The effects of Land-Use on Tree Health: A Study of Public Trees in the Town of Halton Hills

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Abstract

This study looked at the effects of species, DBH and land-use type on tree health condition. Approximately 5000 trees were inventoried in the Town of Halton Hills, Ontario, on 3 different land-use types (parks, facilities and cemeteries). Tree health condition was rated on a scale of 1-5, with 1 being in excellent condition and 5 being dead/death imminent. Results showed significant differences in tree health among species, with most species in good condition (mean condition <2), though Austrian pine and green ash were more vulnerable. Land-use type also significantly affected health, with cemetery trees being in slightly worse condition than those in parks or facilities. Larger DBH classes were linked to lower health condition ratings, suggesting size or age-related stress. Species–land-use interactions indicated maples fared worse in facilities, while thick-barked species, such as oaks and pines, were more resilient in parks. These findings emphasize the importance of species selection, site-specific management, and root and soil protection, in efforts to improve overall tree health status. Recommended practices include root protection, soil mulching, and monitoring soil compaction and nutrients, informing urban forestry strategies to sustain tree health and ecosystem services.

Background and Objectives

Trees in urban areas are shown to have positive effects on the residents living there. They have a positive effect on mental health (Elsadek et al.2019) as well as physical health (Turner-Skoff&Cavender.2019). This is partly due to the amount of air pollution they remove (Turner-Skoff.2019). It is estimated that urban trees remove 711000 metric tons of air pollution, per year in the Unites States alone (Nowak et al.2006) . Trees in urban areas are also shown to cool provide shade and reduce the surface temperature in area (Loughner et al.2012). They are also shown to reduce stormwater run off (Turner-Skoff.2019), provide a food and habitat for animals (Turner-Skoff.2019), increase property values (Anderson&Cordell.1988) and even reduce crime rate (Donovan & Prestemon.2010).

Wounds on trees are a key reason for tree health decline in urban environments. One study found that strimmer wounds commonly contribute to tree decline and death, especially when repeated and combined with stress and pathogens (Schuck & Slater, 2018). Wounds cause resource depletion as resources are allocated to healing the wound, which causes stress and infection and may eventually cause death (Schuck & Slater, 2018). Trees in parks had a significantly greater number of wounds than trees in nature reserves and roadside grass verges (Morgenroth et al., 2015). Trees with surface roots were much more likely to have wounds compared to those that didn't (Morgenroth et al., 2015). Surface roots form due to erosion, as well as soil compaction pushing roots upwards to access oxygen (Morgenroth et al., 2015). This is especially true for sugar maple *(Acer saccharum)* (Chiapperini & Donnelly, 1978), which is planted in abundance in urban environments, including the Town of Halton Hills. Other species such as poplar *(Populus spp)*, willow *(Salix spp)*, silver maple (*Acer saccharinum)*, and Norway maple *(Acer platanoides)* also have shallower root systems more likely to come to the surface (Alfuth, 2024). While these trees are more prone to wounds, it is also important to note variation in how trees react to wounds. It has been shown that certain species like elm (*Ulmus spp),* maple (*Acer spp)*, and oak (*Quercus spp)*, have faster wound closure rates compared to other species such as birch (*Betula spp*), honey locust (*Gleditsia triacanthos)* and sycamore (*Platanus occidentalis*) (Neely, 1988). Thicker bark can also help against wound damage (Morris & Jansen, 2017). Species such as oaks, pines (*Pinus spp)*, and black walnut (*Juglans nigra)* have thicker bark in general as a fire adaption, compared to maples and sycamores (Hengst & Dawson, 1994., Schafer et al., 2015).

Soil compaction, an increase in the bulk density of the soil, decreases the porosity of the soil, slowing down movement of soil and water, and causing root growth to slow (Day & Bassuk, 1994). This can also cause a lack of oxygen which can be fatal at a certain threshold, depending on the species (Day & Bassuk, 1994). A study done on sugar maples found that compacted soils cause poor drainage, causing road salt leaching to slow and accumulate, contributing to the decline of the tree (Ruark et al., 1983). This is why soil compaction is among the leading causes of sugar maple decline in urban environments (Ruark et al., 1983). In addition, soil compaction may also cause the root zone to flood and toxic metals to accumulate (Watson, 1986. Dovletyarova et al., 2017). Long term machine mowing, particularly on organic soil, causes soil compaction (Schrama et al., 2012). Another study found that the principal cause of soil compaction on a farm is pressure from wheels under tractors, trailers, and harvesters (Batey, 2009). Soil compaction is also associated with timber harvesting and other industrial activities such as mineral harvesting (Batey, 2009). In addition to machinery, another reason for soil compaction can be foot traffic (Mosina et al., 2025). A study in Moscow found that soils in urban forests have significantly higher bulk density (1.6-1.8g.cm^3), compared to relatively undisturbed sites (0.6-0.7g.cm^3) (Mosina et al., 2025).

