Species composition and stand structure in the urban forest: Comparing remnant forest patches and secondary growth in Toronto's ravine system

Master of Forest Conservation Final Capstone Project

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University of Toronto

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By: Matthew Tsafaridis

Internal Supervisor: Danijela Puric-Mladenovic

External Supervisor: Murray Fulmer

Abstract

Forested patches within urban areas provide essential ecosystem services and play a critical role in preserving urban biodiversity. Based on their origin, forested patches can be classified as remnant forests, areas that have not been cleared and have remained forested throughout urbanization, or secondary forests, established on land previously cleared for alternative uses. This capstone project compares species composition and stand structure between remnant forest patches and secondary growth within the G. Ross Lord Park, part of Toronto's extensive ravine network. Using the Vegetation Sampling Protocol (VSP), 54 fixed-area plots were surveyed to assess native and nonnative plant abundance, species richness, and floristic quality across canopy and understory strata. Historical forest cover mapping from 1954 was integrated with field data to classify monitoring plots according to their proximity to remnant forest patches. This allowed for the examination of ecological patterns using Kruskal–Wallis tests, Spearman's correlation tests, and Generalized Linear Models. The results demonstrated that remnant forest patches exhibited higher native species richness and stronger floristic quality, particularly within the tree layer. Remnant forest patches also contained fewer nonnative tree species compared to secondary forests. These findings indicate that remnant forests serve as important refuges for native vegetation within urban forests and highlight the long-lasting effects of historical land use on secondary forests. This project provides evidence-based management recommendations to guide conservation and restoration efforts in the G. Ross Lord Park. It emphasizes the need to protect remnant forest patches, prioritize invasive species removal at remnant edges, and support assisted regeneration in secondary forests to strengthen ecological resilience across the ravine system.

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1. Introduction

1.1 Background

Since the mid-20th century, urbanization has increased rapidly around the world (Gu et al., 2021). Between 1990 and 2020, the global urban population grew from 43% to 56%, a figure projected to reach 68% by 2050 (Gu et al., 2021). As urbanization increases, urban forests are becoming increasingly vulnerable and important to protect (Wyse et al., 2015).

Despite becoming more urbanized, human civilization continues to depend on a variety of ecosystem services provided by forests (Bolund & Hunhammar, 1999). Ecosystem services are the benefits that human populations derive from the natural world (Bolund & Hunhammar, 1999). While urban centres can often feel disconnected from nature, they depend on ecosystems beyond and within their boundaries to provide services such as air filtration, microclimate regulation, rainwater drainage, and sewage treatment, as well as recreational and cultural value (Bolund & Hunhammar, 1999). Investing in ecological restoration and rehabilitation in urban areas has proven to be ecologically, socially, and economically beneficial (Elmqvist et al., 2015). Unfortunately, the expansion of urban areas is often directly correlated to the destruction of nature, reducing local biodiversity and hindering the ability of remaining natural areas to provide these critical services (Martinson, 2020).

Urban forested areas can be divided into two major categories based on their origin: remnant forests and secondary forests (Yang et al., 2021). Remnant forests are areas that have remained naturally forested throughout urbanization, and secondary forests are those that were previously cleared for alternative land use (Yang et al., 2021). In urban areas, remnant forests often act as biodiversity hotspots; however, factors such as urban intensification (Wyse et al., 2015) and global climate change (Russo et al., 2025) threaten their integrity and survival (Yang et al., 2021). Given the vulnerability of urban forested areas there is a growing need to better understand the dynamics between remnant forest patches and the urban environment, informing management practices that better support biodiversity and improve ecosystem services (Yang et al., 2021) (Russo et al., 2025).

Research conducted outside urban areas has explored differences in species composition and stand structure between old-growth and secondary-growth forest stands (Abbas et al., 2019). With most global forests composed of secondary growth, understanding successional dynamics is crucial to engaging meaningfully in restoration activities (Abbas et al., 2019). One study, conducted in tropical forests in Panama, demonstrated that species richness in secondary forest stands can return to old growth levels as quickly as 20 years after disturbance, and follows a relatively deterministic model (Dent et al., 2013). While the functional composition of secondary forests reliably converged with old-growth stands, the study found that changes in species composition followed a more stochastic model and reflected variation in species dominance (Dent et al., 2013). While research exploring successional dynamics in an urban context is limited, some findings suggest that urban forested areas with larger remnant forest patches have higher taxonomic diversity and less compositional turnover in woody plants (Yang et al., 2021).

To properly assess the health and resilience of urban forests, it is important to understand the benefits and drawbacks of native and nonnative plant species (Russo et al., 2025). While native species are more likely to be impacted by climate change, they provide ecological benefits, such as supporting local wildlife and pollinators (Russo et al., 2025). Native plants have also been linked to increased plant abundance (Tartaglia & Aronson, 2024), biodiversity, and enhanced ecosystem services in urban areas (Martinson, 2020). Urban centres are often disproportionately vulnerable to the introduction and spread of nonnative species (Gaertner et al., 2017). High population densities and an abundance of transport linkages can facilitate the introduction and dissemination of nonnative species, causing urban ecosystems to be key points of entry to broader local environments (Gaertner et al., 2017). In addition, nonnative plant species are often utilized in urban horticulture (Tartaglia & Aronson, 2024). Research examining invasion dynamics or comparing the impacts of native and nonnative plant species in urban areas remains limited, with most emphasis being placed upon understanding natural and semi-natural ecosystems (Tartaglia & Aronson, 2024; (Gaertner et al., 2017).

The impacts of nonnative species in urban areas can differ significantly from other landscapes, and managing invasive species poses unique and complex challenges (Gaertner et al., 2017). Urban areas are often home to a variety of stakeholders with differing perspectives on management practices (Gaertner et al., 2017). However, arguments surrounding nonnative species management in urban areas typically revolve around the perceived delivery of ecosystem services and disservices (Gaertner et al., 2017). While nonnative species can be introduced with the intention of creating or restoring a particular ecosystem service, they can oftentimes cause unintended consequences (Gaertner et al., 2017). The impacts of nonnative species are also likely dependent on forest age and origin (Zipperer, 2002). For example, a study exploring the species composition of remnant forest patches in Syracuse, New York, found significantly fewer introduced, or nonnative species compared to secondary forests (Zipperer, 2002). Conversely, research examining post-agricultural sites in Ohio found that nonnative plant species had not stabilized even 80 years after disturbance (Holmes & Matlack, 2019). While nonnative plant abundance in these secondary forests declined over time, the study concluded that a subset of shade-tolerant species should be considered a long-term component of secondary growth forest stands (Holmes & Matlack, 2019).

Toronto, Ontario, is the largest urban centre in Canada and boasts an expansive network of green spaces and ravines (Davies et al., 2018). Covering over 11,000 hectares and approximately 17% of the city's geographical area, Toronto's ravine network is one of the largest urban ecosystems in the world (Davies et al., 2018). Toronto's forested urban areas provide valuable ecosystem services such as reducing air pollution, mitigating stormwater runoff, and sequestering carbon (City of Toronto, 2008). Forested urban areas also moderate extreme seasonal temperatures, serving as windbreaks in winter and providing evaporative cooling in summer (City of Toronto, 2008). In 2008, the estimated value of ecosystem services provided by Toronto's forested urban areas was $60 million annually, a figure that greatly exceeded its management costs (City of Toronto, 2008). However, over the last several decades, the ecological health of Toronto's forested urban areas has declined significantly, placing these ecosystems at the edge of collapse (Davies et al., 2018). With the increase of invasive plant

abundance and decrease of native plant biodiversity, ecosystem services are inevitably negatively impacted (Davies et al., 2018; (Martinson, 2020). To improve the condition of Toronto's forested urban areas, evidence-based adaptive management frameworks are urgently needed (Davies et al., 2018).

1.2 Study Area

The G. Ross Lord Park is located in North York, Ontario, and is a part of the Don River West watershed. The park is used by the public for recreational activities such as dog walking, cycling, and organized sports. It is adjacent to major city roads and built-up commercial areas, including the North York campus of the pharmaceutical company, Sanofi Pasteur. Historical mapping dating back to 1954 provides insight into the park's land use. Much of the park was previously used for agricultural purposes and has been reforested over the past 71 years. However, certain areas of the park include original forest remnants that are over 100 years old.

