SUSTAINABLE FOREST MANAGEMENT: POTENTIAL IMPACTS OF UNDERUTILIZATION IN ONTARIO CROWN FORESTS

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ABSTRACT

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Keywords: Average Allowable Cut, annual increment, underutilization, volume, fire risk, mixedwood, old-growth, water quality, economics, forestry, landscape goals.

Ontario has in recent history harvested a volume in cubic meters less than the volume available to harvest as dictated by the Average Allowable Cut (AAC). While harvesting more than the AAC dictates is unsustainable and will lead to mature wood supply shortages, this study aims to analyze and discuss the impacts of the current rate of underutilization in Ontario's forests, whether positive or negative. A literature review was conducted, and the following were identified as components potentially impacted by underutilization: water quality, old growth area, mixedwood biodiversity, fire risk, economic consequences, volume, and future landscape goals. A case study was conducted on two forests experiencing underutilization: the Algoma Forest and the Kenogami Forest. It was found that water quality, old growth area, and mixedwood biodiversity are potentially positively impacted by the current rates of utilization in Ontario. However, there are negative implications for volume, economies associated with the forest, and in the ability to meet future landscape targets and long-term management directions (LTMD's). It is inconclusive whether there is an impact to fire risk associated with underutilization.

Further studies are needed to completely understand the impacts that the current harvesting rates are having on the landscape to inform Ontario Forest managers and acquire a better understanding of anthropogenic impact, or lack thereof, on the landscape.

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INTRODUCTION

Annual Allowable Cut (AAC) is the volume of industrial roundwood able to be harvested from provincial crown land in each province, each year, sustainably (Environment and Climate Change Canada, 2018). The volume will fluctuate up or down with each passing year and is an estimate made by professional foresters based on several calculations and values (Environment and Climate Change Canada, 2018). One of the most important values associated with AAC is the mean annual increment (MAI). MAI is the yearly average volume growth of a stand, represented as cubic meters per hectare in Canada. MAI represents the volume of forest growing back yearly, so AAC must take that into account to avoid cutting more volume than can be replenished. Other values affecting AAC include animal habitat area, and down woody material quantities (Environment and Climate Change Canada, 2018).

As stated previously, the AAC is a measure of sustainability. It is measured as a percentage out of 100, with 100% representing harvesting the maximum amount of volume able to be removed that year before you begin to cut more volume or area than can be replenished within that year. Therefore, a reasonable conclusion to harvest levels above AAC (over a period of time) would be that it is an unsustainable practice which may jeopardize the future wood supply. While harvesting above AAC would be unsustainable, there is little work done analyzing the potential impacts, whether positive or negative, of continuous harvest below volumes or area allowed, as dictated by the AAC. Another metric used to dictate allowable harvest levels is Available Harvest Volume (AHV). Another harvest centered measure of sustainability is the approved Available Harvest Area (AHA). The AHA is important within the context of Ontario, as

Forest Management Units (FMU's) within the province dictate their allowable cut based on area, rather than volume (Bisschop et al., 2003). AHA is expressed by forest unit and age class, providing important contextual information on which sections of the forest the planned harvest volume will derive from (Bisschop et al., 2003). Similar to the AAC, the AHA represents the maximum area that can be harvested within an FMU over the duration of a management plan (Bisschop et al., 2003). There are several benefits to using area as the harvest level indicator. Doing so allows for management to base operations on landscape values, with both timber and non-timber resources considered when harvest planning (Bisschop et al., 2003). Non-timber values are considered with allowances for residual areas that will not be impacted by harvesting or forestry operations (Bisschop et al., 2003). Non-timber values can include important wildlife habitat, or areas of social importance, such as stands adjacent to cottage lakes where aesthetics are wanted and valued. It also allows for a higher amount of strategy in planning for desired future landscape goals, by taking a land base approach to allowable harvest (Bisschop et al., 2003). Once the AHA is calculated and potential harvest areas are selected, volume estimates are then created for those areas, which are then compared to the forests AAC or AHV to ensure harvests are sustainable.

Underutilization in Forest Management

It is important to understand what is meant by underutilization within a forest management context. Underutilization itself is defined as utilizing less than the full amount or below the potential use (Merriam-Webster, n.d.). A forest resource-based interpretation from Finland defines the degree of underutilization as the ratio of actual cuttings to planned cutting needs (Kiukaanniemi, 2000). Essentially, underutilization of forest resources can be understood as harvesting a level below what is deemed the available sustainable level. The opposite of this is over exploitation of forest resources. Over exploitation would involve harvesting levels greater than what is deemed ecologically sustainable. Full utilization would be in the middle, where harvest levels are at or just bellow the allowable level. This would allow the maximum amount of area to be managed each year, which would cause more land to be affected by human activity but would also increase industry efficiency and aid in meeting pre-industrial condition goals. Underuse is caused by a variety of reasons. The main drivers found to influence underutilization are demographic, socio-economic, and institutional (Miyanaga & Shimada, 2018). In Ontario, underutilization has occurred for at least two decades. In 2022, Ontario utilized only 43.2% of the AHV of 28,399,823 m^3, with 71% of the utilized volume being spruce/pine/fir (MNRF Forest Explorer, 2023). The ten-year average for percentage of AHV utilized from 2012 to 2022 was 46.8%, representing an average yearly volume of 13,700,593 m^3 during this span (MNRF Forest Explorer, 2023).

History of Sustainable Forest Management in Ontario

Ontario has a deep history of forestry and related management activities. The rationale and goal behind forest management in the province has evolved over time as science and experience developed and created a better understanding of best practices and societal needs have changed. Initial management was centered around revenue maximization, where timber duties and manufacturing conditions were placed on pulp mills in exchange for a secure supply of wood (Winfield & Benevides, 2003). This focus shifted when foresight gave concern to overharvesting and a distaste for rampant forest industry waste developed (Winfield & Benevides, 2003). Sustainable forest management began to take shape with the implementation of the Forest Reserve Act of 1898, allowing the provincial cabinet to designate areas as reserves for the future (Winfield & Benevides, 2003). The Pulpwood Conservation Act of 1929 introduced the first mandatory Forest Management Plans to pulp mills within the forest they had the cutting rights to (Winfield & Benevides, 2003). The basis of which was Sustainable Yield, a management practice with a focus on perpetuating timber resources (Walker, 2011). However, with little enforcement, management planning sometimes became an after thought. 1947 marked another turning point, as the Kennedy Commission (Royal Commission on Forestry) released a report declaring that Ontario's forest resources would be depleted if significant changes to cutting and regeneration requirements were not imposed (Winfield & Benevides, 2003). The just of their suggestions were a shift from sustained yield to future forest policy, and the separation of companies who processed wood fibres from the management duties post-harvest as there was deemed to be a conflict of interest at times due to the need for wood supply in the present outweighing responsible management behaviour (Winfield & Benevides, 2003).

While the Kennedy Commissions suggestions were not implemented, the introduction of the 1947 Forest Management Act introduced mandatory forest inventories as well as long-term cutting and operational plans to be undertaken by industry and approved by the minister (Winfield & Benevides, 2003). In 1953 the government brought changes to the Crown Timber Act. One of the most important changes was a revision of the licensing structure, where 21-year licenses were introduced in the hopes of providing more stability and therefore incentive for licensees to undertake regeneration activities responsibly and properly, which were also assigned to licensees under the changes (Winfield & Benevides, 2003). This policy was short lived however, and in 1963 further amendments to the Crown Timber Act transferred regeneration activities back to the province of Ontario (Winfield & Benevides, 2003).

Another review of Ontario's Forest Management Policy was undertaken in 1976, in large part due to the continuing concerns over the regeneration of Crown forests (Winfield & Benevides, 2003). A University of Toronto forestry professor named Kenneth Armson was given the task of reviewing the condition of the province's forests (Winfield & Benevides, 2003). Armson concluded that Ontario was nearing the end of its natural exploitable forest, and that the separation of regeneration responsibilities from private licensees had been a major misstep (Winfield & Benevides, 2003). Armson found that licensees were not focusing on management, but rather exploitation, which had caused the threat of over-exploitation (Winfield & Benevides, 2003). Armson's main recommendations were the introduction of tenure of Crown Forest lands for large forestry companies, creating security and incentive to properly manage the regeneration of the forests in which they were responsible (Winfield & Benevides, 2003). The Crown used these recommendations in the 1979 Crown Timber Amendment Act, establishing Forest Management Agreements (FMAs): 20-year exclusive harvesting rights agreements between the province and the forestry companies (Winfield & Benevides, 2003). Along with the rights came the responsibility of complete management for the area in question (Winfield & Benevides, 2003).

In 1985 it was recommended that the principle of Sustained Yield become mandated by law, a shift begins in which clearcutting is utilized less, and an independent audit agency be established to monitor and report the status of Ontario's Forests (Winfield & Benevides, 2003). Additional calls for a revitalization of how non-timber values, such as wildlife, were monitored and recorded (Winfield & Benevides, 2003). These led to the establishment of a new forest policy taskforce, the creation of a provincial forester position, and a Class Environmental Assessment of Timber Management on Crown Lands (Winfield & Benevides, 2003).

The Class Environmental Assessment (CEA) of Timber Management on Crown Lands was the largest and most comprehensive review of forest policy and management in the history of Ontario (Winfield & Benevides, 2003). It took place from 1988 to 1992, with final decisions coming in 1994 (Winfield & Benevides, 2003). The CEA results were, in general, favourable to the current direction undertaken by the Government of Ontario, however it imposed 115 terms and conditions within its decision that would guide forest management moving forward (Winfield & Benevides, 2003). Issues addressed by the terms and conditions varied, but primary issues included the development and approval of Timber Management Plans, public participation in forest management processes, and protection of wildlife and other non-timber values (Winfield & Benevides, 2003). A key factor in the decision was the need for better monitoring and reporting (Winfield & Benevides, 2003). Multiple compliance and monitoring stipulations were developed in the decision, which would be introduced in 1994 with the Crown Forest Sustainability Act (CFSA) (Winfield & Benevides, 2003).

The CFSA was a complete replacement of the Crown Timber Act, shifting focus from purely maximizing sustainable yield to including the social, environmental, and economic needs of present and future generations (Winfield & Benevides, 2003). Forest Management and Planning Manuals would be developed to define sustainability, with the goal of producing and conserving large, diverse, healthy forests with a natural emulation-based approach (Winfield & Benevides, 2003). FMAs were replaced with the current licensing system, Sustainable Forest Licenses (SFLs), which established requirements for inventory preparation, silvicultural standards to be met, mandatory report submission requirements, periodic reviews of licensee performance, and the term of license and applicable conditions for license renewal (Winfield & Benevides, 2003). The Minister is also now able to enter new licenses, such as “supply agreements”, known as Forest Resource Licenses (FRLs). Mechanisms were introduced to ensure and enforce compliance, such as Stop, Compliance, and Repair Orders (Winfield & Benevides, 2003). The province is now split into Forest Management Units (FMUs), each of which is licensed with a SFL (Winfield & Benevides, 2003).