Cemeteries have long been neglected as part of the urban forest (Quinton et al., 2020). Despite many people wanting cemeteries to have more trees and acknowledging their benefits such as supporting biodiversity, providing shade and improving mental health (Quinton et al., 2019), increasing the canopy cover of cemeteries is hindered by financial barriers, space requirements for monuments and burials, and environmental concerns regarding soil and groundwater quality due to the caskets (Quinton et al., 2020). Studies looking at trees in cemeteries and public facilities are both in very few numbers, and this is the first study looking at tree health across the 3 land use types (parks, cemeteries, and facilities).

The objectives of this study are to look at what tree species do worse compared to others in urban environments, particularly in southern Ontario, and more specifically, the Town of Halton Hills, which includes Halton Hills, Norval, Acton and surrounding hamlets. This study will also look at how land-use type (in particular, parks, facilities and cemeteries) affects the overall health and condition of the trees and give recommendation to the Town of Halton Hills on how they could improve tree health on town land. Because maples generally have shallower root systems (Alfuth, 2024) and thinner bark (Hengst & Dawson, 1994; Schafer et al., 2015), maple trees are expected to exhibit poorer overall health compared to species with thicker bark and deeper roots, such as oaks, pines, and black walnuts. These species-level difference are expected to be most pronounced in parks, where overall tree health is expected to be lower due to soil compaction from foot traffic (Mosina et al., 2025) and the use of heavy machinery for installing and maintaining infrastructure such as playgrounds, sports fields, and pathways (Batey, 2009). Dog urine, which increases soil nitrogen, pH, and salt levels (Allen et al., 2020), can add further chemical stress to trees, and combined with soil compaction and wounding, can further reduce tree health (Kleiber et al., 2019). Similar declines in tree condition are expected in cemeteries, where excavation equipment is routinely used for grave digging and site maintenance. In municipal facilities on the other hand, tree health should be better overall as heavy equipment use is minimal, often limited to lawnmowers and basic maintenance vehicles. Foot traffic is also lower, as visitors typically move directly between parking areas and buildings rather than across landscaped grounds.

Methodology

A tree inventory of all trees on town land in the Town of Halton Hills, ON was done. 58 parks, 11 facilities and 3 cemeteries were inventoried in Halton Hills, ON, Acton, ON, and the surrounding hamlets, for a total of ~5000 trees.

Each tree that was being inventoried was approached and entered as a point on the town's GIS system *MapLinks*. The tree species was IDed and selected from the drop-down menu on the GIS system. If the species wasn't showing it would be entered manually in the notes, and the species name would show up blank. Then the DBH was measured and entered. The tree status was also entered. Live trees were classified as "In-Service", but occasionally a stump was entered as "Disposed" or "Out of Service". Lastly, a health condition rating was assigned to each tree with 1 being excellent health condition, and 5 being dead or death imminent. This was done by inspecting the crown from a distance and then doing a ground level, 360º inspection of the tree. *Table 1* shows the criteria for rating a tree's health condition.

Condition Rating	Rating	Criteria
Good	1	Growth occurs mostly as extensions from the terminal bud with little epicormic branching. Shoot growth usually exceeds 10cm. Full, symmetrical crown. No sign of active decay, chronic or acute insect attack, large open wounds, tissue necrosis, dieback, or chlorotic foliage, not leaning, falling or about to be uprooted.
Satisfactory	2	Growth occurs mostly as extensions from the terminal bud. Epicormic branching may be heavy providing that the growth is healthy and abundant. May have a partially leaved or disfigured crown (>74% crown density), combined with a few dead branches or limbs, or small open wounds and small trunk tissue necrosis. Tree health will likely not decline further in the next 5 years.
Potential trouble	3	Growth occurs mostly as epicormic branching or basal sprouts. Usually no growth from terminal buds. New growth may be thin with small buds showing lack of vigour. May improve or decline in health over the next 5 years. May have a partially leaved or disfigured crown (50-74% crown density). These trees usually have a combination of problems which may include poor form or lean, chronic, or acute insect attack, small trunk tissue necrosis, small stem scars, twig dieback, dead branches, exposed roots, or root ball, and/or animals burrowing in to rooting area. Infection may be present in its early stages.
Declining	4	Declining in health. Crowns have significant twig dieback and dead branches. Usually describes trees having large trunk tissue necrosis, large stem scars. Foliage discolouration is often associated with this condition as is moderate to heavy top dieback and epicormic branching (<50% crown density). Chronic fungal infection or insect infestation may be present. These trees may require major corrective pruning, or replacement.
Death imminent	5	Symptoms as in Declining but more acute. Will likely die within 5 years. Will require replacement or removal.
Dead	6	No leaves, brittle twigs, dry buds.