Currently, the G. Ross Lord Park is experiencing ecological degradation due to the encroachment of nonnative plant species, including Common Buckthorn (*Rhamnus cathartica*), Garlic mustard (*Alliaria petiolate*), Dog-strangling vine (*Cynanchum rossicum*), Manitoba Maple (*Acer negundo*), and Common Reed (*Phragmites australis*). This invasion threatens the survival and regeneration of native plant species, undermining the ecological integrity of the park. Despite preliminary observations identifying these issues, there is currently no comprehensive, evidence-based management strategy to restore native vegetation and protect vulnerable habitats.

Its location, current-day recreational use, and varied historical land use make the G. Ross Lord Park an ideal case study to analyze the state of the forested urban areas in Toronto's ravine network. In particular, the park provides an opportunity to explore differences between stands given their relative proximity to the remnant forest patches present in the area. The University of Toronto has formed a partnership with Sanofi Pasteur, which aims to carry out management activities in the park as part of its company-wide biodiversity initiative. One component of this partnership is the completion of an updated biodiversity report, including recommendations for future management solutions. Without targeted conservation and restoration actions, the spread of invasive species is likely to continue, further compromising biodiversity and ecosystem function.

1.3 Objectives

This capstone project compares different-aged stands within the G. Ross Lord Park, analyzing the differences between secondary growth and remnant forest patches in the urban environment. Specifically, the project compares the presence of native and nonnative plant species across the study area, considering both canopy and understory vegetation. This project aims to inform management strategies for Sanofi Pasteur, the City of Toronto, and their partners, focusing on the protection and reintroduction of native plant species. Special attention will be given to the restoration of riparian areas, leveraging the collaboration between the University of

Toronto, Sanofi Pasteur, and the City of Toronto to implement a strategic, evidence-based restoration plan.

Objectives:

1. To identify and evaluate the factors that influence the abundance and diversity of native plant species within urban forest ecosystems.
2. To examine how plant community composition differs across various forest types and areas experiencing different levels of disturbance.
3. To assess the effectiveness of diverse management approaches in supporting native species and sustaining essential ecosystem functions.
4. To determine whether distinct areas of the forest require customized management strategies to meet restoration and conservation objectives successfully.

2. Methods

2.1 Data Collection

During the summer of 2025, forest monitoring based on a sampling protocol (VSP) (Puric-Mladenovic, 2016) was carried out in the G. Ross Lord Park. VSP is a quantitative, integrative, and adaptable method of field work used to sample vegetation types at a site-specific or landscape level. The VSP conducted at the G. Ross Lord Park followed the standards established by the VSP program at Forestry, Daniels Faculty, University of Toronto. A total of 54 random fixed area plots were sampled between June and August (Image 2). Of these plots, 37 were newly established, and 17 were resampled plots from 2021. Plots are circular, with a fixed radius of 11.28m and an area of 400m^2 (Image 1). Plots are divided into quadrants using the cardinal directions, and vegetation is stratified based on height. The four strata of vegetation utilized in statistical analysis are as follows: groundcover layer (< 0.5m), shrub layer (0.5 – 2m), subcanopy layer (2 – 10m), and canopy layer (> 10m). Additionally, sampling included the identification, measurement, and basic health assessment of all trees (> 5cm diameter breast height) present in each plot. This project used data from the VSP plant abundance (cover) module and tree measurements module to assign values for the dependent variables used in statistical analysis.

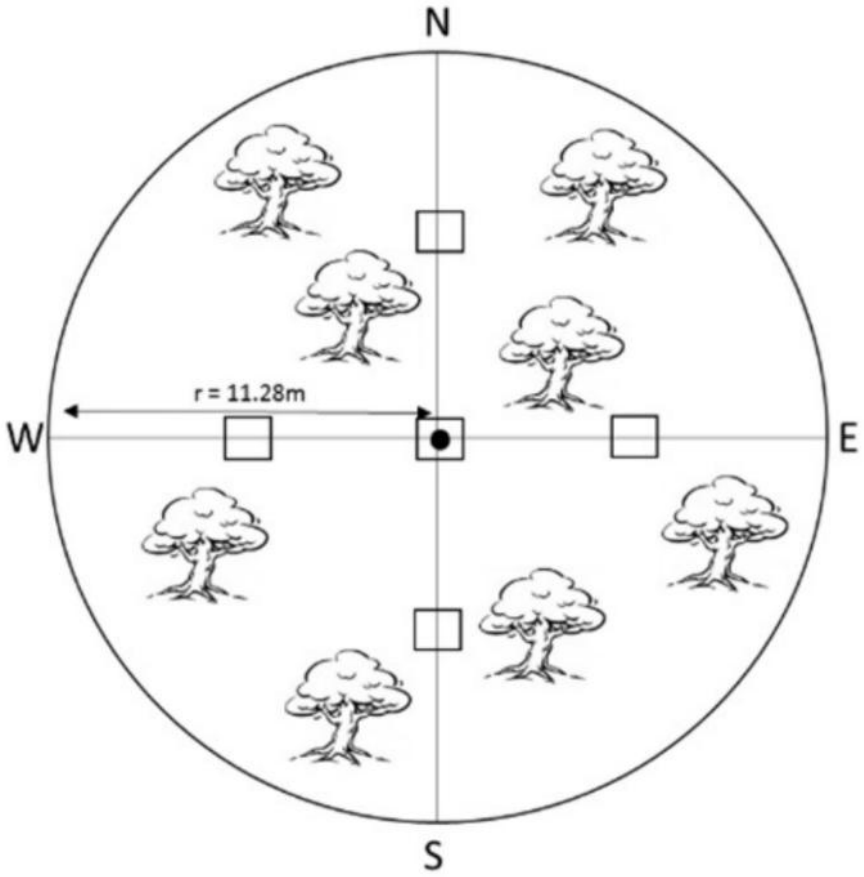

Figure 1: VSP Fixed Area Plot (Puric-Mladenovic, 2016).