Annual Allowable Cut and Underutilization

Within Ontario, AAC is not determined in area or volume, instead area regulation is used. This then determines the harvest level in hectares for each forest management plan for each forest management unit in the province (National Forestry Database, 2023). It should be noted that allowable cut levels are not dictated by economic conditions or motivations, but a balanced view of economic, environmental, and social use considerations.

AACs, or AHA's are calculated for each FMU in Ontario during the planning process. These are derived from planning processes and the Long-Term Management Directions (LTMD) of the forest. LTMDs are planned future goals of the forest. The direction of LTMD is often a shift in landscape composition to estimated "pre-industrial" conditions (i.e. conditions occurring naturally in Ontario forests before the intervention of industry driven human activity) (Ontario Ministry of Natural Resources and Forestry, 2014). With this considered, it makes sense for Ontario to dictate harvest levels by area, rather than volume, as it serves as an ideal method in converting large areas of the land base over time. Stands are selected for harvest with modeling. For instance, in the Lakehead Forest, the allowable harvest area is a modeling output that considers sub-management units or management zones (areas with different management priorities or situations), areas important to moose, and the amount of area belonging to each forest unit and age class (Greenmantle Forest Inc., 2020). Allowable cut figures can be derived using a variety of formulas or methods, with the common denominator between them being the allowable cut must be within what the forest can replenish within a given period.

Ontario as a whole has harvested considerably less than the AAC since the mid to late 2000's (MNRF Forest Explorer, 2023). This is in large part due to the U.S. recession in 2007, which had worldwide economic impacts. Lumber production in Canada decreased from 81.2 million cubic meters to 45.5 million cubic meters between 2006 and 2009 (Couture & Macdonald, 2013). While the industry has partially recovered since then, demand for lumber and pulp and paper products still are not what they once were.

This directly affects harvest levels, as without demand, there is no need to spend time and resources amassing extra supply.

OBJECTIVE

The objective of this undergraduate thesis is to define and analyze some potential impacts of underutilization of Ontario's Crown forests. Impacts identified can either be labeled as positive, negative, or inconclusive. For the purpose of this thesis, underutilization will be defined as harvesting at a level far below what can be ecologically sustained by the landscape. In Ontario, this is represented with AAC or AHA. This analysis will be conducted using peer-reviewed scientific literature, publicly available government documents and resources, both provincial and federal, and critical thought. The hope of this study is to examine underutilization, the potential impacts associated, and the importance or relevance of these impacts. Underutilization is a reality faced by most forest managers today because of the economic conditions within the forest resource sector. As such, it is important to understand the affects underutilization can have on forests, so that managers can better adapt and adjust management activities to meet future goals.

HYPOTHESIS

The hypothesis of this paper is that there are identifiable impacts, whether positive or negative, caused by or associated with the current underutilization of Crown Forests in Ontario. The alternative hypothesis is that there are no identifiable impacts, whether positive or negative, caused by or associated with the current underutilization of Crown Forests in Ontario.

LITERATURE REVIEW

Old Growth Habitat

Old growth forest is an important ecosystem found within Ontario. As the name suggests, old growth forest takes many years to establish. Ontario defines old growth forest as the age at which a species has attained at *least* 75% of its maximum potential diameter and makes up *more than* 50% of the stand basal area (Uhlig et al. 2001). As such, the definition varies based on eco-type, with different tree species reaching the old-growth age-of-onset at different ages (Issekutz, 2020). Other factors are also considered when defining old growth, like snag quantity and quality, downed woody material accumulation, and ecosystem functions that differ from young to intermediate stages of forest development (Issekutz, 2020).

The optimum rotation age for Ontario boreal forest is 100 years of age, based on economic gains and ecosystem services provided (Chen et al. 2017). Earlier or later rotations will yield diminishing returns or will not yield the maximum economic gain (Chen et al. 2017).

Old growth forests provide a multitude of ecosystem services and benefits. For instance, old growth forest can fix large amounts of Carbon Dioxide (CO^2) from the atmosphere, storing it within the biomass of the forest and helping to battle against climate change (Gihlen-Baker at al. 2022). They serve as niche habitat, often creating microclimates within them that sustain wildlife (Gihlen-Baker at al. 2022). One of Ontario's most prevalent species at risk, the Caribou (*Rangifer tarandus*), require large areas of mature and old growth forest to inhabit, as there is less competition from other ungulates and a lower density of predator species (Environment and Climate Change Canada, 2023).

Caribou are also very sensitive to the inevitable disturbance caused by forestry operations. A study conducted in the boreal regions of Ontario and Quebec found that the average percent of the level of disturbance within local caribou population ranges was 53.5% (Mackey et al. 2024). This is especially concerning as the recognized maximum level of disturbance that will still sustain local, range self-sustaining caribou populations is ≤35% (Mackey et al. 2024). The study covered 21 boreal caribou ranges and found that four were at very high risk, 15 were at high risk, and only two were low risk (Mackey et al. 2024). The ranged found to have ≤35% level of disturbance has passed the "conservation" phase of management, and now require "restoration" management if they are to persist and recover (Mackey et al. 2024).

Within the total study area, it was found that approximately 28% of the total area had been recently logged (since 1976), however a large area was likely also logged pre-1976 (Mackey et al. 2024). Most of the "un-logged" area within the study was within the Northern most areas, where there is often less infrastructure and lower incentive to log (Mackey et al. 2024). While disturbance is a naturally occurring factor within the boreal forest, the impacts of non-natural disturbance differ from natural disturbance regimes and the resulting successional forest composition (Mackey et al. 2024). Notably, the landscape-level extent of older forests was found to decrease when managing for industrial wood production (Mackey et al. 2024).

Another important species reliant on old-growth conifer characteristics is the American Marten (*Martes americana*). American Marten are often utilized as an indicator species (Parks Canada, 2022). Indicator species serve as environmental indicators, with their health serving as a reflection of the state of their environments (Lawton & Gaston, 2001). As such, they are often the first species in an ecosystem to indicate the impacts of environmental change within an ecosystem (Lawton & Gaston, 2001). Marten serve as an indicator species of forest ecosystem integrity, specifically ecosystems with old growth conifer characteristics (Parks Canada, 2022). Logging especially disrupts Marten production and survival rates (Thompson, & Colgan, 1994). In uncut, old growth forests, Marten are able to catch more prey (Thompson & Colgan, 1994).

However, harvesting, and silvicultural practices may play a large role in the preconceived notion of marten and other old growth species doing poorly around forest management (NCASI, 2005). There are studies from a variety of Canadian provinces that suggest that while undisturbed old-growth coniferous forests may be the best quality habitat for American marten, responsible harvesting and silvicultural practices can create areas where a viable population of marten can persist while deriving natural resources from the forest (NCASI, 2005). It may be that age is not the deciding factor in marten habitat quality, but rather the vertical and horizontal structure commonly found in these forest types (NCASI, 2005). As such, silviculture and harvest strategies that maintain large patches of residual forest and promote vertical and horizontal structure can serve as a compromise between wildlife habitat and anthropogenic natural resource needs (NCASI, 2005).

Ontario and boreal forest old growth is in decline. Anthropogenic activities have begun to take their toll, especially industrialized forestry (Martin et al. 2021). Natural disturbance has always been the driving factor behind stand-replacing processes in the boreal forest, and while fire disturbance does and will affect old growth forest, it differs from the impacts human activity has on old growth removal (Martin et al. 2021). The economically driven decision making that often affects industrial forestry can cause stands with higher economic value to be targeted first, or only, by logging activity. By doing so, the ecosystem value these stands provide are removed, and the biodiversity of the forest can be weakened. A study by Martin et al. in Quebec boreal forests conducted between 1985 and 2016 and published in 2021 found that old growth removed by wildfire was low to moderately productive or recently disturbed, while logging activity was conducted in old growth with the highest economic value and productivity. The study concluded that anthropogenic activity reduced the functionality and diversity of old growth, leaving remnant primary forests with questionable resilience and lower resistance, higher risks of regeneration failure, and higher fire susceptibility (Martin et al. 2021).

When forest management areas have a large proportion of old forest, it can add flexibility to meeting landscape targets while keeping volume targets (Mathey et al. 2009). High volumes of old growth forest can allow managers to fill missing age classes by allocating volumes in a more flexible manner (Mathey et al. 2009). High amount of old growth allows managers to have more freedom in choosing where and when they want to harvest (Mathey et al. 2009).

Mixed Wood Biodiversity

Mixed wood forests are a boreal stand type containing a mix of tree species, often including both softwoods and hardwoods. In the Ontario boreal forest, these species usually include a mix of Jackpine (*Pinus banksiana*), White Birch (*Betula papyrifera*), Trembling Aspen (*Populus tremuloides*), Balsam Fir (*Abies balsamea*), and spruce (*Picea sp*.) (Ontario Ministry of Natural Resources and Forestry, 2023). Most of the mixed wood forest in Ontario is classified as within a mature age class, and most mixed woods are concentrated in the boreal regions of the province (Ontario Ministry of Natural Resources and Forestry, 2023). These forests represent important pieces of the boreal landscape. Recent years have seen a shift in forestry practices, with mixed woods being incorporated into future land base goals and strategies (Cavard et al. 2011). Research regarding mixed woods have suggested they bolster the biodiversity of avian species diversity in boreal forests, as well as ectomycorrhizal communities within temperate forests (Cavard et al. 2011). Boreal mixed woods have also been identified as important carbon stocks, typically storing more carbon per hectare than coniferous boreal forests (Payne, 2019). Much of this carbon is stored in the forest floor, which provides a medium of relatively stable storage throughout the stand’s lifetime, even when harvested (Payne, 2019). Additionally, mixed woods are created naturally within the disturbance produced mosaic of natural boreal regions and in the spirit of natural emulation and a shift to pre-industrial conditions, need to be developed and maintained within sustainable forest management (MacDonald, 1995).