Table 1: This table, provided by the Town of Halton Hills shows how to assign a condition rating to trees in The Town of Halton Hills. It is important to note that for this inventory, condition ratings 5 and 6 were combined.

Rstudio (Posit team.2023) was used for all statistical analysis. First the data was cleaned so that only trees labeled as "In-Service" were included in the statistical analysis (n=4971). The first analysis done was an ordinal regression using the *polr* function in the *MASS* package. An ordinal regression predicts the dependent ordinal (categorical) variable based on 1 or more independent variable. This function is being used because the tree health condition falls on a scale of 1-5, as shown in *Table 1*. This ordinal regression model looked at the effects of species on condition (condition ~ species). An ANOVA was then done on this model to test the significance of the species variable. A second model was then created to look at the effects of species and land-use type on tree health condition (condition ~ species + land-use type). An ANOVA was also performed on this model to test the significance of the independent variables. Following this, the data was cleaned again so that only species that have an abundance of more than 30 trees will be present for the data analysis (n=4259). This is to make results of the interactions between species and land more accurate. Individual trees that did not have a species name assigned to them were also removed. This shouldn't affect the overall objectives as they were primarily either invasive buckthorn (*Rhamnus cathartica),* very rare trees of which there were only a couple in the whole town, or tree-like shrubs. Once the interaction model was created (condition ~ species*land-use type), an ANOVA was performed to test the significance of the independent variables and the interaction. It was after performing this analysis that many figures looking at the tree health condition of most common species by land-use type were created using the *ggplot2* library. Following the creation of these figures, regression models were created for a third variable, DBH. The data was first filtered to create DBH classes in increments of 10 cm, with anything over 100 cm DBH, being put into the highest DBH class. The data was then filtered to only include species with a 100 more individual trees (n=3429). This is because in order to test for a third variable, especially one with as much variability among species as DBH, a greater sample size is required (n => 100). With this data set, 4 more models were created. One of the effects of DBH on condition (condition ~ DBHclass), one of how land -use type and DBH can both affect tree health condition (condition ~ DBHclass+Land-use type), one with the interaction term(condition ~ DBHclass*Land-use type), and one on how DBH and species and land-use type interactions affect tree health condition (condition ~ species + DBHclass*Land-use type). An ANOVA was done on all 4 regression models to assess the significance of the independent variables and their interactions. Lastly, a linear model was created looking at how tree health condition is affected by each of the variable (condition~ species + Land-use type + DBHclass), and the sum of squares was analyzed

<u>Results</u>

The ANOVA testing for differences among species for health condition(condition ~ species) showed significant variation among species (p<<0.001). This can be seen in *figure 1.* All species seem to be in relatively good health with the condition rating still being less than 2. The only exception to this is Austrian pine (*Pinus nigra*).

When land-use type was added to that (condition ~ species + Land-use type), the results were still showing a significant variation for health condition among land-use type (p = ~ 0.02). These results can be seen in *figure 2.* Cemetery trees are in slightly worse condition than park and facility trees but only by about 0.1-0.2 points on the scale. Doing an ANOVA for a regression model with the interaction term (condition ~ species*Land-use type) also showed significant variation, with the interaction term having a p-value far smaller than 0.001. These results can be seen in *figure 3* and *figure 4*. Different species seem to do well in different land-use types.