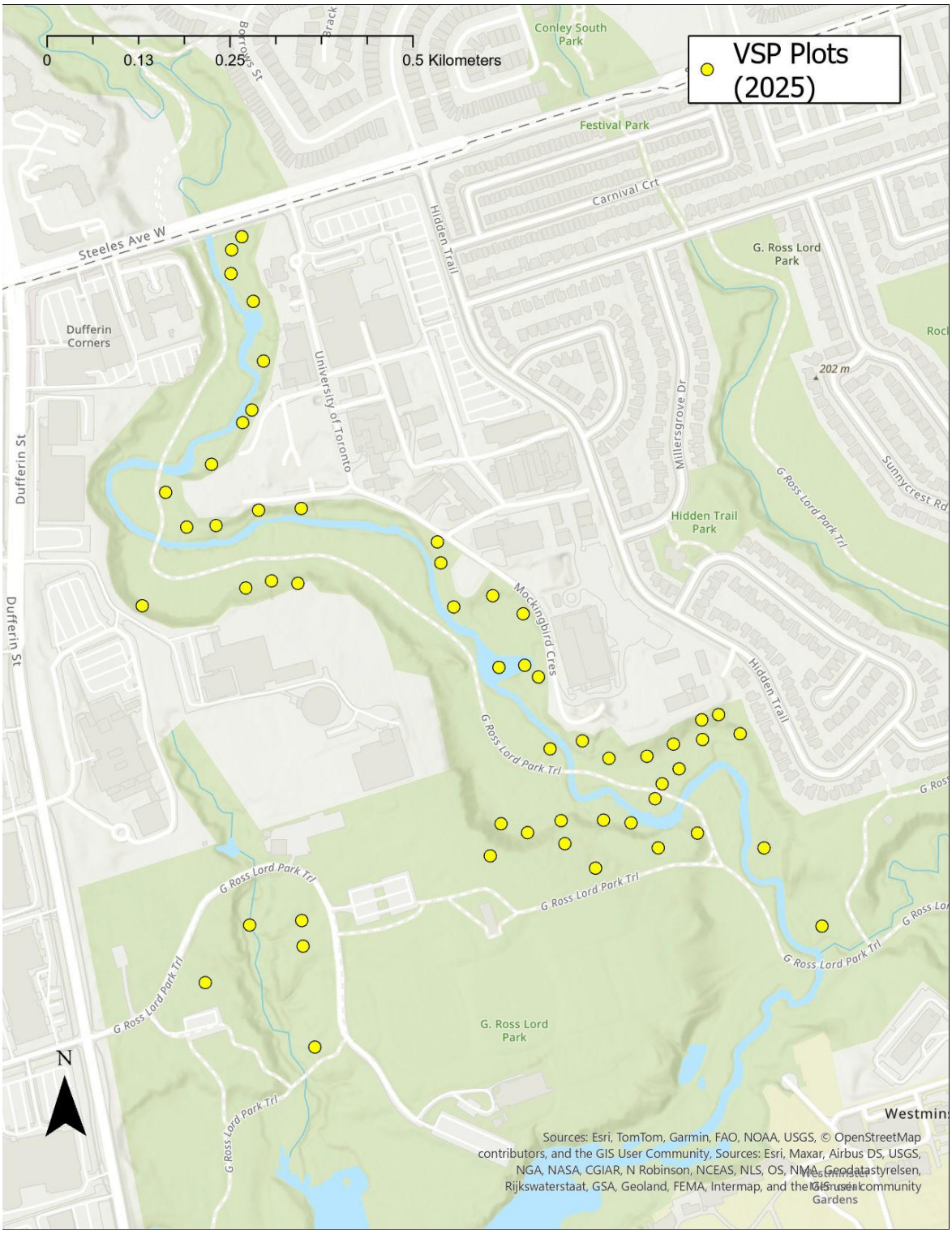

Figure 2: Location of VSP plots sampled within the study area during 2025.

2.2 Statistical Analysis

Using the mapped historical distribution of the forest in 1954 (Yuan, 2025), it was determined that a portion of the G. Ross Lord Park is situated within presumed patches of remnant forest. By overlaying this historical mapping with the 2025 VSP data (Image 3), the plots were classified using four metrics, which served as independent variables in the statistical analysis (Table 1).

Data compiled during VSP were used to determine values for the eighteen dependent variables, which were used for statistical analysis (Table 2). The dependent variables include measures of native and nonnative plant abundance and native and nonnative plant species richness. Additionally, the dependent variables include two measures of floristic quality. Floristic quality is a method used to assess the ecological health of a natural area by examining species composition (Oldham et al., 1995). To measure floristic quality, a coefficient of conservatism (CC) is assigned to each native plant (Oldham et al., 1995). CC values range from 1 – 10, with 10 representing the highest conservation value. All nonnative plants are assigned a CC value of 0 (Oldham et al., 1995). Using this data, average and maximum CC values for each plot were determined.

Dependent variables were further divided into three distinct categories based on plant strata. These categories are total plot (including plants recorded in all four height-based stratifications), groundcover layer (only includes plants < 0.5m in height), and trees (only includes trees with a diameter breast height > 5cm).

After assigning metrics and spatial classifications to each of the 54 plots, RStudio was used to assess whether statistically significant differences exist between plots based on their location relative to remnant forest patches. The normality of all data was evaluated using Shapiro-Wilk tests. Kruskal-Wallis tests were used to examine the relationships between the two categorical independent variables, Remnant Forest Position (Binary) (Figure 4) and Remnant Forest Position (Categorical) (Figure 5), and all eighteen dependent variables. Spearman's Correlation tests were used to examine the relationships between the two continuous independent variables, Percent Remnant Forest Cover (Figure 6) and Distance to Forest Edge (Figure 7), and all eighteen dependent variables. If the Kruskal-Wallis tests indicated that a statistically significant relationship existed between Remnant Forest Position (Categorical) and the dependent variable, a post-hoc Dunn test was used to identify which of the three groups (outside forest, forest edge, forest interior) differed significantly. If the Spearman's Correlation tests indicated that a statistically significant relationship existed between the independent and dependent variables, a Generalized Linear Model was used further to examine the strength and direction of the relationship. Poisson GLM was used if overdispersion was greater than 1.5, and Negative Binomial GLM was used if overdispersion was less than 1.5. Boxplots and scatterplots were used to visualize notable findings.

Table 1: Description of independent variables used in statistical analysis.

Independent Variable	Description
Remnant Forest Position (Binary)	Binary categorization of each VSP plot (2025), indicating whether the plot centre is located inside or outside the remnant forest patches (1954)
Remnant Forest Position (Categorical)	Categorization of each VSP plot (2025), indicating whether the plot centre is located in the remnant forest edge, interior, or outside the remnant forest patches (1954). Forest edge is characterized as all areas inside the remnant forest patches that are within 15m of the forest patch boundary. Forest interior is characterized as all areas inside the remnant forest patches that are farther than 15m from the forest patch boundary.
Percent Remnant Forest Cover	Numerical value assigned to each VSP plot (2025), indicating the percentage of the plot that falls within the remnant forest patches (1954).
Distance to Remnant Forest Edge (m)	Numerical value assigned to each VSP plot (2025), indicating the distance between the plot centre and the nearest boundary of the remnant forest patches (1954). Plots located within remnant forest patches are assigned positive values, and plots located outside remnant forest patches are assigned negative values.

Figure 3: Sampled VSP plots (2025) overlayed with remnant forest patches that existed and were observed as forests (1954).

Table 2: Description of dependent variables used in statistical analysis.

Dependent Variable	Description
Average CC	Mean value of coefficients of conservatism, including all plant species present in a plot.
Maximum CC	The maximum value of the coefficients of conservatism, out of all plant species present in a plot.
Native Abundance	Total abundance of all native plants in each plot. Value determined by adding the cover total estimates from all four height-based stratifications.
Nonnative Abundance	Total abundance of all nonnative plants in each plot. Value determined by adding the cover total estimates from all four height-based stratifications.
Native Richness	Total species richness of all native plants in each plot. Value determined using species recorded in all four height-based stratifications.
Nonnative Richness	Total species richness of all nonnative plants in each plot. Value determined using species recorded in all four height-based stratifications.
Average CC (Tree)	Mean value of coefficients of conservatism, including all trees present in a plot with a diameter breast height 5cm or greater.
Maximum CC (Tree)	Maximum value of coefficients of conservatism, out of all trees present in a plot with a diameter breast height 5cm or greater.
Native Abundance (Tree)	Total abundance of all native trees in each plot with a diameter breast height 5cm or greater.
Nonnative Abundance (Tree)	Total abundance of all nonnative trees in each plot with a diameter breast height 5cm or greater.
Native Richness (Tree)	Total species richness of all native trees in each plot with a diameter breast height 5cm or greater.
Nonnative Richness (Tree)	Total species richness of all nonnative trees in each plot with a diameter breast height 5cm or greater.
Average CC (Groundcover)	Mean value of coefficients of conservatism, including only plant species present in the groundcover layer (< 0.5m).
Maximum CC (Groundcover)	Maximum value of coefficients of conservatism, including only plant species present in the groundcover layer (< 0.5m).
Native Abundance (Groundcover)	Total abundance of all native plants in each plot that are below 0.5m in height. Value determined by adding cover total estimates from the groundcover layer.
Nonnative Abundance (Groundcover)	Total abundance of all native plants in each plot that are below 0.5m in height. Value determined by adding cover total estimates from the groundcover layer.
Native Richness (Groundcover)	Total species richness of all native plants in each plot that are below 0.5m in height. Value determined using species recorded in the groundcover layer.
Nonnative Richness (Groundcover)	Total species richness of all nonnative plants in each plot that are below 0.5m in height. Value determined using species recorded in the groundcover layer.