Water Quality

Ontario contains over 250,000 defined lakes, with countless rivers, streams, and ponds between (Ontario, 2023). The prevalence of water bodies is felt by those in the industrial forestry industry, as they are often encountered during forest management activities. Water is defined in the Ontario Forest Management Guide for Boreal Landscapes (OFMGBL) as a value that may require coarse and fine filter approaches for adequate protection (Ontario, 2023). One of the key aspects of the OFMGBL is minimizing impacts of forest practices on water while utilizing natural disturbance emulation as much as possible (Ontario, 2023). SFL holders develop Area of Concern (AOC) procedures that dictate management activities in the vicinity of sensitive values, such as water bodies (Ontario, 2023). These are often derived from the Ontario Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales, 2010, such as the relatively new cut to shore practice. However, though natural emulation is heavily utilized, there is evidence that the impacts on water quality differ when disturbance is a result of forestry activities, rather than natural. A study conducted for three years between 1996 and 1998 in thirty-eight Boreal Shield lakes compared the impacts of harvesting disturbance and fire disturbance on water quality (Carignan et al. 2000). Disturbance took place at the onset of the three years, with the lakes being monitored and compared to reference lakes and each other (Carignan et al. 2000). Both disturbance types impacted water quality, however they differed in effect and severity in some thresholds (Carignan et al. 2000). Dissolved organic carbon (DOC), and light attenuation coefficient were higher in burnt and reference lakes (Carignan et al. 2000). Both disturbance types had higher levels of total phosphorus, total organic nitrogen, potassium, chlorine, and calcium, and nitrate than what was found in reference lakes. Sulfates were significantly higher in cut lakes than burnt or reference lakes (Carignan et al. 2000). Sulfate pollution may negatively impact aquatic fresh-water ecosystems, as it may be toxic to aquatic plant and animal organisms (Zak et al. 2021). Forestry operations have also been found to have stand alone impacts on water quality when not compared with other forms of disturbance (Shah et al. 2022). Harvesting activity causes the highest potential for adverse water quality impacts (Shah et al. 2022). Across the globe, sediment delivery was found to be the most significant and frequently impacted aspect of water quality due to forest management activity (Shah et al. 2022). It should be noted that annual mean concentrations were found to be below levels deemed ecologically damaging, however if storm events occur these levels can be raised and become damaging (Shah et al. 2022). Temperature of woodland stream and surfaces are found be impacted by management activity, as riparian zones are removed or diminished, weakening the temperature regulation potential (Shah et al. 2022). Dissolved organic carbon (DOC) and nutrient loses can occur after operations, however these are often short-lived impacts (Shah et al. 2022). It is also important to discern that factors such as local conditions, geography, and topography as well as operation methods play important roles in the type and severity of the impact generated by forest management activities (Shah et al. 2022).

Economic Consequences

While Ontario is currently experiencing underutilization, there is still a large industry in forest products. The situation is dire when compared to the forest industry the province once had before the 2000's. Another country facing challenges with underutilization is Japan. Due to a rise in reliance on imported wood products and substitutes, Japan has largely abandoned forest management practices (Oono et al. 2020). Japan has depended on wood imports for never less than 64% of its needs since 1973 (Oono et al. 2020). This is a massive percentage for a country with 68.5% forest cover (Oono et al. 2020). There are multiple reasons for why this is. The main two reasons are socio-economic conditions, and the implementation of nature protection plans that permanently exempt areas from management (Oono et al. 2020). The "abandonment" has created issues for Japan's forested land. The Japanese Ministry of the Environment claims that underuse is one of the primary drivers of biodiversity loss (Oono et al. 2020). The cessation of forest management in Japan was and is seen in both naturally occurring woodlands and conifer plantations, which differs from the norm in other countries where plantation management persists when management of other areas stops (Oono et al. 2020). The decline of management activity was also found to cause higher levels of forest and stand homogeneity through canopy closure and stand densification (Oono et al. 2020). Growth stagnation was also found to occur, causing stands to be more susceptible to interspecies competition and damage from severe weather events (Oono et al. 2020).

Forestry under sustained yield practices has placed focus on maintaining and sustaining a constant harvest level over time (Mathey et al. 2009). This may be uneconomic, and there is a case that under current economic conditions, harvesting up to the AAC may not be economically advisable (Mathey et al. 2009). A study conducted in Northern Ontario found that forest management policies emphasizing maximizing harvest levels may not be economically viable (Mathey et al. 2009). The study found that annual harvest levels and annual net economic margins had a direct relationship, though model limitations may have impacted this result (Mathey et al. 2009). Should harvest levels be forced upwards, there was a diminishment to margins and shift from profits to losses (Mathey et al. 2009). This can be due to increased block accessing costs, or because less economically rewarding blocks need to be explored to meet volume quotas (Mathey et al. 2009). Access costs were found to be the greatest factor affecting profitability (Mathey et al. 2009). When even-flow requirements are dropped, the study model showed a significant increase in profitability and a slight drop in average harvest levels (Mathey et al. 2009). This caused a fluctuation in harvest rates however, with initial rates high before dropping very low, eventually rebounding near the end of the planning horizon (Mathey et al. 2009). Using the model developed for the study, it was found that when harvesting the full AAC volume amount (375,000 cubic meters), there was a projected loss of $500,000 (Mathey et al. 2009). After dropping volume harvested to 300,000 cubic meters, the projected gain was $1.2 million annually (Mathey et al. 2009). This reinforces the idea that AAC levels are dictated by the “best case scenario” and not linked to economic considerations. It also aids in explaining why exactly Ontario forests are not being harvested up to the AAC, as doing so for the sake of landscape management would be economically negative.

Due to most FMU's in Ontario being managed by non-government, private industry groups, this is an unrealistic expectation and increased harvest levels will only coincide with economic upturns in the forest product industry.

Volume

Decline of volume due to old age in forests could be an impact in underutilized land-bases. The argument being each year certain areas planned are pushed back into the next cycle, or certain areas being avoided all together due to less productive or economically viable forest. The latter may occur in an underutilization scenario where the economic optimization of the forest dictates resources go to the "best" (high value or high volume) areas as there is insufficient labor force or economic incentive to utilize "worse" areas at the time. These areas would still hold value and would likely be well suited to harvest and renewal operations to better meet social, economic, or environmental land base goals. However, if left for long periods of time with no disturbance to regenerate the stand, volume loss may occur. This would in turn reduce harvesting incentive even further due to decreased economic potential.

There have been multiple studies done on the affect of age on volume. A study on the relationship between age and volume conducted in old growth boreal forest in Norway by Jogeir N. Stokland found that the gross volume increment in stands up to 100 years older than their optimum rotation age remained constant and stable for 50 to 100 years after their rotation age (Stokland 2021). Harvesting rotation ages are not only based on volume maximization but also on the value of time in forest investments, and as such they are often less time than the biological rotation age (Stokland 2021). The study also found a low risk of stand collapse and low natural mortality occurring within these stands, with recommendations to extend rotation length in well stocked stands to derive climate change mitigation benefits for longer periods (Stokland 2021). Stockland's study has been disputed however, such as a published correspondence article by Andreas Brunner. Brunner argues that analyses of changes in volume growth across stand ages must take into account independent variables and their non-linear affects (Brunner, 2021). Norway's National Forest Inventory (NFI) data was deemed "unbalanced", and Stockland's analysis did not use the recommended approach (Brunner, 2021). For instance, it lacked data for full density stands, the stage at which stand volume growth is maximized (Brunner, 2021). There was also issue raised with the sample plots chosen, as due to the stand age (over 90) they have never been clear cut and as such the findings may not be applicable to forested areas that have undergone clear cutting (Brunner, 2021). Norway experiences a large variation in growth conditions between regions, meaning site index alone cannot be used to compare stands from different regions in the growth models (Brunner, 2021). These older stands were also subject to selective cutting historically, resulting in an un-even age condition in many stands. The ages for these stands are estimated using weighted means for a range of tree ages, which contain larger errors (Brunner, 2021). Errors can be corrected by using statistical method, yet they will still not be applicable to clear cut even-aged stands without risking age distortion (Brunner, 2021). Due to this, Brunner deemed Stockland's study to not provide a clear answer on the impact stand age has on volume over time (Brunner, 2021).

Stand decline may also cause volume loss in older stands. Stand decline occurs with the cumulative mortality of main canopy trees, often caused by old age (Potheir et al. 2004). It can be seen in yield curves as the point in which maximum merchantable volume is reached and volume begins to decline (Potheir et al. 2004). Trembling aspen (*Populus tremuloides* Michx.) for instance has been shown to begin decline around age 60, however this will vary based on site qualities (Potheir et al. 2004). In areas such as the Lake States aspen stands may completely deteriorate in as little as 4 to 6 years without replacing forest cover replacement (Potheir et al. 2004). Boreal aspen stands will often be replaced by a conifer mixedwood eager to take advantage of newly opened canopy space (Potheir et al. 2004). Aspen stands may decline due to old age, insect damage, or fungal pathogens (Potheir et al. 2004). In contradiction, there may be positive impacts on volume due to underutilization. For instance, the rotation age for aspen is often earlier than the age at which maximum merchantable volume is achieved (Potheir et al. 2004). If underutilization factors cause aspen stands to go unharvested for longer, they may reach the maximum merchantable volume.

The cessation of management in areas may also have little effect on volume. Forests in Central Europe were found to have little change in stand basal area and number of living trees whether they were managed or unmanaged (Dieler et al. 2017). These same forests were found be significantly more productive with regular moderate thinning, however this is not widely carried out in Ontario (Dieler et al. 2017). Productivity also increased significantly in forests with greater species diversity than mono-species plantation stands, which are often favoured in Ontario silvicultural practices (Dieler et al. 2017).

Future Landscape Targets

There is potential that longer rotation periods caused by underutilization may in fact aid in the achievements of future landscape targets (Etheridge & Kayahara, 2013). A study in Northeastern Ontario found that while current even-aged management meets even-aged targets it may not meet multi-aged targets (Etheridge & Kayahara, 2013). In a simulation with extended rotation times and multi-cohort management, multi-aged landscape goals and targets were met over the long term (Etheridge & Kayahara, 2013). Managing with longer rotation times may result in a decrease in wood allocation and an increase in unit cost, and a decreased wood supply in comparison to short-rotation forestry, however (Etheridge & Kayahara, 2013). Undercurrent economic conditions, only a portion of Ontario's sustainable wood supply is harvested annually, and assuming conditions remain the same, a loss in wood supply due to changes in management may not impact the forestry industry in a grand scale.

Ontario bases future landscape goals on area-based indicators to target landscape patterns or habitat indicators (OMRNF, 2014). Landscape structure, composition, and pattern are used as targets to guide the development and implementation of management plans (OMRNF, 2014). These are developed from simulation modelling, as well as historic conditions of the landscape (OMRNF, 2014). Historic conditions are referred to as "Pre-Industrial Conditions" (PIC) which are estimates of the landscape using information from Ontario's Lands Survey Notes (OMRNF, 2014). There is a general lack of information regarding forest age in PICs (OMRNF, 2014). Each FMU has estimated Simulated Ranges of Natural Variation (SRNV) that the PIC must be within in order to properly emulate natural disturbance and processes in a managed landscape (OMRNF, 2014).