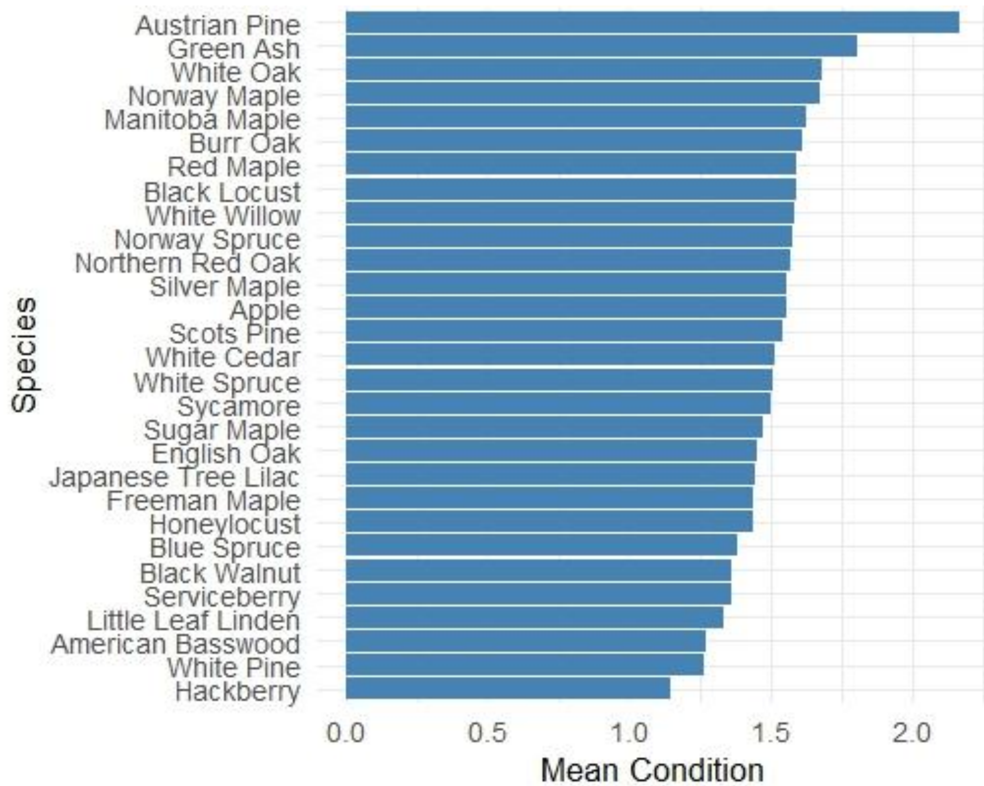

Figure 1: Mean tree health condition for all tree species in the Town of Halton Hills, with more than 30 individual trees in the tree inventory. The tree health condition is rated on a scale of 1-5 with 1 being excellent condition and 5 being dead/death imminent.