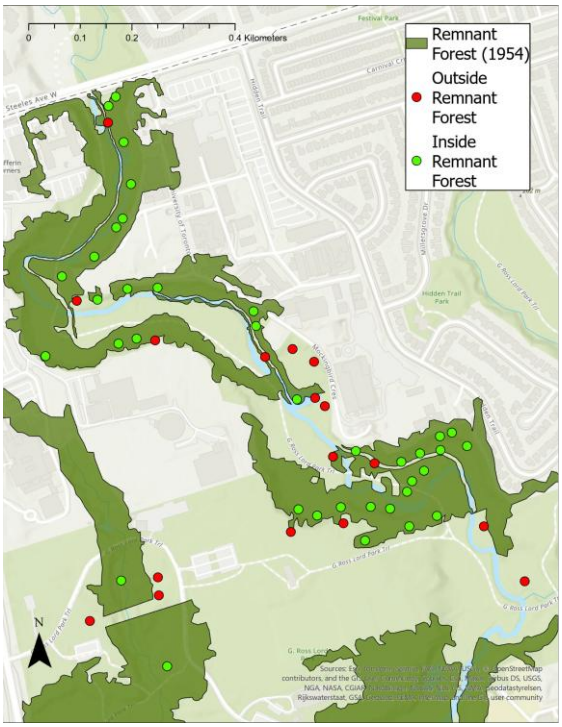

Figure 4: Location of sampled plots in relation to remnant forest patches (classified based on location inside or outside remnant forest patches)

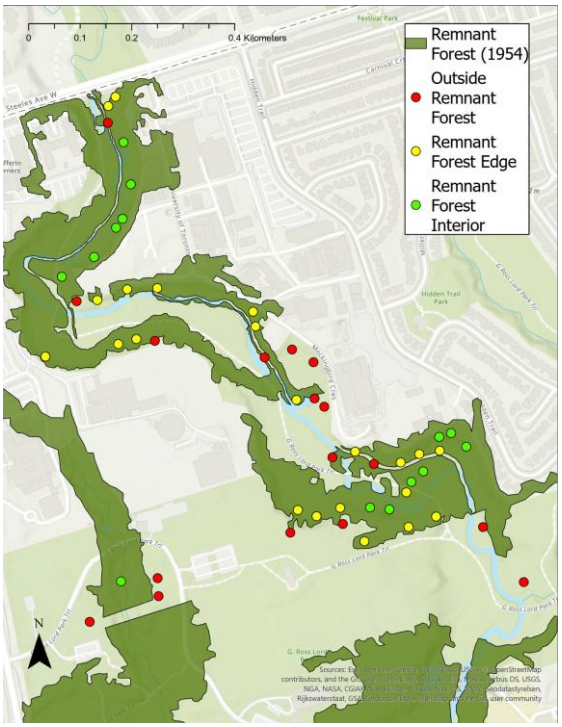

Figure 5: Location of sampled plots in relation to remnant forest patches (classified based on location inside, outside, or at the edges of remnant forest patches)

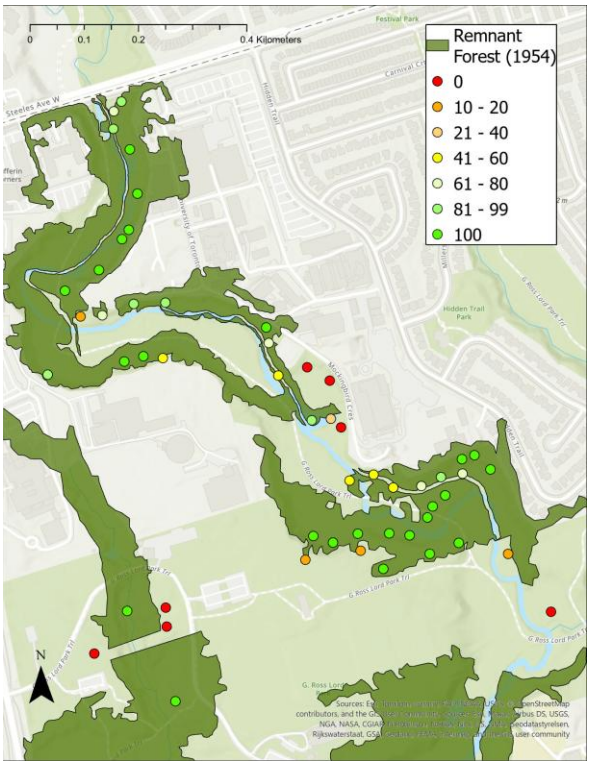

Figure 6: Percent of each sampled plot (total area 400m^2) that falls within remnant forest patches.

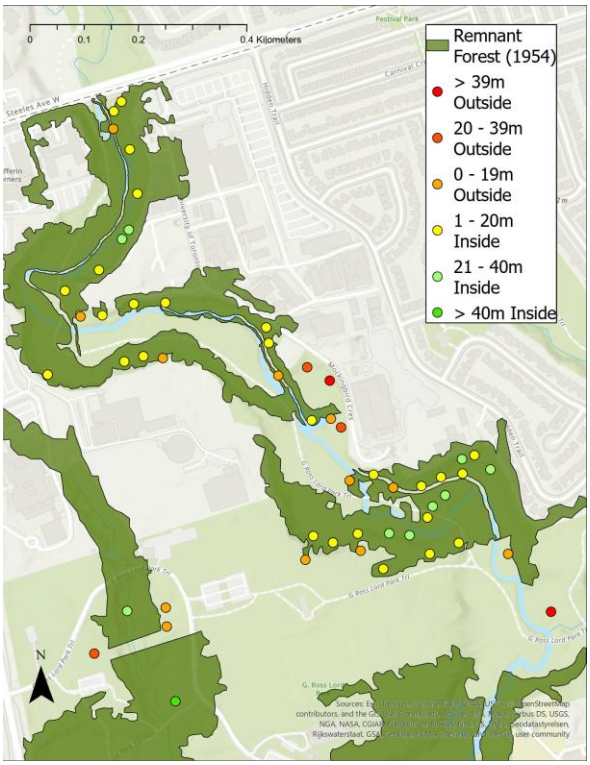

Figure 7: Distance of each sampled plot (in m) from the edge of remnant forest patches.

3. Results

Based on the results of the Shapiro-Wilk Normality Tests, we can conclude that the data for four of the independent variables are normally distributed. These four variables are Average CC, Native Richness, Average CC (Groundcover), and Native Richness (Groundcover). The data for the remaining fourteen independent variables is not normally distributed (Table 3).

Table 3: Summary of results from Shapiro-Wilk Normality Tests, used to assess the normality of dependent variables.

Variable	**W statistic**	**p-value**
Average CC	0.97731	0.394
Maximum CC	0.81478	9.33e-07
Native Abundance	0.91908	0.00138
Nonnative Abundance	0.90458	0.000409
Native Richness	0.96157	0.08103
Nonnative Richness	0.93481	0.005698
Average CC (Tree)	0.95302	0.03374
Maximum CC (Tree)	0.83170	2.53e-06
Native Abundance (Tree)	0.92743	0.00289
Nonnative Abundance (Tree)	0.88066	6.518e-05
Native Richness (Tree)	0.95170	0.02951
Nonnative Richness (Tree)	0.91763	0.001216
Average CC (Groundcover)	0.98472	0.7182
Maximum CC (Groundcover)	0.81268	8.274e-07
Native Abundance (Groundcover)	0.89679	0.0002202
Nonnative Abundance (Groundcover)	0.82917	2.172e-06
Native Richness (Groundcover)	0.96032	0.07122
Nonnative Richness (Groundcover)	0.92785	0.003002

Note: p-values > 0.05 indicate that data is normally distributed.

The Kruskal–Wallis test was used to assess whether Remnant Forest Position (Binary) was associated with various measures of plant community characteristics across different vegetation layers. The results show significant relationships for three variables: Average CC (χ^2 = 4.83, p = 0.02797), Native Richness (χ^2 = 6.08, p = 0.01366), and Average CC (Tree) (χ^2 = 5.09, p = 0.02409), indicating that these indices differ depending on if a site is located inside or outside a remnant forest patch. In contrast, the remaining variables, including measures of abundance, nonnative richness, maximum CC, and groundcover metrics, did not show significant differences (p > 0.05). This suggests that while overall native species richness and some measures of conservatism value, particularly within the tree layer, are influenced by remnant forest position, other structural or compositional attributes appear to be more uniform across the different forest types (Table 4).

Table 4: Summary of results from Kruskal-Wallis tests, used to examine the relationship between Remnant Forest Position (Binary) and the dependent variables.

Variable	Chi-squared	df	p-value
Average CC	4.8302	1	0.02797
Maximum CC	1.9697	1	0.1605
Native Abundance	0.094436	1	0.7586
Nonnative Abundance	1.1871	1	0.2759
Native Richness	6.0821	1	0.01366
Nonnative Richness	0.1612	1	0.6881
Average CC (Tree)	5.0878	1	0.02409
Maximum CC (Tree)	2.5685	1	0.109
Native Abundance (Tree)	0.5287	1	0.4672
Nonnative Abundance (Tree)	3.4385	1	0.06369
Native Richness (Tree)	3.4338	1	0.06388
Nonnative Richness (Tree)	1.5498	1	0.2132
Average CC (Groundcover)	2.0835	1	0.1489
Maximum CC (Groundcover)	0.80635	1	0.3692
Native Abundance (Groundcover)	0.65639	1	0.4178
Nonnative Abundance (Groundcover)	0.2168	1	0.6415
Native Richness (Groundcover)	3.6612	1	0.05569
Nonnative Richness (Groundcover)	0.37954	1	0.5379

Note: p-values < 0.05 indicate a significant relationship between the independent variable (Remnant Forest Position (Binary)) and the dependent variable.