Increased Fire Risk

Forest fire and is an extremely relevant topic in recent times, as a record 15.2 million hectares burned from wildfire in Canada in 2023 (Can Geo, 2023). As such, fire risk mitigation is more necessary then ever for forest managers. Ontario has developed a manual for wildland fire risk assessment and mitigation. The outlined mitigation techniques for vegetation or fuel management are based on the modification of forest structure and composition to reduce fuel build up and build stand resilience to fire (OMNRF, 2017). Hardwood stands are more resilient to wildfire than conifer stands, such as spruce or pine plantations (OMNRF, 2017). When considering underutilization, it is the mixed wood or naturally occurring birch and aspen stands that are more likely to be unutilized when compared to conifer dominated stands. A study conducted in Northwestern Portugal assessed fire resistance in natural broadleaved forests and planted pine plantations (Proenca et al., 2010). Understory fire was similar between the two forest types, canopy fire severity was low in the broadleaved forest and heterogeneous in the pine plantation (Proenca et al., 2010). The mean tree mortality was found to be much higher in the pine plantations in comparison to the natural broadleaved forest however (Proenca et al., 2010). Additionally, communities post-fire were less diverse and rich in the pine plantation (Proenca et al., 2010). In general, it was found that the native broadleaved forest had a higher resistance and resilient (Proenca et al., 2010).

A study was conducted in the boreal regions of Northern Saskatchewan in order to compare fire size and fuel fragmentation in the boreal plains (intensively managed) and the boreal shield (not managed) areas (Lehsten et al. 2016). While both areas were mostly affected by medium sized fires, it was found that the total area burned, and the level of fuel fragmentation was lower in the managed boreal plains area (Lehsten et al. 2016). Characteristic fire size was found to be slightly higher in the managed areas, likely due to the lower amount of fragmentation (Lehsten et al. 2016). Not all management is the same, however. Under intensive management regimes, more potential fuel is removed during forestry operations, helping with fire suppression (O'Laughlin, 2013). Without management, a build up of litter and decreased human presence on the landscape can increase fire risk (Oono et al. 2020).

MATERIALS AND METHODS

Potential impacts of underutilization were first identified using critical thought, meetings with Lakehead University Professors, and Joe Ladouceur, general manager of GreenMantle Forest Inc. GreenMantle Inc also provided insight on forest management decision making as well as the history of sustainable forest management in Ontario, which was further explored and compiled within the introduction section. Ontario's crown land forests are managed under sustainable forest licenses, the distribution of which is shown in Figure 1 below.

Figure 1. Forest Management Units of Ontario.

These forests act as independent management areas. As Figure 1 above displays, not all of Ontario is managed forest. For the purposes of this paper, when referring to "Ontario's Forests" or "Ontario", it will represent the managed forest zone.

A literature review was undertaken to further expand upon the identified potential impacts, as well as identify additional potential impacts. Most literature was identified with Google Scholar, with a preference for material specifically from Ontario, boreal forests, or boreal transition zones. Search terms were tailored for each identified potential impact, and multiple viewpoints for each topic were sought. The resulting literature was analyzed, discussed, and expanded upon. Table 1 below identifies the specific type of source (published paper, government data source, etc.) used during the development of this thesis.

Table 1. Data Source Type.

Source Type	Count
Scientific Literature	34
Government	17
Article	3
Other	9
Sum	63

Most sources consisted of peer-reviewed, scientific papers. While a preference for Ontario-based literature was applied, literature conducted in other areas of Canada, or internationally were used due to a lack of information from Ontario. A breakdown of source location for the references used in this paper is shown in Table 2 below.

Table 2. Data Source Location.

Source Location	Count
Ontario (Canada)	23
Canada	25
Japan	2
Europe	5
USA	2
Multiple	6
Sum	63

In total, 63 sources were used in the completion of this thesis, from multiple Canadian provinces and countries outside of Canada. While there was a preference placed on literature from Ontario or similar regions in Canada, availability of relevant literature necessitated the use of a broader range of source locations.

CASE STUDIES

Two FMU's in Ontario where underutilization is prevalent were examined to explore the reasoning behind the underutilization and the impact is has or may have on the economics of the area, the LTMD's, and disturbance. The chosen forests were the Kenogami Forest and the Algoma Forest. Both forests have been historically managed and support multiple communities within them. These factors influenced the choice of the forests reviewed. There are other forests in Ontario with lower levels of utilization or where no utilization occurs at all, however some of this is due to remoteness and lack of infrastructure, discouraging large scale management.

Kenogami Forest

The Kenogami Forest encompasses several Northern Ontario communities, such as Terrace Bay, Longlac, and Geraldton. The location of the Kenogami Forest in relation to Ontario is shown in Figure 2 below.

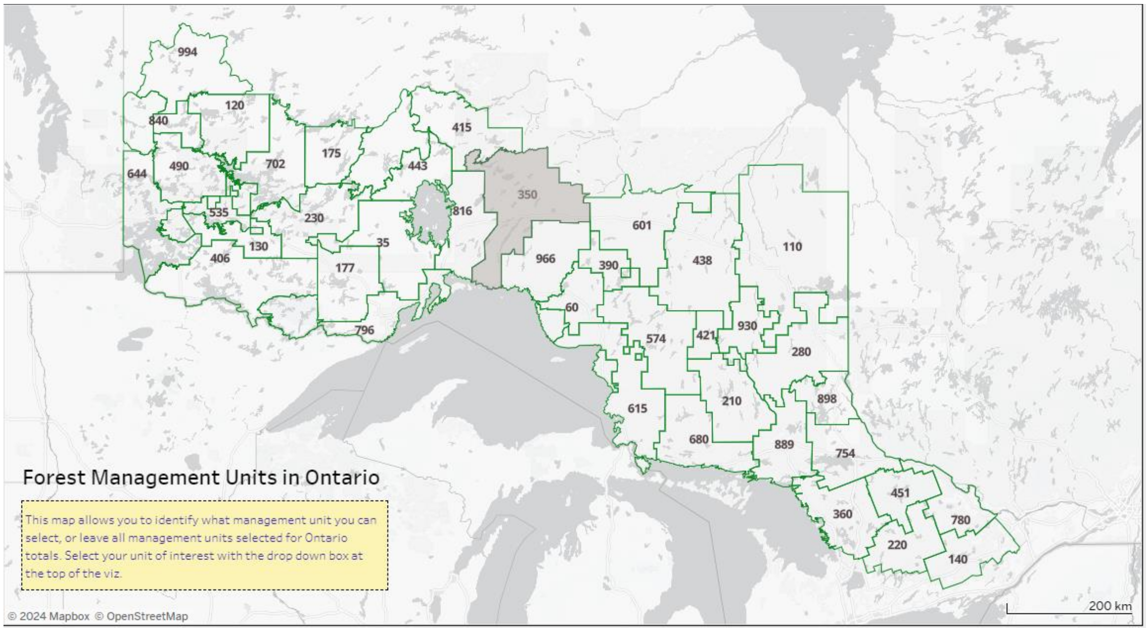

Figure 2. Location of the Kenogami Forest (350) (MNRF Forest Explorer, 2024).

Like many other FMU's, the Kenogami Forest has historically operated with an actual harvest level far below the AHV and AHA (MNRF Forest Explorer, 2024). Figure 3 below shows the harvest area compared to AHA since 2007, and Figure 4 below shows the harvest volume compared to AHV since 2007 in the Kenogami Forest.

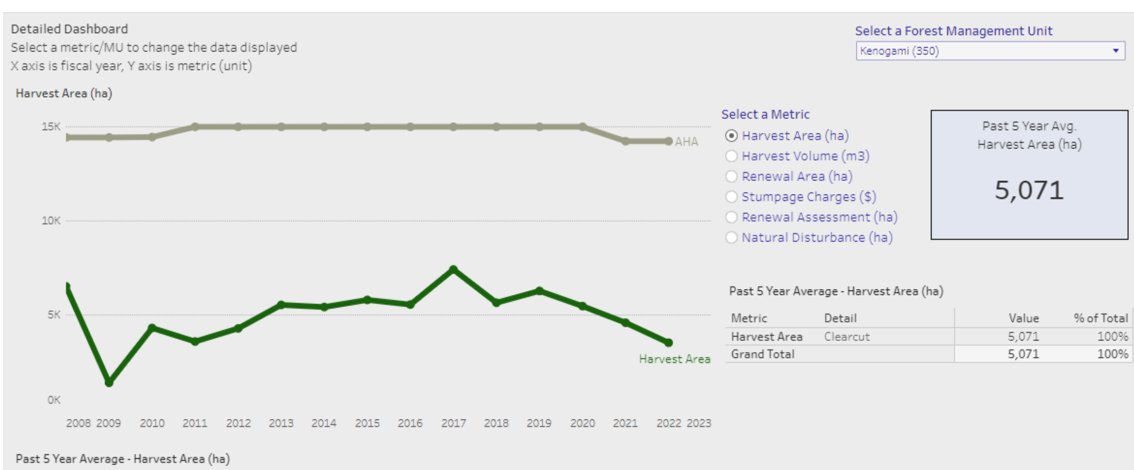

Figure 3. Harvested Area for the Kenogami Forest (ha) (MNRF Forest Explorer, 2024).

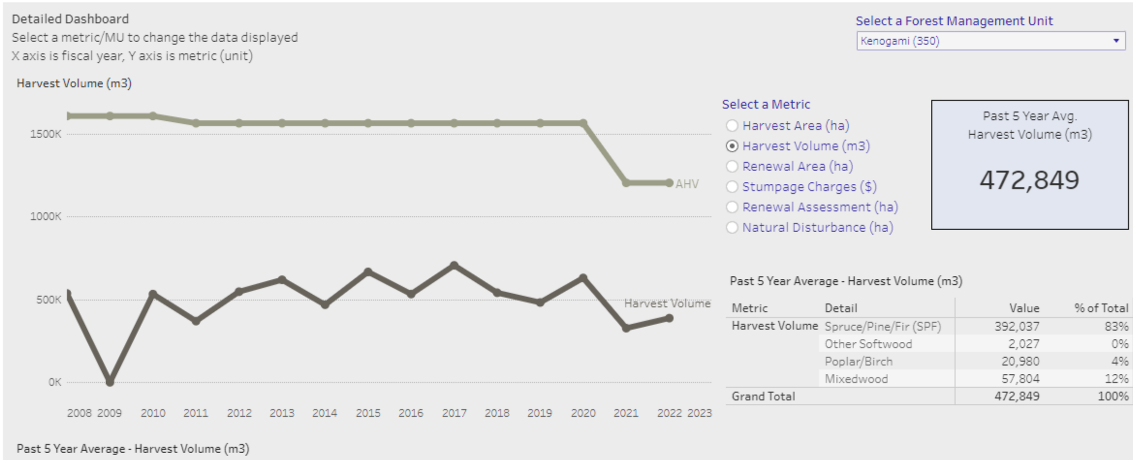

Figure 4. Harvested volume for the Kenogami Forest (ha) (MNRF Forest Explorer, 2024).

