneuverability issues within stands that can cause rubbing on standing trees. Rubbing damage can be subsided through use of felling operators placing stems in areas with favorable room and smooth skid routes out to road landings.


Figure 9. 240 Timberjack Cable Skidder. Lamont 2018.

Figure 10. 225 Timberjack Cable Skidder. Lamont 2018.

From skilled tree markers to machinery there are many other factors that have the potential to influence rates of residual disturbance. Harvest time periods demonstrated to have major influence on wounds found post-harvest. Harvest's occurring within the winter and fall seasonal periods were verified to have lower rates of revealed damage to stems. Dormancy during the colder months improves bond strength throughout the entirety of the tree, proving to be a reliable time of harvest if one is wishing to decrease damage to the bark and inner parts of trees. Colder harvest periods demonstrate protection as well to the bole and roots with snowfall present. Spring and summer harvest periods are known to have wet, mucky periods, increasing soil compaction. Site two had been wet for several days during harvest, operators paused work until the site had dried up. If not given the chance to dry elevated rates of compaction and site damage would have occurred.

Recorded wound damage brought forth uncertainty on whether trees observed with damage had the potential to heal and reboot themselves rather than a decline in health and value. It is stated that wounds present on the remaining standing trees will deteriorate timber quality through the process of wood staining and decay (Bobik 2008).

Two main concerns within the observed study sites is the future result of the recorded wounds found and the prediction of what stands hold in the future. Having little time to see what the future holds for the studied sites, background from other studies were put together to give predictions on damaged stems. Caspersen (2006) reported trees over 10cm in diameter would see an increased mortality rate by 5% immediately after cutting. Stands examined hold high composition of the species sugar maple, species of which hold a 40% chance of dying after and before next cut cycle begins. The recorded wounds are sampled on trees higher than 10cm in diameter in order to show proof of short term mortality for stems experiencing wound damage. The wound present within Figure 11 is one of the many wounds found on the different sites. This particular wound is not wide nor long in length and found at breast height giving way to a lower percentage of decay and any type of mortality that could occur due to harvesting (Zeglen 1997).

Figure 11. Tree experiencing wound damage due to felling, using a chainsaw. Lamont 2018.

The tree present in Figure 12 is experiencing a large dark-faced scar that is in contact with the ground and root base. Contact with ground allows the surface to remain moist providing suitable habitat for fungi (Anderson 1994). The width, length, and placement of such a scar will lead to the eventual mortality of the tree.

Figure 12. Bumper tree with large wound. Lamont 2018.

# CONCLUSION

Prevention of residual damage can happen in a variety of ways. It is important for forestry workers alike to know and acknowledge preventative measures during all stages of harvesting. As damage can occur at any time, any place and under any condition, the inevitability of harvest damage will always have a factor yet can be minimized if precautions are put in place. Through observation regarding equipment used, time of harvest and wound damage present on sites, steps on how harvests can develop stands into holding not only economic value but a future healthy sustainable stand can be accomplished. The projected hypothesis on harvest during winter proved to be correct in nature, with lower rates of damage occurring on sites that were harvested during the fall and winter dormancy periods. The second hypothesis of the recommended machinery was rejected as the feller buncher harvest combination proved to have the least amount of damage when compared to the chainsaw harvest sites.

The ending results indicate that disturbances were recorded on stands. Wounding still occurred where careful logging techniques were put in place even though pre-harvest walkthroughs and planned cut and skid routes were implemented. Disturbance towards soils, stems, and biodiversity will almost always occur, however logging in a careful mindset will decrease the rates in which damage effects in a negative way. Positive influences within harvest can not only lead to decreased rates of damage but lead to a better understanding of why careful logging practices can impact stands in a viably healthy perspective.

In closing, there are few recommendations based on the knowledge and results gained from the study that can be implemented before harvest as a means of prevention. Steps included are: 1) restrictions on harvesting operation season, 2) matching size of machinery to site conditions, 3) plan the needed skid and fell routes, 4) place bumper trees, and 5) establish the right skill level of an operator based on site characteristics (Zeglan 1997). Although some implications may arise among harvest sites making steps to reduce damage almost impossible, it should be noted that as long as multiple prevention measures are placed into harvest plans, potential disturbance can be mitigated. Through close stand observations and special care over stands, residual damage can be limited thus resulting in a future stand that encompasses healthy, high-quality stems of all ages and sizes.

# LITERATURE CITED

Anderson, H.W. 1994. Logging damage: The problems and practical solutions. OMNR. Ontario Forest Research Institute. For. Res. Info. Paper. Queens Printer for Ontario. 117.

Anderson, H.W., and Rice. J.A. 1993. A tree marking guide for tolerant hardwoods working within group in Ontario. Ontario Ministry of Natural Resources, Science and Technology Series, Volume 8. 227pp.

Anderson, H. 1991. Some implications of logging damage in the tolerant hardwood forests of Ontario. OFRI. Maple. Ontario.

Bobik, M. 2008. Damages to residual stand in commercial thinnings. Master's thesis. SLU, Southern Swedish Forest Research Centre. Volume 127.