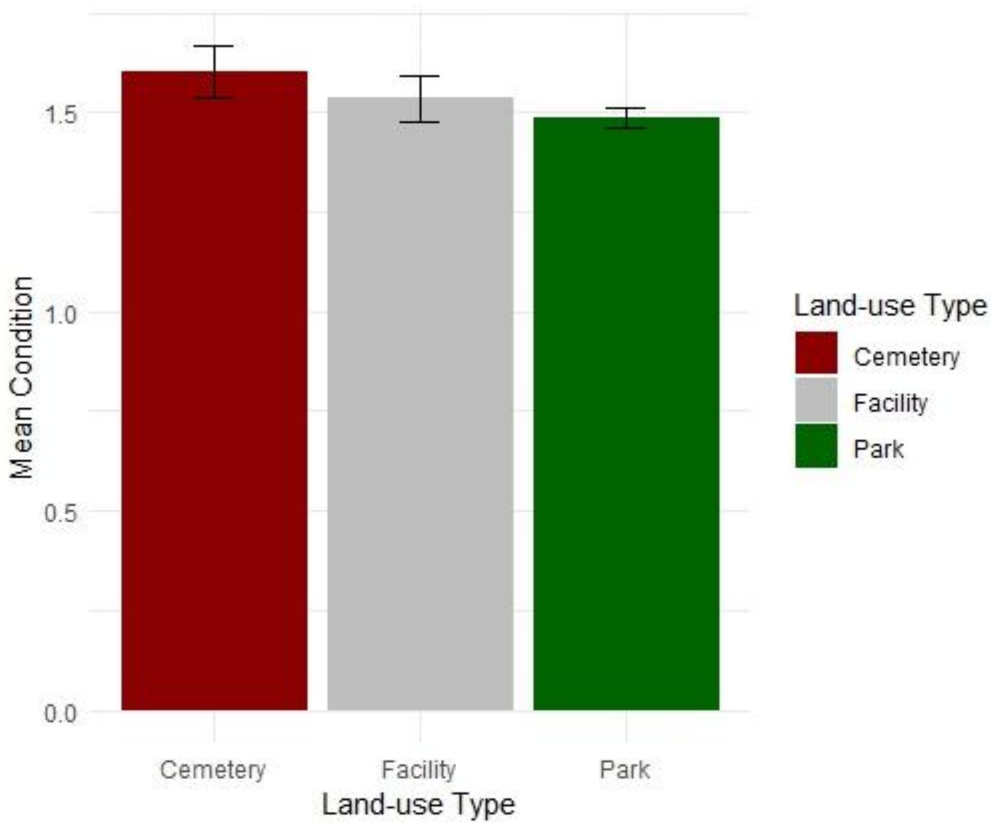

Figure 2: Mean tree health condition (see *Table 1)* by 3 different land-use types in the Town of Halton Hills. Park trees were in the best health condition, followed by facility trees. Cemetery trees were in the poorest overall condition.

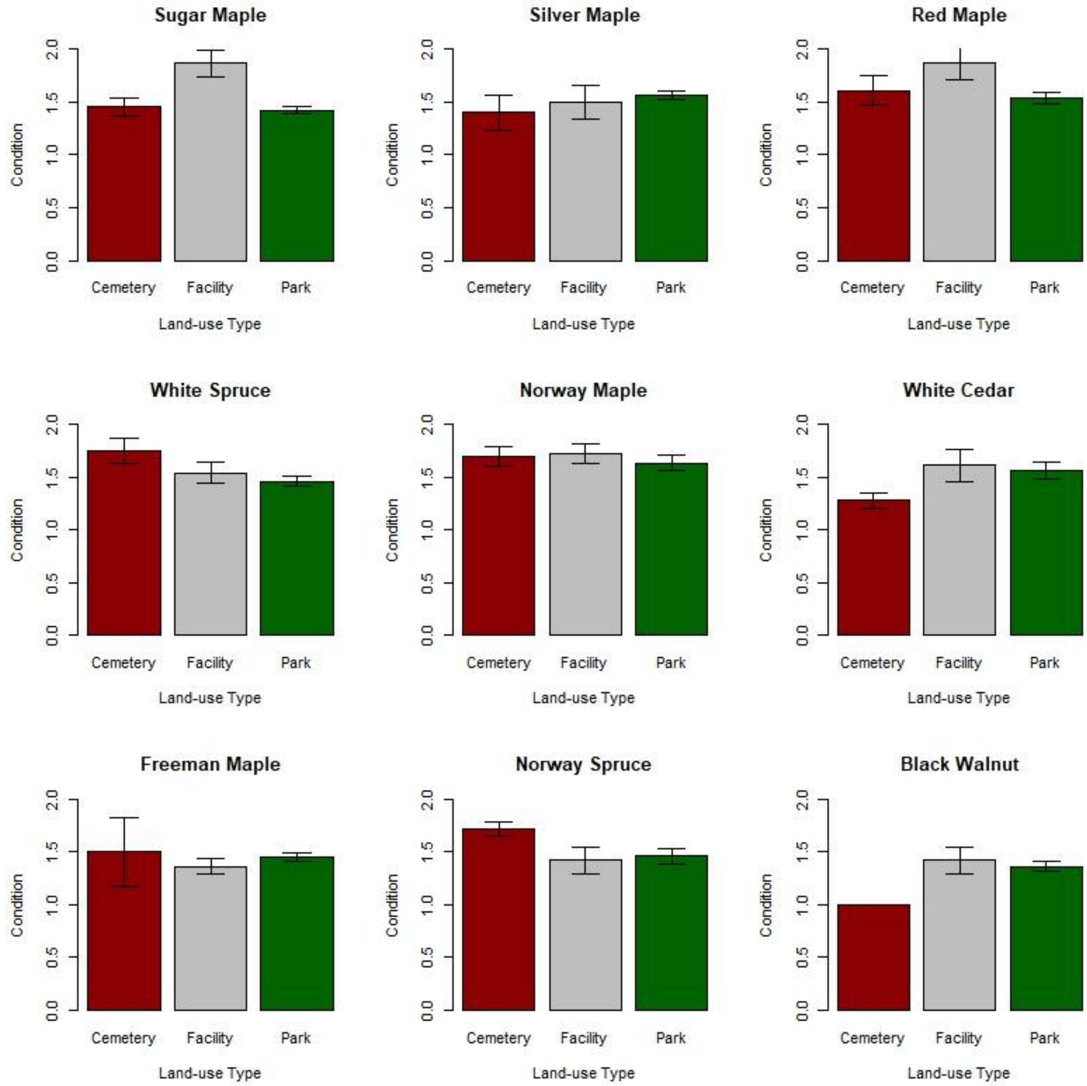

Figure 3: The health condition (see *Table 1* for condition ratings) of the most common species in The Town of Halton Hills by land use type. White spruce, sugar maple, Norway maple and red maple do better in parks. Norway Spruce and freeman maple do better in facilities. Black walnut, silver maple and white cedar do better in cemeteries.