There did not appear to be a correlation between managed/utilized area and disturbance for the Kenogami Forest (MNRF Forest Explorer, 2024). As previously mentioned, the Kenogami Forest contains the town of Terrace Bay, and the AV Terrace Bay Mill. According to the 2021 Annual Report for the Kenogami Forest, underutilization of available resources was due to a multitude of factors, such as bankruptcies, limited contractor availability, slow commencement of operations, and short winter harvesting seasons (Ne-Daa-Kii-Me-Naan Inc., 2021). The harvest levels for the duration of the 2011-2022 management plan has also caused changes in the future forest composition of certain forest units that may not be as planned in the LTMD (Ne-Daa-Kii-Me-Naan Inc., 2021). Namely, there is concern that some of the pure conifer forest is slipping into the definition of a conifer mix forest unit. This may be a direct impact of the lack of utilization, and enhanced silviculture techniques will need to be invested in to slow or stop this from occurring (Ne-Daa-Kii-Me-Naan Inc., 2021).

The AV Terrace Bay Mill was by far the largest licensee for the forest in terms of volume utilization, with 3,532 ha area harvested, and 76,686 m3 byproduct, and 236,449 m3 of pulp utilized by the AV Terrace Bay Mill in 2021(Ne-Daa-Kii-Me-Naan Inc., 2021). AV Terrace Bay operations represent 403,074 m3 of the total volume of 533,195 m3, or 75.6% of the total volume derived from the Kenogami Forest in 2020/2021 (Ne-Daa-Kii-Me-Naan Inc., 2021). The AV Terrace Bay pulp and paper mill used 313,135 m3 of pulp and byproduct alone, which is equal to 58.7% of the total volume in 2020/2021(Ne-Daa-Kii-Me-Naan Inc., 2021). While no annual reports are publicly available past 2020/2021, the 2021 to 2031 Kenogami Forest FMP sheds light on how much volume was expected to go to the AV Terrace Bay mill via a supply agreement. In total, the AV Terrace Bay Mill was set to receive 1,293,140 m3 of volume per year, totalling 12,555,670 m3 for the plan's duration equating to 70.6% of the volume planned to be extracted for this period (Ne-Daa-Kii-Me-Naan Inc., 2021).

The AV Terrace Bay Mill has since shut down operations indefinitely (AV Terrace Bay, 2024). This leaves a massive amount of planned volume without a destination in place. While some of the volume may find a home elsewhere, the likely outcome is a large scale down in operations on the Kenogami Forest. The forest already had trouble finding available contractors to conduct operations, many of whom are now going to go elsewhere. Considering the previous management plan period and the difficulty had meeting planned volumes, and the risk of missing LTMD targets, the current economic situation will likely have a long-lasting impact on the state of the forest.

The Municipality of Greenstone lies partly within the Kenogami Forest and has close ties to the management of the forest. In 2016 there were 145 individuals employed in the agriculture, forestry, fishing, and hunting industry in Greenstone, while in 2021 that number had decreased to 10 individuals (Stats Canada, 2016, 2021). Median total income among recipients totaled $34,842 in 2015, but this has increased to $42,800 in 2020 (Stats Canada, 2016, 2021). Unemployed members of the labor force has also decreased over time, with 230 unemployed individuals in 2016 and 170 unemployed individuals in 2021 (Stats Canada, 2016, 2021). These numbers are from after the initial AV Terrace Bay Mill reopening, and before the AV Terrace Bay mill closure of 2024, the impact of which may not be recorded until the next census.

Algoma Forest

The Algoma Forest resides in Northeastern Ontario around the Sault Ste. Marie area going north towards Wawa.

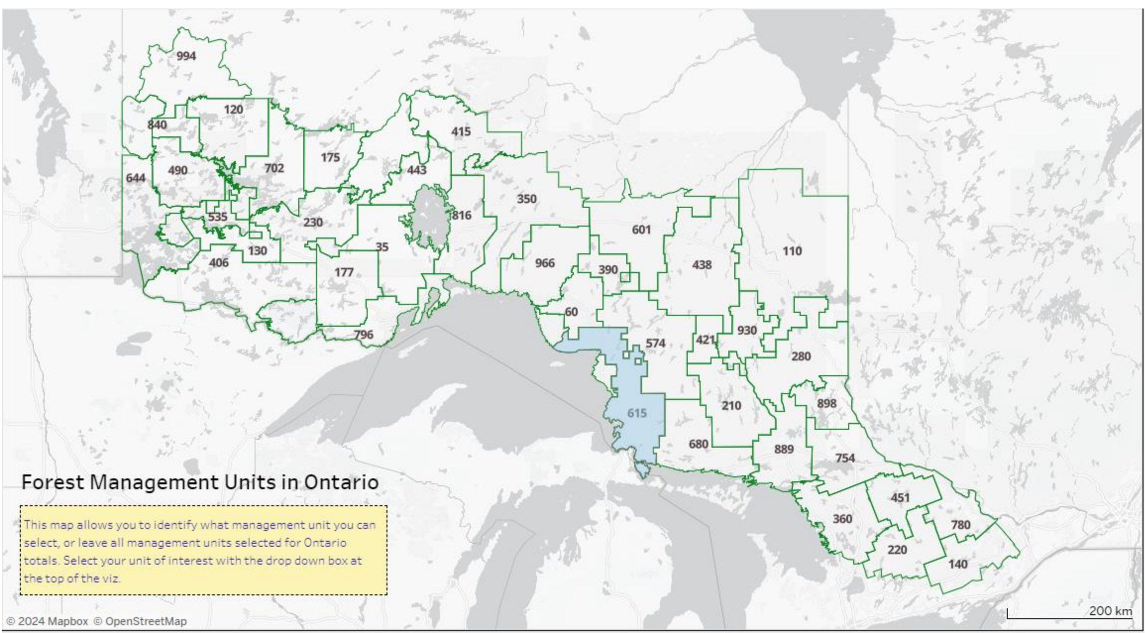

Figure 5. Location of the Algoma Forest (615) (MNRF Forest Explorer, 2024).

The Algoma Forest has seen an upturn in available harvest area, yet the forest has seen a general downturn in forestry activity since 2007 (MNRF Forest Explorer, 2024). Figure 6 below displays the area harvested per year in comparison with the AHA, and Figure 7 below illustrates the harvested volume per year in comparison to the AHV since 2007.

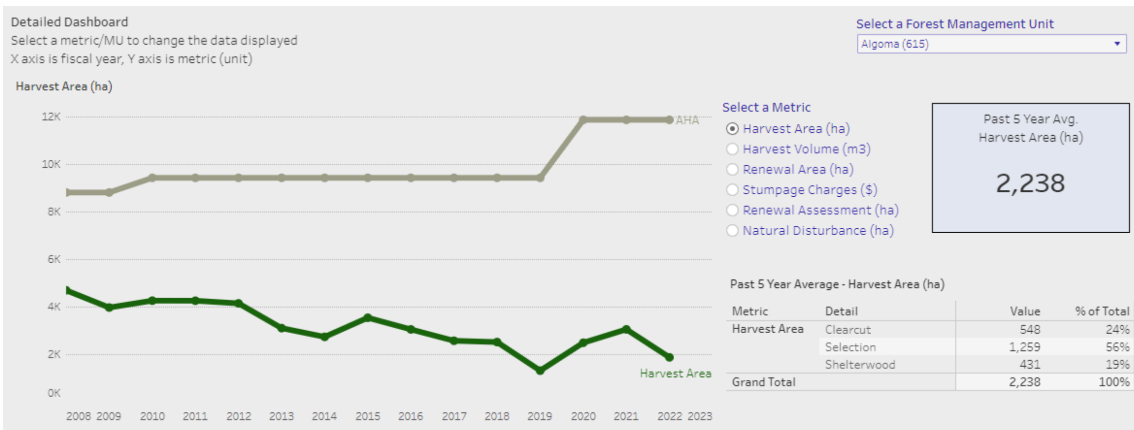

Figure 6. Algoma Harvest Area (ha) (MNRF Forest Explorer, 2024).

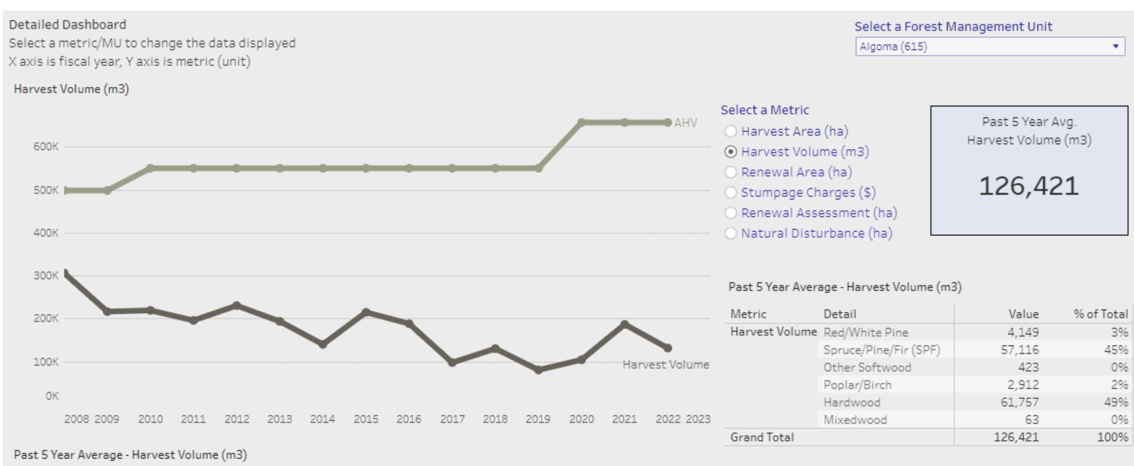

Figure 7. Algoma Harvest Volume (m3) (MNRF Forest Explorer, 2024).

The underutilization in the forest does not seem to correspond with an increase in natural disturbance, as severe and moderate disturbance levels have remained mostly consistent, with the exception of 2017 (MNRF Forest Explorer, 2024). Disturbance levels for the Algoma Forest are shown in Figure 8 below.