Average CC values (Figure 8) differ between sites located inside and outside remnant forest patches. Sites inside remnant forests have higher Average CC values, indicated by a tighter distribution around a higher mean, suggesting the presence of species with greater ecological fidelity and sensitivity to disturbance. In contrast, sites outside remnant forests display lower Average CC values and greater variability, reflecting communities composed of species that are generally less conservative. The mean and standard error markers highlight this distinction, reinforcing the pattern that remnant forest position is associated with higher floristic quality.

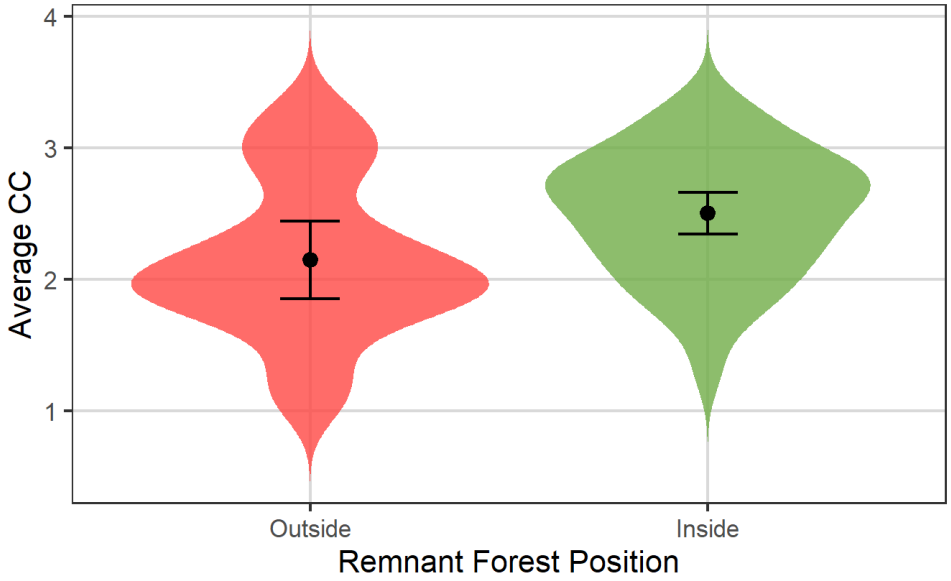

Figure 8: Average coefficient of conservatism (CC) values in plots located inside and outside remnant forest patches.

There is a positive relationship identified between remnant forest patches and higher floristic quality (Figure 9). Symbol size is proportional to Average CC values, with larger symbols representing higher values. Plots with higher Average CC values are predominantly located within remnant forest patches, whereas plots outside remnant forest patches display lower Average CC values and greater variability.

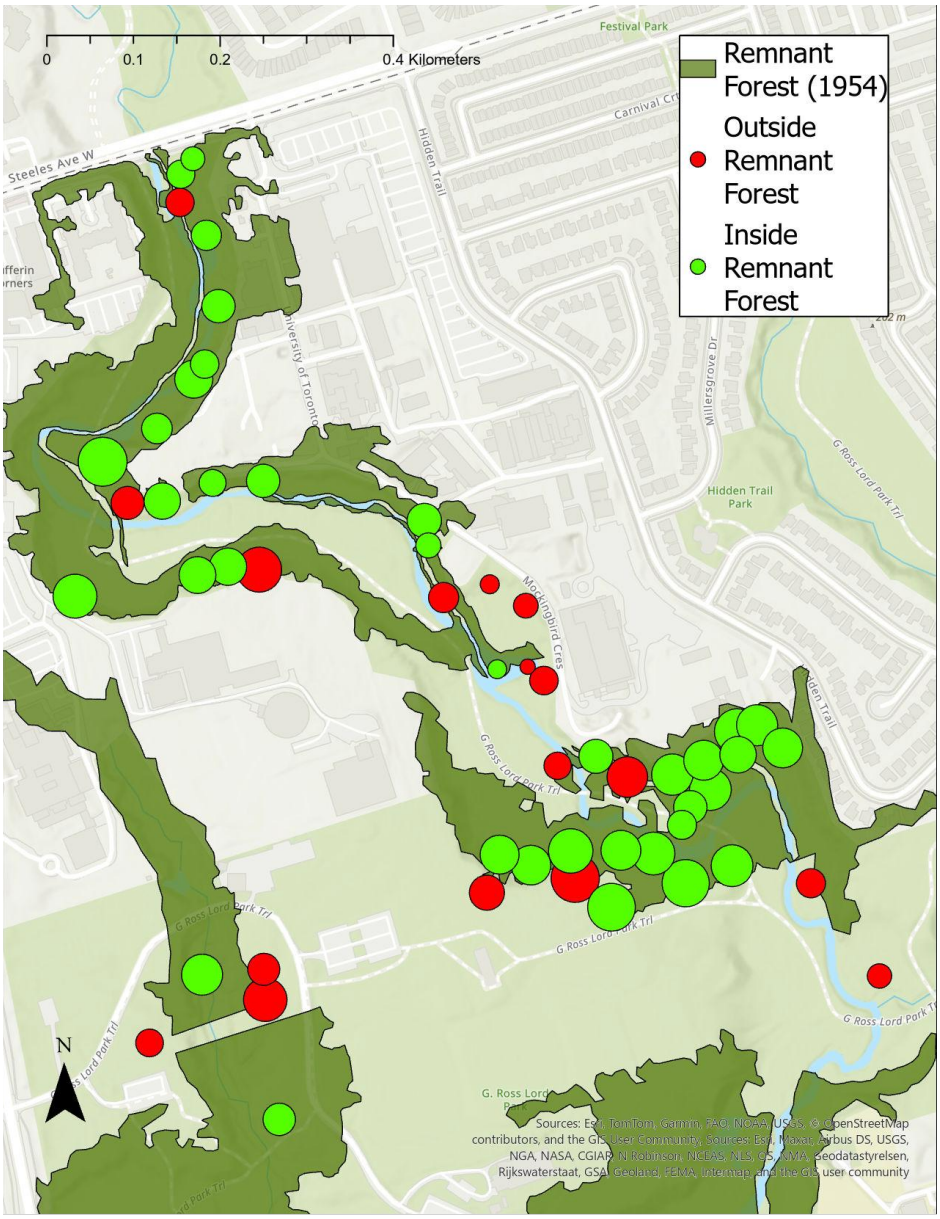

Figure 9: Spatial distribution of average coefficient of conservatism (CC) values in plots located inside and outside remnant forest patches.

Native Richness (Figure 10) differs between sites located inside and outside remnant forest patches. Sites within remnant forests have higher overall Native Richness, as indicated by a tighter distribution around a higher mean. In contrast, sites outside remnant forests exhibit lower overall Native Richness, reflecting less diverse plant communities with more nonnative species. The mean and standard error markers highlight this distinction, reinforcing the pattern that remnant forest position is associated with plant communities that possess higher overall Native Richness.

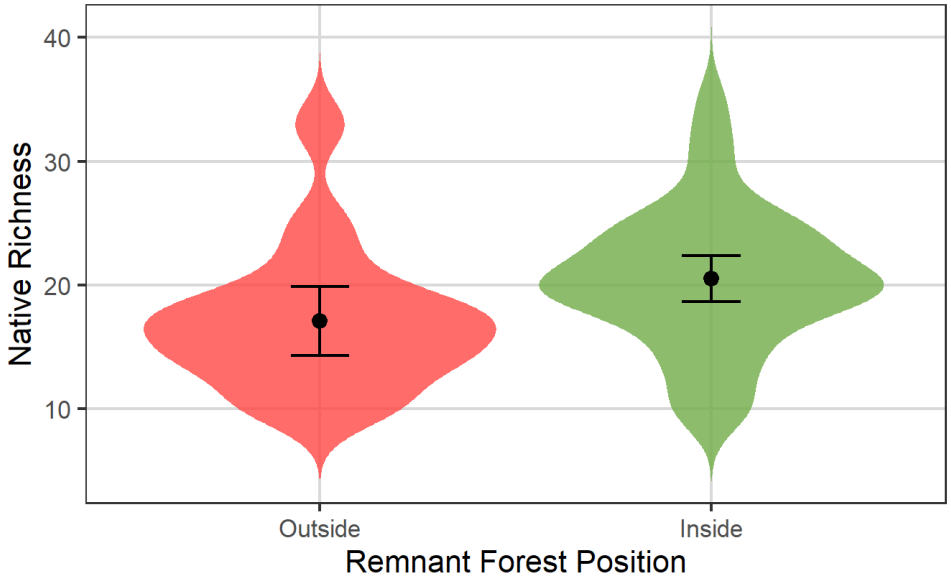

Figure 10: Native species richness in plots located inside and outside remnant forest patches.