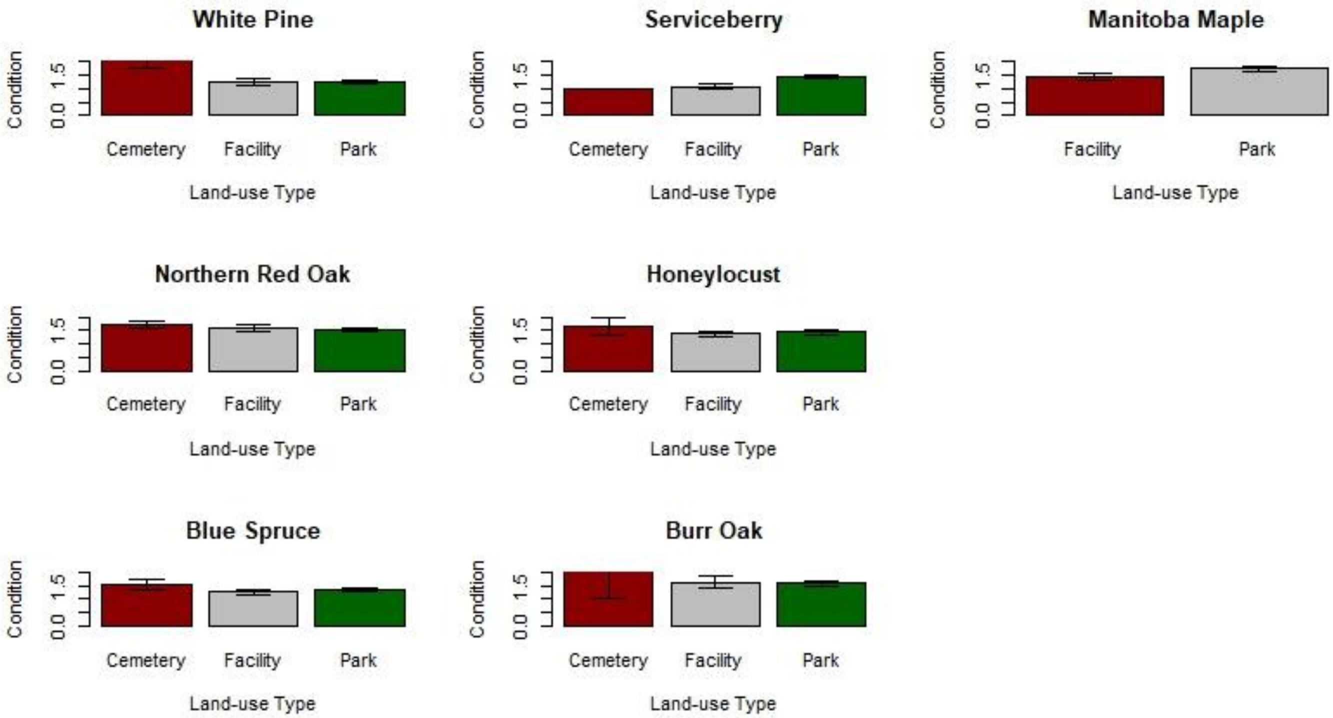

Figure 4: The health condition (see *Table 1* for condition ratings) of the next 7 (see *figure 3)* most common species in The Town of Halton Hills by land use type. Manitoba Maple, honeylocust, and blue spruce did better in the facilities. Serviceberry did better in the cemeteries. Everything else did better in the parks.

The next set of models factored in the DBH. The effects of DBH on tree health condition (condition ~ DBHclass) were statistically significant (p<<0.001). Factoring in land-use type (condition ~ DBHclass*Land-use type), neither the interaction (p = ~ 0.26), nor land-use type on its own (p=0.23) are statistically significant. However, adding in the species interaction (condition ~ DBHclass + species*land-use type), showed significant differences for both the species, as well as the species-land-use type interaction (p<<0.001). The size class distribution by land use type can be seen in *figure 5.* The cemeteries have more larger trees compared to parks and facilities. *Figure 6* shows the mean tree health condition by DBH class. As DBH increases, condition rating increases and trees get less healthy.