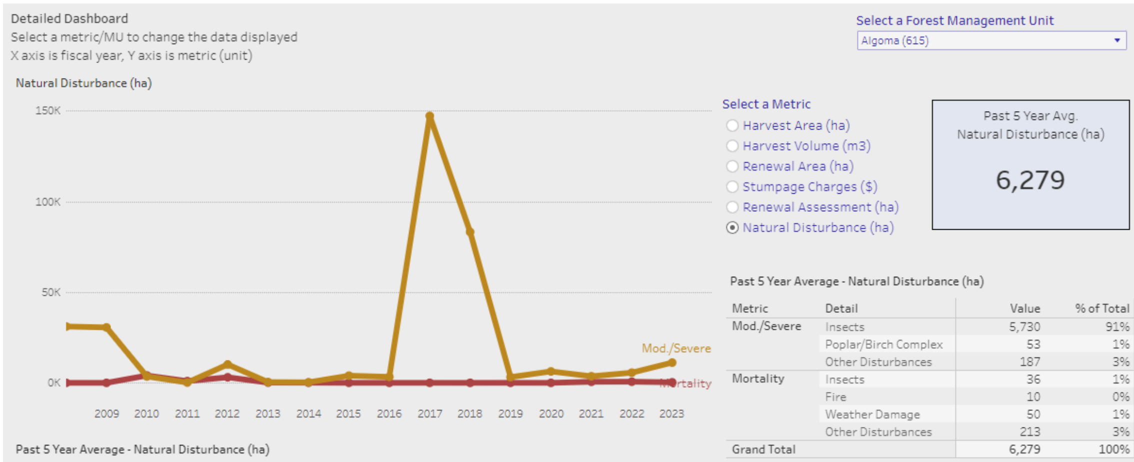

Figure 8. Natural Disturbance levels (ha) in the Algoma Forest (MNRF Forest Explorer, 2024).

Stumpage charges have stayed mostly consistent as well despite the decrease in harvest area with 2021 having the highest stumpage charges since 2008 while only utilizing 25.7% of the AHA (MNRF Forest Explorer, 2024). Stumpage charges fore the Algoma Forest are shown in Figure 9 below.

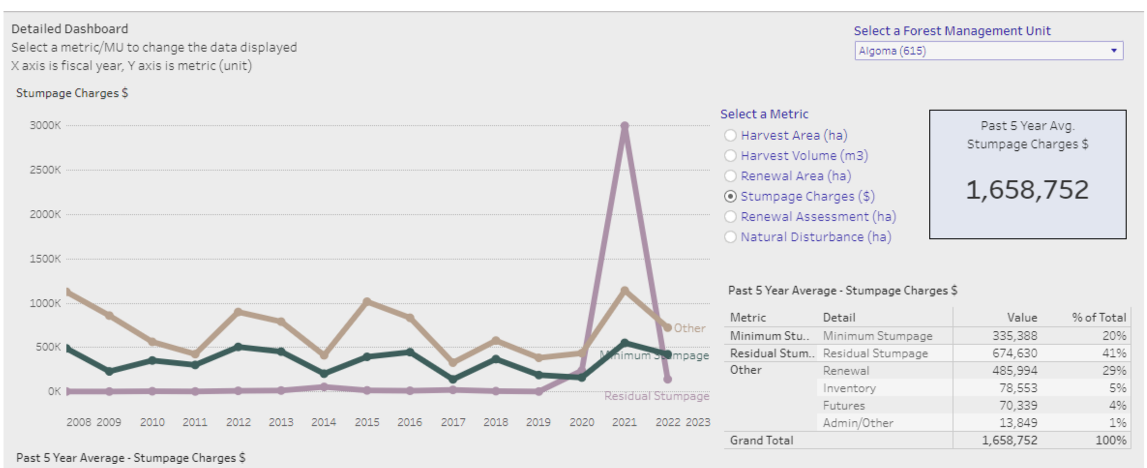

Figure 9. Algoma Forest Stumpage Charges (MNRF Forest Explorer, 2024).

An independent forest audit conducted in 2021 for the Algoma Forest from 2006-2021 found that planned harvest areas had not been achieved which has resulted in underachievement for the targets for silviculture activities, LTMD targets, and economic benefits (Arbex, 2021). The audit found that only 21% of the planned harvest was achieved for Conifer stand types and 26% of the planned harvest for Hardwood stand types were met during the period (Arbex, 2021). An explanation for the underutilization is the economic factors facing the forest at the time, mainly mill closures, timber quality, and species compositions (Arbex, 2021). However, the audit concluded that sustainability is not at risk and the established planning objectives have been achieved or are moving towards achievement, indicating that the situation in terms of objectives should be improving for the Algoma Forest. (Arbex, 2021).

The 2021 Stats Canada Census revealed that there were 50 individuals employed under the agriculture, forestry, fishing, and hunting category in the Wawa area (Stats Canada, 2021). In 2016, there were 30 individuals employed in the same category in Wawa (Stats Canada, 2016). Between 2006 and 2021, the population 15 years or older of Wawa decreased by 395 individuals (Stats Canada 2006, 2021). Unemployed individuals increased by 25 between 2006 and 2021 (Stats Canada, 2006, 2021). Another city located in the Algoma Forest is Sault Ste. Marie. Sault Ste. Marie has decreased in population by 1040 individuals between 2016 and 2021 (Stats Canada 2016, 2021). There has however been an increase in workers in the Agriculture, Forestry, fishing and hunting sector, going from 290 in 2016 to 465 in 2021 (Stats Canada, 2016, 2021). Median total income has also increased, going from a median total income of $33,103 in 2015 to $40,800 in 2020 (Stats Canada, 2016, 2020). These findings would suggest that the impact of underutilization has not been widely felt in the Algoma Forest economically. The population of the Algoma Forest likely plays a role in this however, as they are less dependent on timber resources due to other industries in the region.

However, it is likely that the economic conditions will still dictate harvest levels for the forest. Even though the AHV and AHA for the forest increased in 2020, the economic conditions have not yet led to an increase in utilization (MNRF Forest Explorer, 2024). There is likely still a risk of underachievement of LTMD's if economic conditions cause a similar pattern of utilization versus planned utilization going forward. In contrast, there is a belief that there may also be benefits derived concerning LTMD's and harvest shortfalls (Clergue Forest Management Inc., 2023). The natural regeneration occurring in these areas may facilitate the transition into forest types in line with the plan objectives (Clergue Forest Management Inc., 2023). While this may be true, it is inherently uncertain. An ideal situation would have controlled and planned forest transitions to ensure these goals are met. Past experiences in Ontario indicate that to sustainably harvest timber indefinitely, there needs to be active regeneration activities taken place, less we experience the supply issues that threatened the province from unsustainable practices historically (Winfield & Benevides, 2003).

DISCUSSION

Old Growth Habitat

Old growth is a vital ecosystem across all of Ontario's forests. If Ontario were to maximize AHA and cut up to the designated AAC, one would expect old growth forests to play a major role in harvest volumes. Boreal old growth forest is often targeted first during harvesting schedules (Martin et al., 2023). This may be for a variety of reasons, such as availability and economic drivers such as stand height, basal area, and tree density (Martin et al., 2021). As such, it is unclear if harvest rates below the AAC in Ontario positively impact the amount of old growth or allow more old growth to remain undisturbed. If old growth is available and harvest rates are limited due to current economic conditions, it makes sense for logging to still occur in these areas from a cost-benefit perspective. If harvest levels were at or near AAC, a decrease in AAC would likely see a positive impact on old growth forests, in comparison to what would have been taken under a full utilization scenario. When the modern mantra of sustainable forest management is considered, old growth harvest rates may be proportional to area harvested. In this scenario, old growth harvest would increase and decrease with utilization levels, with lower utilization scenarios not necessarily resulting in disproportionate harvesting rates of old growth as if it were targeted to maximize productive forest removed under economic constraints.

When comparing the amount of old growth or older age forest in Ontario in 2024 with the levels in 2000, there is a general trend towards older forests (95+ years) dominating much of the tracked landscape. This is shown in Figure 10 below.

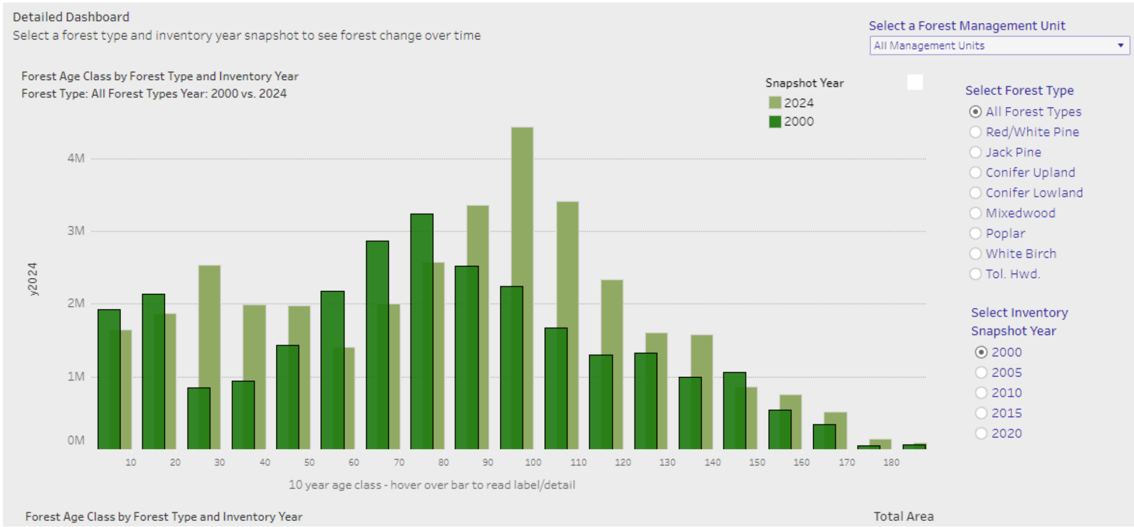

Figure 10. Old Growth Area Comparison (in ha) between 2000 (dark green) and 2024 (light green) (MNRF Forest Explorer, 2024).

While it is uncertain whether this is due to underutilization, it does at least display that Ontario's managed forests have been trending upwards in age. This means that there is more old growth on the landscape now then in the past, regardless of the reasons behind its increase. Further research is needed to fully assess the impact underutilization may have on old growth forests. This question has not been readily asked or investigated. However, the benefits and importance of Ontario's old growth ecosystems have been heavily researched. A lower rate of utilization would also have benefits on caribou in the forests that support them, due to a lessened rater of industrial operations occurring on the landscape.

Mixed Wood biodiversity

Underutilization causes areas of a forest to go undisturbed. Areas that are left undisturbed by anthropogenic activity can become or continue to be mixed woods. When economic drivers dictate the actual annual harvest volume, industrialized forestry is more likely to focus on the most economically viable species or stand type that is readily available or with the shortest rotation age for maximum value extraction. These areas are often man-made monocrop plantations, or natural pure or near pure stands rather than the "mixed bag" of mature to late-successional mixed wood stands found in the boreal forest. As such, mixed wood forests may be left to persist for longer periods of time before being harvested. There is little work done surround underutilization, lower levels of harvest, and mixed woods.

Mixed wood harvest trends have remained mostly consistent since 2000, indicating that they are not necessarily targeted when harvest levels are below AAC. Figure 11 below shows the three-year rolling average percentage of mixed wood forests in the total harvest.