There is a positive relationship identified between remnant forest patches and higher rates of overall native species richness (Figure 11). Symbol size is proportional to Native Richness, with larger symbols indicating higher levels of Native Richness. Plots with higher levels of Native Richness are predominantly located within remnant forest patches. In contrast, plots outside remnant forest patches have less diverse plant communities and contain more nonnative species.

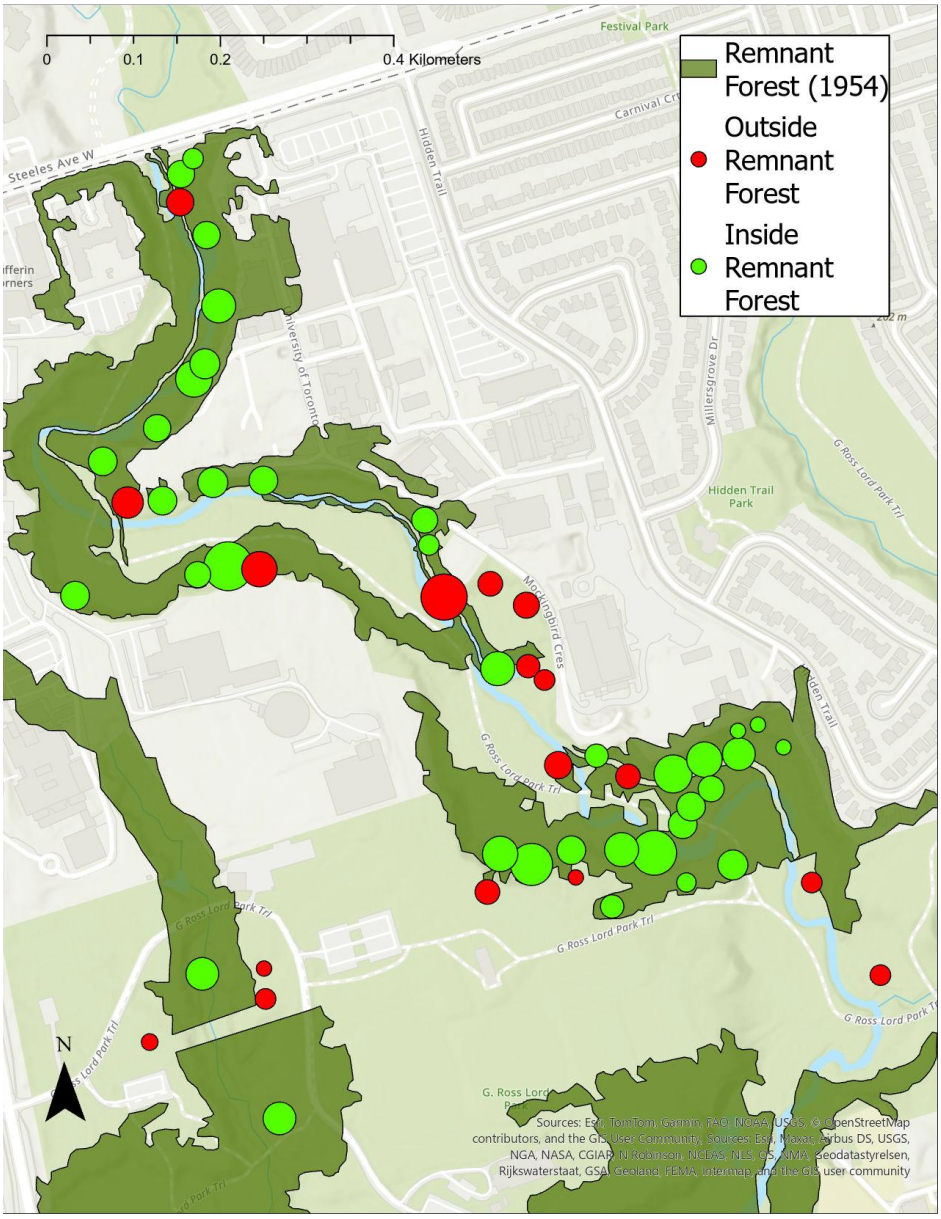

Figure 11: Spatial distribution of native species richness in plots located inside and outside remnant forest patches.

Average CC values of trees (Figure 12) differ between sites located inside and outside remnant forest patches. Sites inside remnant forests have trees with higher Average CC values, indicated by a tighter distribution around a higher mean, suggesting the presence of tree species with greater ecological fidelity and sensitivity to disturbance. In contrast, sites outside remnant forests include trees with lower Average CC values and greater variability, reflecting communities composed of tree species that are generally less conservative. The mean and standard error markers highlight this distinction, reinforcing the pattern that remnant forest position is associated with higher floristic quality.

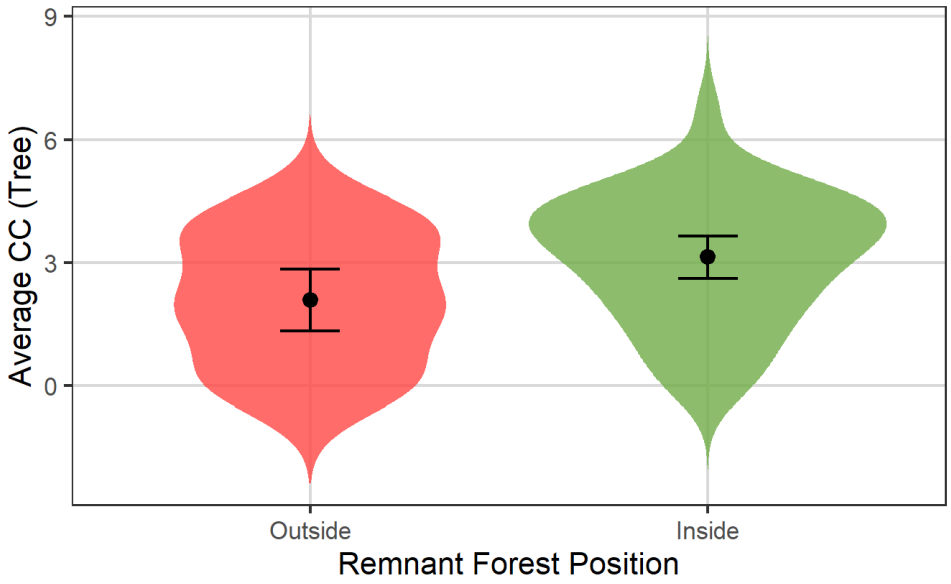

Figure 12: Average coefficient of conservatism (CC) values of trees in plots located inside and outside remnant forest patches.

There is a positive relationship identified between remnant forest patches and higher floristic quality of trees (Figure 13). Symbol size is proportional to the Average CC values of trees, with larger symbols representing higher values. Plots with higher Average CC values of trees are predominantly located within remnant forest patches, whereas plots outside remnant forest patches display lower Average CC values and greater variability.