Caspersen, J. 2006. Elevated mortality of residual trees following single-tree felling in northern hardwood forests. Can. J. For. Res. 36: 1255-1265.

Dey, D. 1993. Careful logging, partial logging and the protection of terrestrial and aquatic habitats.

McNarma, R. 1997. Jardiage de Forets feuillus tolerants avec abatteuse. Groupe Forestier Intech Inc., Lachute, Que. In: R.McNarma, et al. Strategies for reducing the cost of mechanized selection harvesting in hardwood forests. For.Eng.Inst.Can.(FERIC), Pointe-Claire, Que. Tech. Note TN-298. 8pp.

Meadows, J. 1993. Logging damage to residual trees following partial cutting in a green-ash sugar berry stand in the Mississippi Delta. USDA For. Serv. Southern Forest Experiment. 9th central hardwood forest conference. Miscellaneous publication.

Meek, P. 1997. Mechanized selection harvesting in hardwoods with Timbco T-445. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Tech. Note.TN-265.12.

Ministry of Natural Resources. February 2003. Interim Investigation of Selection Harvesting Damage to Tolerant Hardwood Stands in Central Ontario.

Nambiar, E.K., Sands, R. 1992. Effects of compaction and simulated root channels in the subsoil on root development, water intake, and growth of radiata pine. Tree Physiol. 297-306.

Nyland, R.D. 1991. Careful logging in northern hardwoods. Syracuse University, New York, College of Environmental Science and Forestry, Syracuse, New York. 22 pp.

Ontario Ministry of Natural Resources. 2004. Ontario tree marking guide, Science and Technology Series, Version 1.1. 72-73pp.

Ontario Woodlot Association. January 2009. A landowner's guide to Careful logging.

Robe, S. 1988. Comparison of a large and small grapple skidder in a pine plantation thinning application. Personal thesis. Faculty of the Virginia Polytechnic Institute and State University.

Silversides, R.C. 1997. Broadaxe to flying shear. The mechanization of forest harvesting east of the Rockies. Transformation Series. National Museum of Science and Technology.

Sist, P., and Nguyen-The, N. 2002. Logging damage and the subsequent dynamics of dipterocarp forest in East Kalimantan (1990– 1996). For. Ecol. Manage. 165: 85–103.

Smeltzer, D.LK., D. R. Bergdahl, and , J. R. Donnelly. 1986. Forest ecosystem responses to artificially induced soil compaction II. Selected soil microorganism populations. Can. J. For. Res. 16: 870-872.

Straughan, A. 2003. Selection harvesting damage in tolerant hardwoods of central Ontario. Personal Thesis.18pp.

USDA. 2019. Feller Buncher. https://www.fs.fed.us/forestmanagement/equipment-catalog/fellerbuncher.shtml. March 2019.

Wilde, O. 1891. The Soul of Man under Socialism. https://www.marxists.org/reference/archive/wilde-oscar/index.htm. December 2018.

Zeglen, S. 1997. Tree wounding and partial -cut harvesting: a literature review for British Columbia. Pest Management Report 14: 1-48.

# APPENDIX

**Total trees found within each plot.**

| Plot Number | Stand 1 | Stand 2 | Stand 3 | Stand 4 | Stand 5 | Stand 6 | Stand 7 |
|---|---|---|---|---|---|---|---|
| 1 | 12 | 11 | 10 | 8 | 10 | 8 | 12 |
| 2 | 13 | 12 | 9 | 6 | 6 | 12 | 13 |
| Sum of all trees | 25 | 23 | 19 | 14 | 16 | 20 | 25 |

**Fall and Winter Harvest**

| **Type of Damage** | Stand 3- Plot 1 | Stand 3- Plot 2 | Stand 4- Plot 1 | Stand 4- Plot 2 | Stand 5- Plot 1 | Stand 5- Plot 2 | Stand 6- Plot 1 | Stand 6 Plot 2 |
|---|---|---|---|---|---|---|---|---|
| Root | | | | | | | | |
| Bole | 3 | 2 | 1 | 1 | 1 | 2 | | |
| Crown | | | | | | | | |
| Multiple | 2 | 1 | | | | | | |
| Destroyed | | 1 | 1 | | | | | |

**Summer Harvest**

| Damage Type | Stand 1- Plot 1 | Stand 1- Plot 2 | Stand 2- Plot 1 | Stand 2- Plot 2 |
|---|---|---|---|---|
| Root | 2 | 3 | | 1 |
| Bole | 4 | | 4 | 3 |
| Crown | 1 | 2 | 2 | |
| Multiple | | | 2 | 1 |
| Destroyed | 1 | 2 | | 1 |

**Spring Harvest**

| Damage Type | Stand 7- Plot 1 | Stand 7- Plot 2 |
|---|---|---|
| Root | 2 | 1 |
| Bole | 5 | 2 |
| Crown | 4 | 3 |
| Multiple | 2 | 1 |
| Destroyed | 2 | 1 |