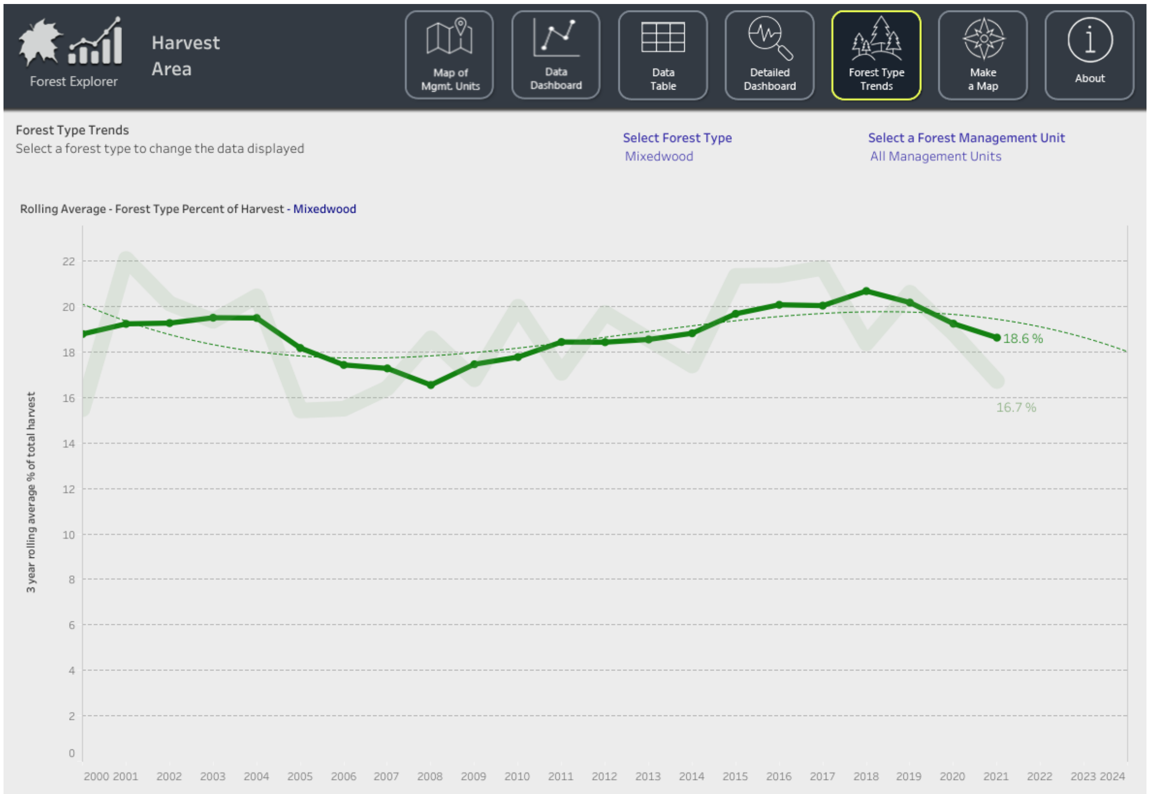

Figure 11. 3 year rolling average percentage of mixed wood harvest from total harvest volume (MNRF Forest Explorer, 2024).

As shown in Figure 11 above, mixedwood forest utilization had decreased leading up to 2007 to 2008, before beginning to rise again. As of 2022, mixed wood utilization rates are once again decreasing.

Another point to be made is that mixed woods that remain unharvested due to underutilization will foreseeably remain mixed woods. Many mixed wood stands, whether conifer or hardwood dominated, are converted into a different forest type post harvest in Ontario. Figure 12 below shows the renewal pathways for harvested mixed wood stands in the last 10 years.

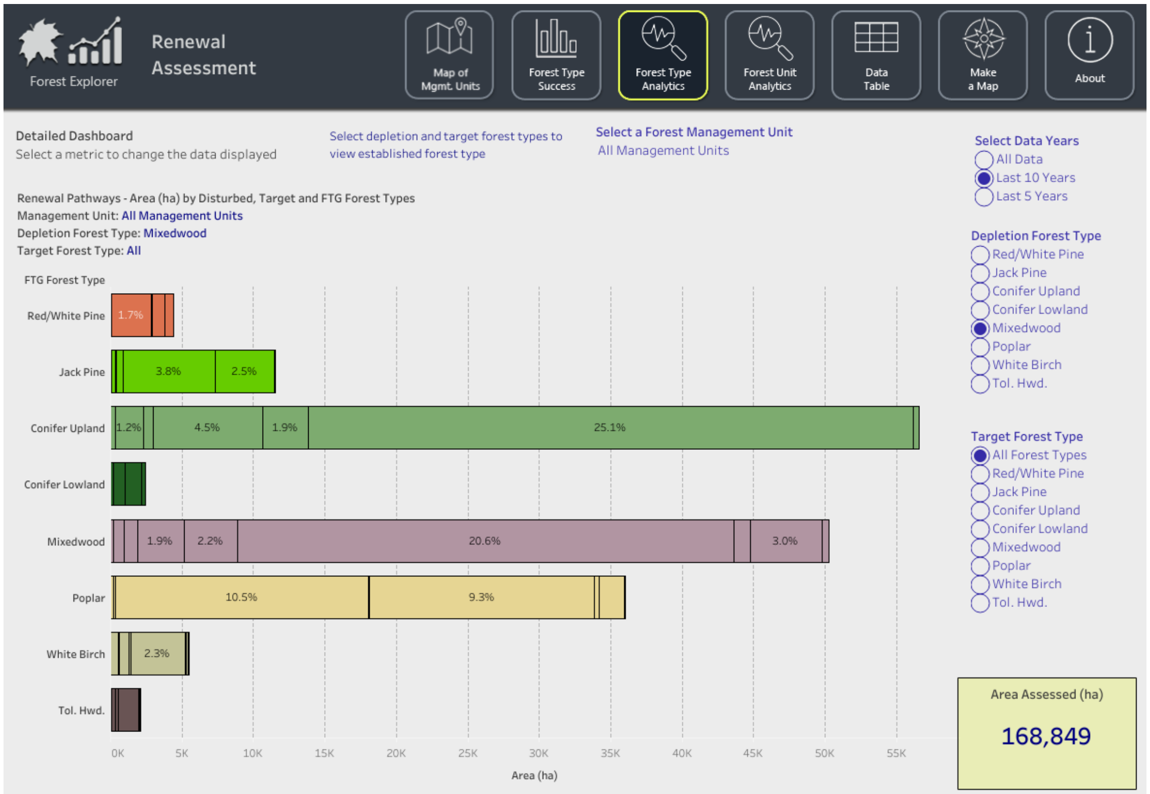

Figure 12. Renewal pathways for Conifer mixed wood stands harvested in the last 10 years in Ontario (MNRF Forest Explorer, 2024).

Figure 12 above shows that of the 168,849 hectares of mixed wood forest harvested in the last 10 years, 29.7% returned to mixed wood conditions. 20.6% of that had a mixed wood renewal pathway, with the remaining 9.1% resulting from the failed establishment of other forest types. This represents 50,148.15 hectares of mixed wood resulting from the initial 168,849 hectares of mixed woods harvested in the last 10 years. As such, there is potential that with underutilization more mixed wood forest types can persist longer as there is less area, and therefore mixed wood area, being harvested.

The amount of mixedwood forest in Ontario has also increased overtime (MNRF Forest Explorer, 2024). Figure 13 below shows a comparison of mixedwood area per age class in Ontario's managed forests between 2005 and 2020.

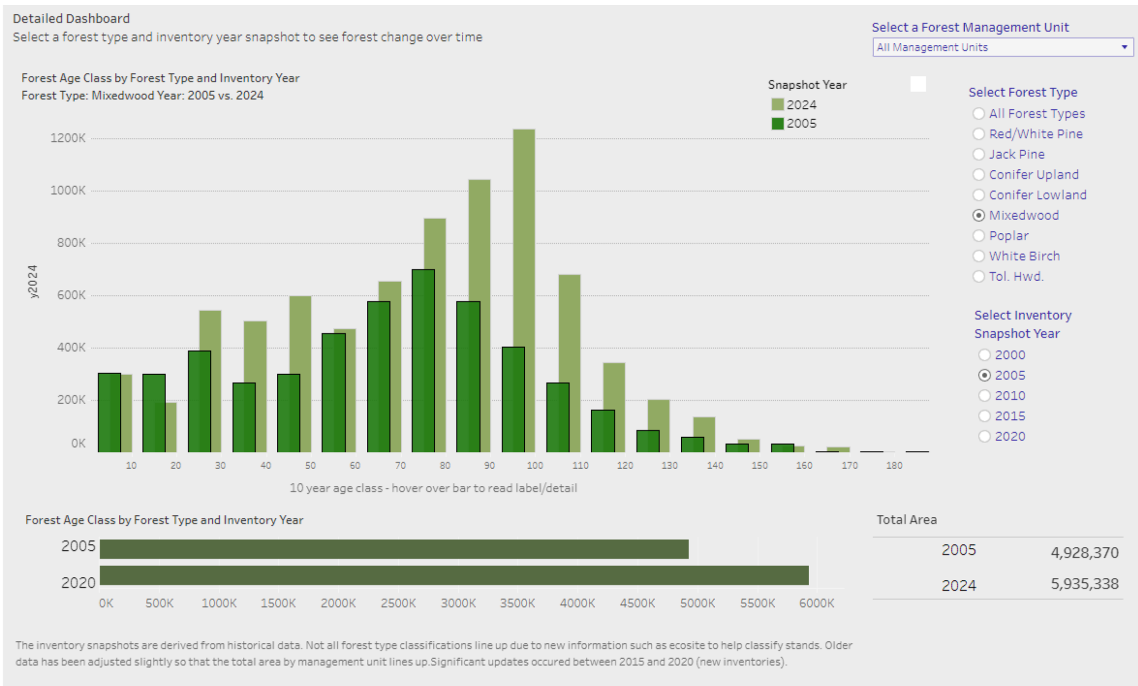

Figure 13. Mixedwood area comparison between 2005 (dark green) and 2020 (light green) (MRNF Forest Explorer, 2024).

Since 2005, there has been an estimated increase of 1,006,968 hectares of mixedwood forest in the province. While this is not explicitly due to utilization levels, utilization levels likely have played a part along with LTMD's and future landscape goals. It is reasonable to conclude that underutilization likely aids in maintaining mixedwood forest conditions in any given year, which then equates to a larger mixedwood area over time.