The linear model looking at the sum of squares of each variable showed that species explained 1.93% of the variation, where as the age/size (DBH class) explained 1.9% of the variation in tree health condition. Land-use type only explained 0.17% of the variation.

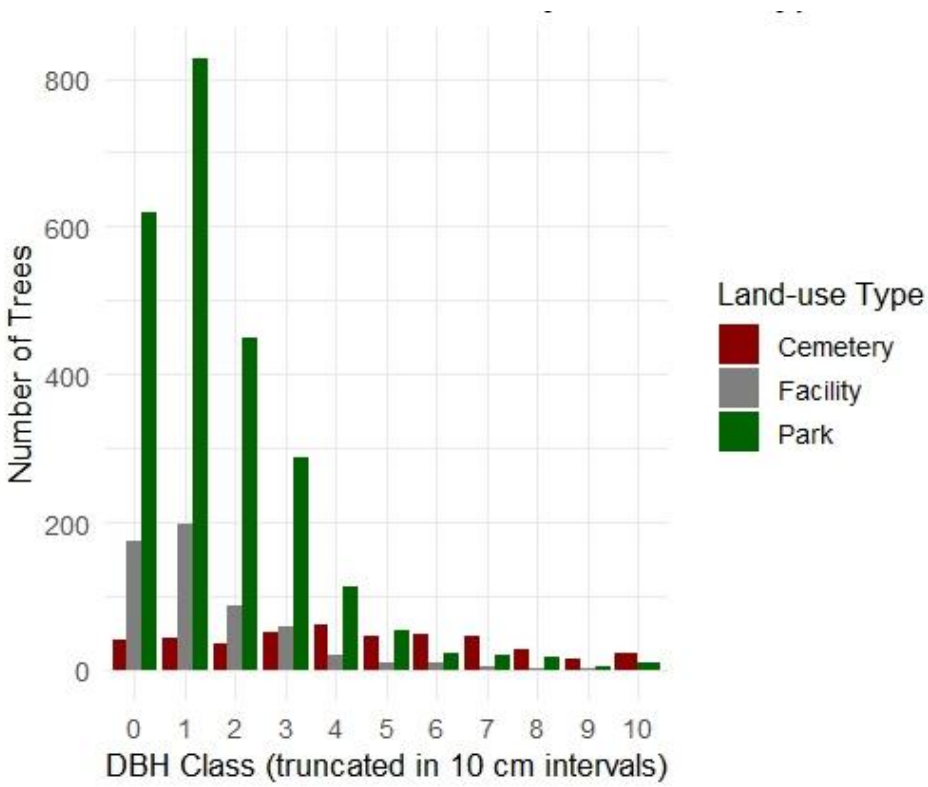

Figure 5: DBH classes are in increments of 10 cm, until 100 cm DBH, after which they are all in age class 10. Parks and facilities have smaller, younger trees, whereas cemeteries have more larger, older trees