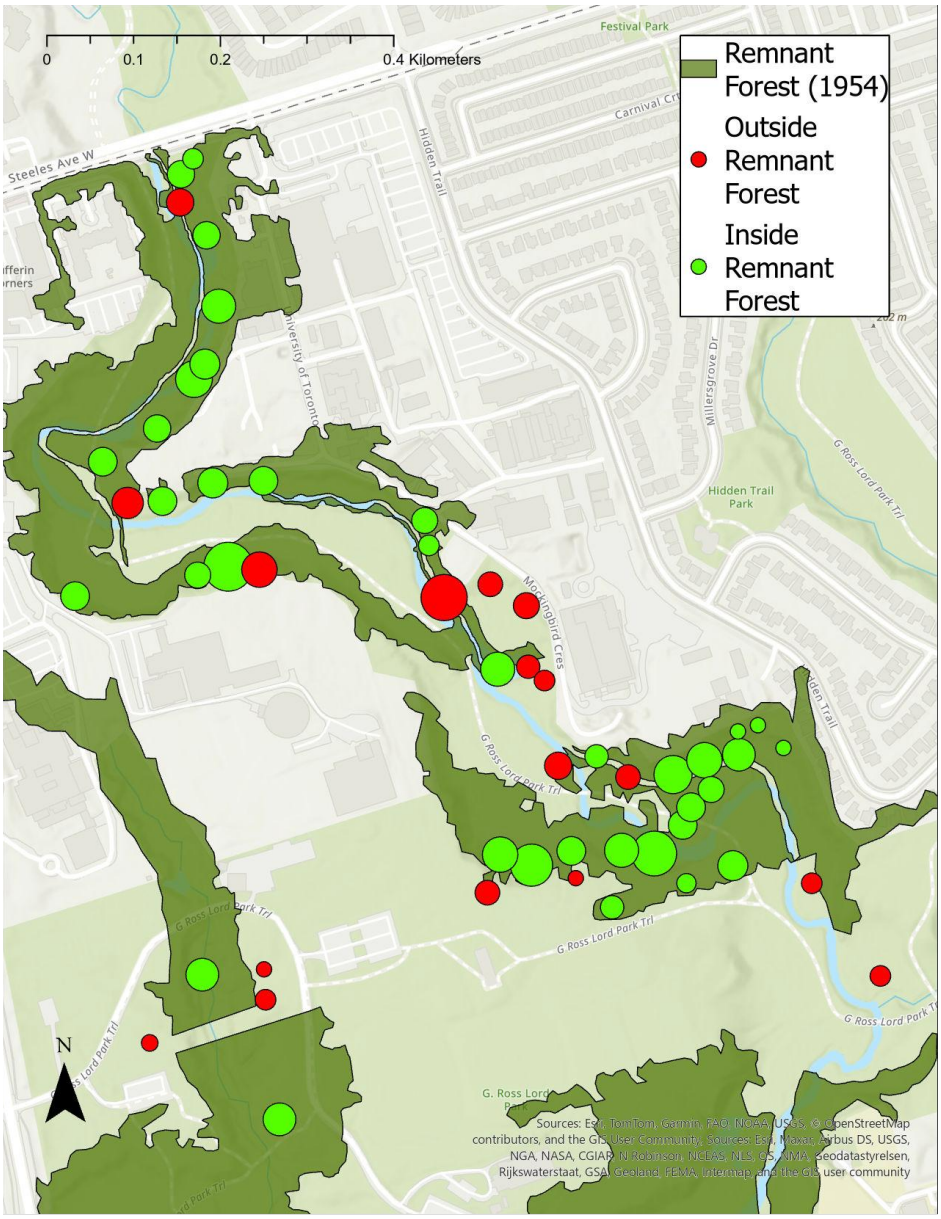

Figure 13: Spatial distribution of average coefficient of conservatism (CC) values of trees in plots located inside and outside remnant forest patches.

Based on the Kruskal–Wallis test results, Native Richness is the only variable that shows a statistically significant relationship with Remnant Forest Position (Categorical) ($\chi^2 = 6.19$, $p = 0.04526$). This finding indicates that at least one of the three position categories—inside, outside, or edge—differ from the others in native species richness. To determine which specific groups are responsible for this difference, a post-hoc comparison (e.g., Dunn's test) is required.

All other variables, including measures of conservatism, abundance, and richness across the whole community, tree layer, and groundcover layer, produced p-values greater than 0.05. These results suggest that Remnant Forest Position (Categorical) does not have a statistically meaningful effect on those metrics. Notably, variables such as Average CC and Native Richness within the groundcover layer approached significance but did not meet the threshold (Table 5).

Table 5: Summary of results from Kruskal-Wallis tests, used to examine the relationship between Remnant Forest Position (Categorical) and the dependent variables.

Variable	Chi-squared	df	p-value
Average CC	4.7344	2	0.09374
Maximum CC	3.9436	2	0.1392
Native Abundance	1.1778	2	0.5549
Nonnative Abundance	0.40974	2	0.8148
Native Richness	6.1905	2	0.04526
Nonnative Richness	0.25204	2	0.8816
Average CC (Tree)	3.9044	2	0.142
Maximum CC (Tree)	3.1693	2	0.205
Native Abundance (Tree)	0.14972	2	0.9279
Nonnative Abundance (Tree)	3.1024	2	0.212
Native Richness (Tree)	2.0478	2	0.3592
Nonnative Richness (Tree)	2.1097	2	0.3482
Average CC (Groundcover)	2.0839	2	0.3528
Maximum CC (Groundcover)	1.7362	2	0.4197
Native Abundance (Groundcover)	0.39177	2	0.8221
Nonnative Abundance (Groundcover)	0.028305	2	0.9859
Native Richness (Groundcover)	4.9553	2	0.08394
Nonnative Richness (Groundcover)	0.50044	2	0.7786

Note: p-values < 0.05 indicate a significant relationship between the independent variable (Remnant Forest Position (Binary)) and the dependent variable.

The Dunn test was conducted to identify which pairs of the Remnant Forest Position categories differed in Native Richness. Although the Edge–Outside comparison produced an unadjusted p-value below 0.05, none of the adjusted p-values met the significance threshold after correcting for multiple comparisons. The Edge–Inside and Inside–Outside comparisons also showed no significant differences. These results indicate that, despite the overall significant Kruskal–Wallis test, Native Richness does not differ significantly among the inside, outside, and edge forest positions once adjustments for false positives are applied (Table 6).

Table 6: Summary of results from Dunn Test, used to examine the relationship between Remnant Forest Position (Categorical) and Native Richness.

Comparison	Z	p-value unadjusted	p-value adjusted
Edge – Inside	0.2013211	0.84044748	1.00000000
Edge – Outside	2.3512714	0.01870938	0.05612814
Inside – Outside	1.9438785	0.05191010	0.15573030

Note: p-values < 0.05 indicate a significant difference between the means of the two groups being compared against one another. The Dunn test uses p-values adjustments to control for false positive results.

Native Richness varies across the three Remnant Forest Position categories, Outside, Edge, and Interior, with each distribution illustrated by a violin plot (Figure 14). Black markers indicate mean values and their associated standard errors. The Edge and Interior positions exhibit slightly higher average native species richness compared to sites outside remnant forests, although there is substantial overlap in the distributions. The Outside sites have lower mean richness and a narrower spread, while the Edge and Interior groups show greater variability and slightly higher means. Despite these visible differences in central tendency, the overlap across all three groups corresponds with the Dunn test results, indicating that none of the pairwise comparisons were statistically significant after adjustment.

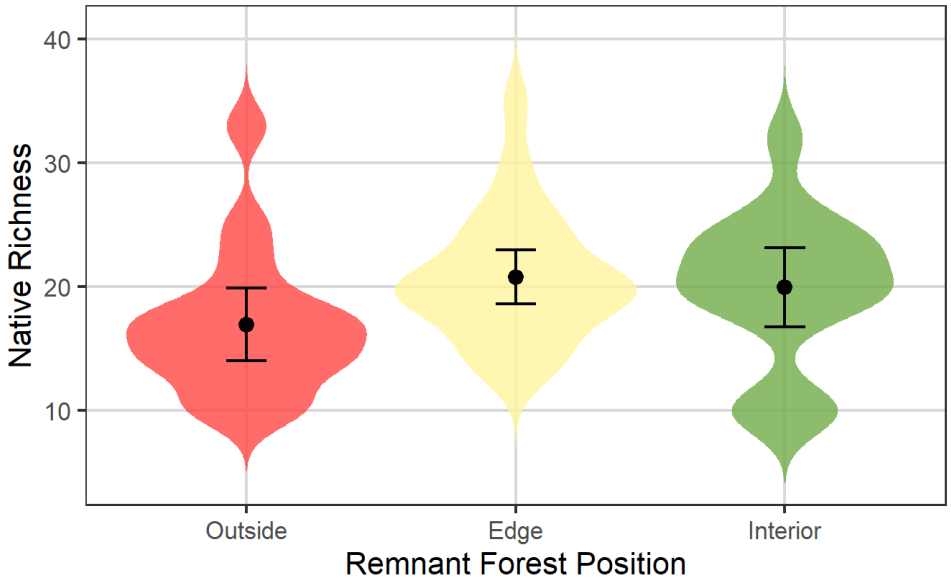

Figure 14: Native species richness in plots located inside, outside, and at the edges of remnant forest patches.