Water Quality

Industrial forestry operations impact water quality. While the extent of the impact varies case by case, forestry operations in general result in higher levels of DOC, phosphorus, calcium, chlorine, potassium, and total organic nitrogen then natural fire disturbance in boreal lakes (Carignan et al. 2000). Important ecological functions are also affected by forestry, such as sediment delivery, temperature regulation, and nutrient losses (Shah et al. 2022). Due to Ontario's AAC representing area rather than volume, the current underutilization in the province directly translates to less area harvested or impacted by forestry operations. The less area impacted equates to less potential for negative impacts on water quality that are a result of extensive forestry operations. Understanding this leads to the conclusion that underutilization would positively impact water quality, assuming harvest activities near or around waterbodies scales with utilization levels. Due to the importance of water quality on aquatic environments, this may also have a positive impact on aquatic values, such as fisheries health. There is less potential for adverse water quality impacts stemming from industrial forestry operations when those large-scale operations as a whole decrease on the landscape for an extended period of time.

Economic Consequences

Current harvest levels in Ontario are likely dictated by economic conditions. There is, in general, a lack of economic incentive to further utilize forest resources beyond current levels. As such, increasing utilization for the sake of a greater degree of management across Ontario forests may have negative economic consequences. While higher rates of harvesting may lead to economic benefits on a micro scale, namely in the creation of jobs, there would be negative economic impacts on a macro scale. There is simply no demand for additional wood supply. Underutilization does not equate to a loss in economic potential, rather economic potential results in underutilization. Once again, the true economic impact of underutilization may be most felt on a micro scale. Individuals who have lost their jobs due to less demand for Ontario timber may feel the brunt of the economic impacts associated with underutilization and the economic conditions of the time. Mill closures and downscaled harvesting operations can have a profound impact on the economies of small, northern Ontario towns whose existence have historically been tied to forestry. For instance, in January of 2024 the AV Terrace Bay Pulp and Paper Mill announced a closure of pulp operations due to prevailing market conditions (AV Terrace Bay, 2024). The mill employed around 400 workers and has been the largest employer in Terrace Bay in recent years (Allan, 2024). Terrace Bay has a population of approximately 1,600 people, with approximately 25% of Terrace Bay residents working at AV Terrace Bay before the closure. While workers are likely not all Terrace Bay residents, with some from surrounding communities, it is still a major economic blow to many individuals and families. The closure will be felt throughout the surrounding area, as licensees who supplied AV Terrace Bay with timber may not be able to find new buyers for those volumes, leading to further reduced harvest levels.

When the Statistics Canada information for some municipalities were looked into for the Algoma and Kenogami Forests, there does not seem to be a decrease in quality of life, median individual income, or employment considering underutilization. A hypothesis for this is that the economic impacts to individuals are felt in shorter term than the periods between censuses. Forestry workers are likely able to transfer their skills (such as heavy equipment operations) into other career fields. This is good for any individual who may lose their jobs due to unforeseen circumstances, such as bankruptcies and mill closures, however, should these individuals switch careers it will remove experienced workers from the career pool should operations ramp up again in the future.

Underutilization is not the primary driver of the economic downturn felt by much of forestry industry in Ontario. While there is certainty that underutilization has negative economic impacts for individuals and small companies working in the forest sector, underutilization itself is a product of the current economic conditions facing the forest industry. As such, underutilization is more accurately described as a negative impact of a weakened forest product market, rather than the primary driver of negative economic consequences itself.

Volume

Underutilization would lead to a loss in produced wood volume due to less harvesting across a landscape. There are mixed findings regarding volume loss due to stand age. While some research suggests volume remains rather constant for a significant period longer than suggested rotation ages (Stockland, 2021), there is evidence to suggest that volume loss can occur in stands of certain species, such as Trembling Aspen (Potheir et al., 2004). At the very least, growth and yield theory suggests that volume gain in stands decreases following a peak age, with volume growth slowly stagnating. In many cases of aspen or birch dominated stands, conifer mixed woods will eagerly replace declining hardwoods, taking advantage of newly opened space in the canopy (Potheir et al., 2004). Conifer stands may be more sought after from a forestry perspective, dependent on what the market demands are at the time. However, should an existing stand collapse and become replaced with regeneration or the understory community, this may still represent a loss in volume potential. The new, regenerating stand must then reach maturity or a point of economically viable volume before a harvesting operation can occur adding to the rotation age of an area. The collapsed stand volume would be lost without a chance to derive any economic benefit before regeneration occurs. Should a stand collapse without the opportunity to harvest and regeneration fails, a cost sink may develop where silvicultural investment may need to be made without the financial support of a previous harvesting operation. This situation is entirely possible, with factors such as stand location, economic demand of species within the stand, and contractor availability all playing a role in if the area is harvested or not. With the decreased demand for timber resources in Ontario, it is reasonable to believe that the economic viability of certain stands may outweigh other factors, such as volume loss or desired areas of conversion, when choosing which areas will be harvested with the limited resources and demand available. As such, underutilization likely does negatively impact the volume potential of some stands, if it causes those stands to go unmanaged for too long. Further research is required to identify which species compositions and stand types this would likely impact the most, as well as to identify whether volume impacts would be significant on the forest as a whole across the landscape.

Future Landscape Targets

Underutilization may lead to a diminished reach of management across a landscape that may then impact the ability of the forest to meet future landscape goals as planned. Land that is harvested is managed, if less area is harvested annually due to economic constraints, there will be a smaller portion of the landscape managed. Under the current goals of PICs in forest management within Ontario, stand conversion is often wanted. Lands that are not harvested cannot be converted, hindering the ability of managers to meet landscape goals. It would be uneconomic to attempt silviculture activities in areas that do not receive a prior harvest in most areas of Ontario. However, would are that is “left alone” from a forestry perspective not contribute to landscape goals through natural processes? This is unclear, as the PICs were developed from a period where the anthropogenic impact on the landscape in Ontario was small or non-existent. Much of the land base within Ontario’s managed forests has already been impacted by forestry or development, so even if some areas no longer undergo intensive management, they may not reflect naturally occurring conditions due to past management and utilization. Simulations run under longer rotation periods and multi-cohort management in Eastern Ontario show that landscape goals may be better met with a change in approach to the current short rotation, single cohort management often utilized in the province (Etheridge & Kayahara, 2013). This helps to meet multi-aged landscape goals over time at a cost of wood supply (Etheridge & Kayahara, 2013). These results would also likely require the area being at least passively managed.

The results of the case studies at least suggest there is cause for concern when considering the impact of current underutilization across most FMU’s in the province.

Especially considering LTMD's, as due to history of management across the managed forests of Ontario, active management and silvicultural strategies often need to be employed to meet the desired landscape goals. When forests that are already experiencing issues with future landscape targets experience further economic downturn it can snowball and compound into a major issue. While trends in natural regeneration might suggest landscape goals can be met through natural processes, this is never certain. Utilization will never exceed what is economically viable, that is what can be supported through demand. As such, there needs to either be an increase in demand through diversification of timber products or a rebound of current markets, or future landscape goals and LTMD's need to be reassessed to factor in the level of management able to be conducted under the current, and likely continuing, level of utilization.

While research on the topic is limited, it is fair to conclude that underutilization does and will affect the ability of managers to meet anthropogenically dictated landscape goals through a diminished management reach and presence. Desired future conditions often require extensive silvicultural work in the present to facilitate, and without meeting planned harvest allotments as dictated in a forest management plan, those areas cannot be converted.

Increased Fire Risk

Forest management strategies inevitably contain fire mitigation strategy within them. Managed forests are valuable resources, and these values are protected from natural disturbance whenever possible. Within changing climatic conditions, wildfire mitigation is more important than ever. There is evidence to suggest that hardwood stands are more resilient to wildfire when compared to conifer dominate plantations (OMNRF, 2017) (Proenca et al, 2010). Hardwood and mixedwood forest groups make up a smaller percentage of annual harvests then spruce/pine/fir (SPF) in Ontario (MNRF Forest Explorer, 2023). In 2022, SPF accounted for 8,708,785 m^3 of the total harvest of 12,269,965 m^3, or 70.9% (MNRF Forest Explorer, 2023). In contrast, poplar/birch, hardwood, and mixedwood combined accounted for 3,024,466 m^3, or 24.6% of the total harvest (MNRF Forest Explorer, 2023). This information reveals that there is simply a lower amount of hardwood and mixedwood forest harvested in Ontario. While part of the reason for this is availability, a preference for SPF timber also likely plays a part. As such, it would be likely that hardwood and mixedwood forests would have a higher degree of underutilization, dependent on wants and needs of mills. In this scenario, underutilization may have a positive impact on fire risk on the landscape, as more fire prone conifer stands are removed at a higher degree, while more hardwood and mixedwood stands are left for longer periods.

However, areas that do not receive intensive management may become more susceptible. Intensive forest management in the west of North America is shown to make forests more resilient to wildfire (O'Laughlin, 2013). Additionally, it was found in Northern Saskatchewan that the managed boreal plains region was more resilient to wildfire and fuel fragmentation then the unmanaged boreal shield area (Lehsten et al, 2016). As such, underutilization could increase fire risk in forests if it causes less area to be managed.

It is inconclusive whether underutilization would positively or negatively impact fire risk in Ontario forests. It is a complex question that is muddied by a changing climate. There is potential that underutilization both positively and negatively impacts forested area concerning wildfire, however more research would be needed to arrive at a definitive conclusion. There may be an increase in area burned associated with underutilization in certain forests, where remote areas are unlikely to see the infrastructural investment to manage the entire extent of a forest due to economic constraints. In this case, there may be less of a drive to actively combat wildfires when compared with other forests who have more socially important infrastructure or a greater degree of forest management.

CONCLUSION

While underutilization is currently a reality faced in Ontario's managed forests, the impacts and consequences are not widely studied or understood. While common perception may be that underutilization is perceived as ecologically beneficial and economically harmful, the reality is that it is a nuanced topic that is not "black and white". A diminished management presence may have several beneficial impacts on some aspects of the forest, such as water quality, mixed wood biodiversity, and the persistence of old-growth forests. There may also be several negative impacts, such as volume loss and volume potential loss, and difficulty reaching established future landscape targets and LTMD's. Fire risk may be positively or negatively associated with underutilization. Economically, underutilization can impact individuals, communities, and regions, however it is a product of current conditions rather than a cause. The case studies undertaken reveal that there is cause for concern regarding current utilization levels, and the potential for issues to compound and hinder progress towards LTMD's. The economic circumstances regarding forestry in Ontario will hopefully improve under Ontario's Forest Sector Strategy (FSS), however research and work should still be conducted regarding the impact of current utilization levels on the forest to adjust management strategies as needed.

In closing, further studies surrounding this topic are suggested. Each of the potential individual impacts identified may require further research in relation to current levels of utilization in Ontario. Namely, how it is impacting future landscape goals across the province and the implications of that for the future. In order to continue to responsibly and sustainably manage Ontario's Forest, it is vital to try to understand the impact the situation today will have on the landscape in the future.

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