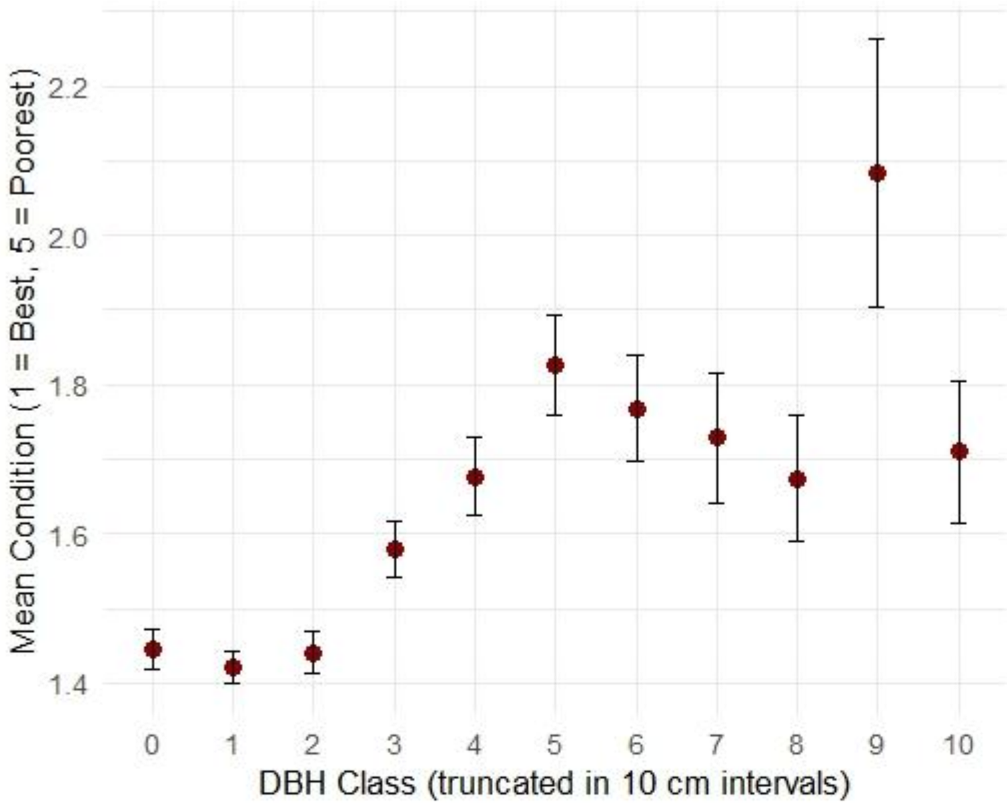

Figure 6: DBH classes are in increments of 10 cm, until 100 cm DBH, after which they are all in age class 10. Tree condition is on a scale of 1-5 (see *Table 1*). There is a positive correlation between DBH and Tree condition rating, and negative correlation between DBH class and overall tree health.

Discussion and Management Implications

While there were significant differences in tree health among species, all tree species were in good condition (mean condition=1-<2) with the exception of Austrian pine (*Pinus nigra*). This could be due to the fact that trees decrease in health as they age (Eickenscheidt et al., 2019, Binkley et al., 2002) most of the Austrian pine trees are greater than 30 cm DBH, putting them above 50 years of age (Van Haverbeke.1990). Green ash (*Fraxinus pennsylvanica)* was also in slightly worse health than other species, but that was expected due to emerald ash borer (*Agrilus planipennis*) (Herms & McCullough, 2014). In terms of land-use, the cemeteries had trees in slightly worse condition than those in parks and facilities, which supports the prediction that cemeteries will do worse than facilities, but goes against the prediction that facility trees will be healthier than park trees. This could be due to the maintenance being done on trees improving their health (Fini et al., 2015., Esperon-Rodriguez et al., 2025), or the trees in parks being younger as shown in *figure 5*. It is important to note that while statistically significant, these differences are minuscule, with the differences being 0.1-0.2 on the rating scale, even though the ratings are ordered 1-5 with no in-between options. It is also important to note that land-use type only explained 0.17% of the variation in the data, although the linear model crated to look at residuals did not look at health condition as an ordinal variable, unlike the ordinal regression.

In terms of the species and land-use type interaction, maple trees, which were expected to do better in facilities, ended up doing worse in facilities. This could be due to the care being put into trees at parks (Fini et al., 2015., Esperon-Rodriguez et al., 2025) as well as the park trees being younger (Eickenscheidt et al., 2019, Binkley et al., 2002). However, the prediction was correct in that trees with thicker barks, such as oaks and pines did better in parks. These trees did worse in cemeteries likely due to their age (Eickenscheidt et al., 2019, Binkley et al., 2002).

For the management implications, extra care should be taken around trees when mowing the grass. The Town of Halton Hills should remove the turf grass near trees or apply mulch as that will deter mowers from coming close to the trunk (Morgenroth et al., 2015). I also believe that exposed roots should be covered with a thin layer of sand/topsoil (Harivandi & Gibeault, 1996). The town should also look into other soil amendments such as biochar and biosolids to improve soil quality and tree growth (Scharenbroch et al., 2013). Trees should also be covered with a metal guard to protect the base of the trunk from wounds (Shinwary, 2021). The Town of Halton Hills should also monitor the soil for compaction and nutrient deficiency and provide aeration and nutrients as needed.

Acknowledgments

I would like to thank my fellow tree inventory interns at the Town of Halton Hills, Mindy Wu, and Charlotte Arruda, for helping me with the data collection, as well as Eric Johnson at the Town of Halton Hills for helping me ID and assess trees. I would also like to thank my internal supervisor Dr. Sean Thomas at the University of Toronto for helping me with data analysis. Lastly, I would like to thank Catherine Edwards at the Town of Halton hills for helping me brainstorm ideas and giving me the internship at the Town of Halton Hills.

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