There were slight differences identified in overall native species richness between some of the three Remnant Forest Position categories: Outside, Edge, and Interior (Figure 15). Symbol size is proportional to Native Richness, with larger symbols indicating higher levels of Native Richness. While Edge and Interior positions exhibit slightly higher average native species richness compared to sites outside remnant forests, there is substantial overlap in the distributions.

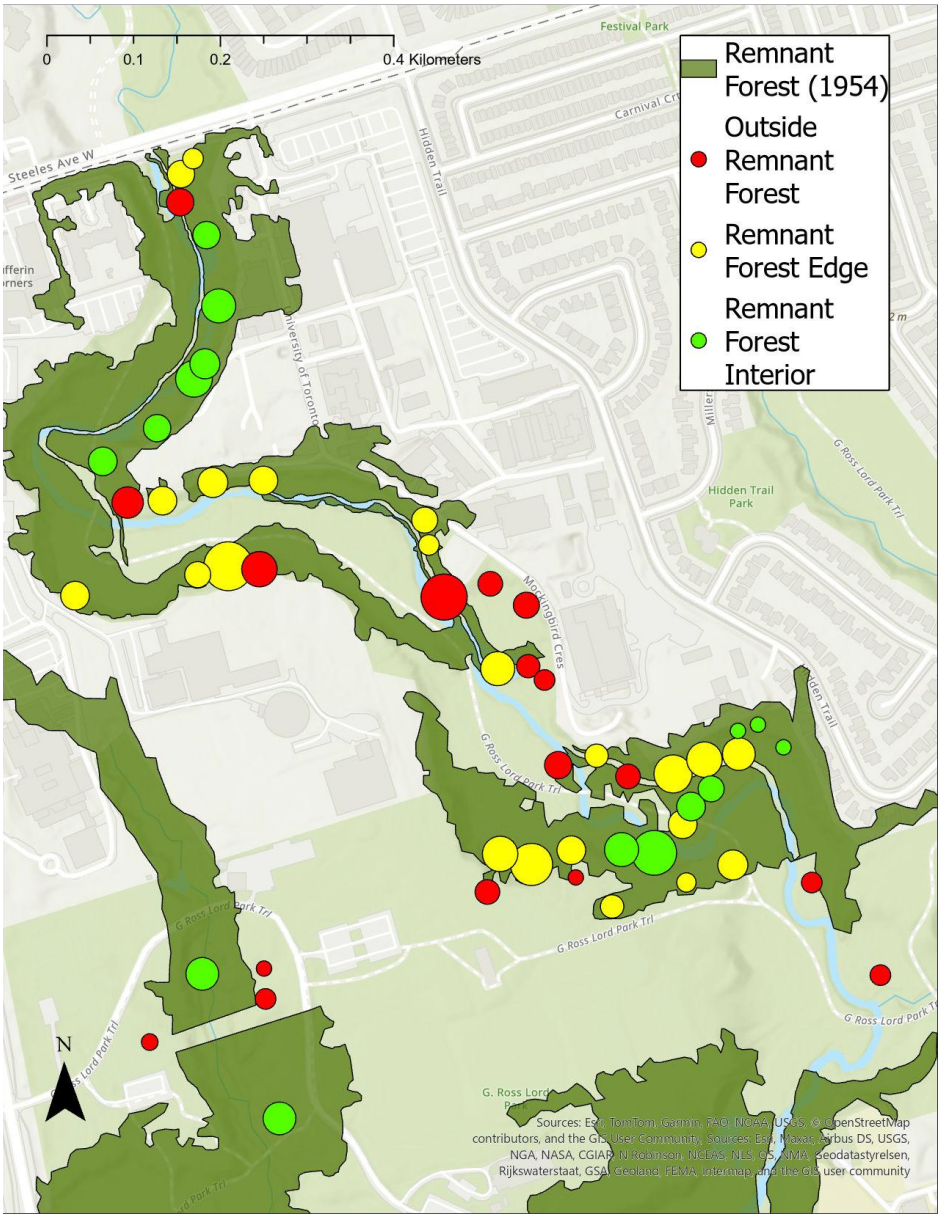

Figure 15: Spatial distribution of native species richness in plots located inside, outside, and at the edges of remnant forest patches.

The results of Spearman's Correlation Tests were used to assess the relationship between Percent Remnant Forest Cover and various ecological variables. The test statistics (S), p-values, and Spearman's Rho are reported for each dependent variable; p-values below 0.05 indicate statistically significant relationships. Six variables—Average CC, Maximum CC, Native Richness, Average CC (Tree), Native Richness (Tree), and Native Richness (Groundcover)—show significant correlations, all of which are weakly positive, suggesting that higher Percent Remnant Forest Cover is associated with slight increases in these measures. Other variables, including nonnative abundance and richness, as well as some tree and groundcover metrics, did not exhibit significant relationships (Table 7).

Table 7: Summary of results from Spearman's Correlation Tests, used to examine the relationship between Percent Remnant Forest Cover and the dependent variables.

Variable	S	p-value	Rho
Average CC	16895	0.008241	0.3560031
Maximum CC	16142	0.004074	0.3847171
Native Abundance	25203	0.7776	0.03934009
Nonnative Abundance	30270	0.2668	-0.1538083
Native Richness	16521	0.005854	0.3702564
Nonnative Richness	24829	0.7004	0.05357588
Average CC (Tree)	17650	0.01573	0.3272232
Maximum CC (Tree)	20398	0.1059	0.2224961
Native Abundance (Tree)	23254	0.4133	0.1136325
Nonnative Abundance (Tree)	33142	0.05442	-0.2632729
Native Richness (Tree)	18751	0.03653	0.2852798
Nonnative Richness (Tree)	32582	0.07799	-0.2419243
Average CC (Groundcover)	19752	0.07164	0.2471025
Maximum CC (Groundcover)	19794	0.07355	0.245509
Native Abundance (Groundcover)	32267	0.09441	-0.2299294
Nonnative Abundance (Groundcover)	28572	0.5219	-0.08907071
Native Richness (Groundcover)	17703	0.01642	0.325211
Nonnative Richness (Groundcover)	24054	0.5501	0.08313553

Note: p-values < 0.05 indicate a significant relationship between the independent variable (Percent Remnant Forest Cover) and the dependent variable. Rho indicates the strength and polarity of the relationship within a range of 1 to -1, with larger values indicating a stronger relationship.

Spearman's Correlation Tests were conducted to examine the relationship between Distance to Remnant Forest Edge (m) and various ecological variables. The test statistics (S), p-values, and Spearman's Rho are reported for each dependent variable; p-values below 0.05 indicate statistically significant relationships. Seven variables showed significant correlations with distance: Average CC, Maximum CC, Native Richness, Average CC (Tree), Maximum CC (Tree), Nonnative Abundance (Tree), and Nonnative Richness (Tree). The correlation with Average CC was moderately positive, while Maximum CC, Native Richness, Average CC (Tree), and Maximum CC (Tree) exhibited weak positive correlations. In contrast, Nonnative Abundance (Tree) and Nonnative Richness (Tree) showed weak negative correlations, suggesting that proximity to the forest edge is slightly associated with these changes in ecological patterns.

Table 8: Summary of results from Spearman's Correlation Tests, used to examine the relationship between Distance to Remnant Forest Edge (m) and the dependent variables.

Variable	S	p-value	Rho
Average CC	15548	0.002233	0.4073721
Maximum CC	17691	0.01626	0.3256541
Native Abundance	23250	0.4116	0.1137793
Nonnative Abundance	31572	0.1399	-0.2034305
Native Richness	17640	0.01559	0.3276185
Nonnative Richness	25882	0.9231	0.01345288
Average CC (Tree)	16317	0.004825	0.3780475
Maximum CC (Tree)	18107	0.02262	0.3098064
Native Abundance (Tree)	22518	0.3068	0.1416771
Nonnative Abundance (Tree)	33968	0.0305	-0.2947493
Native Richness (Tree)	20313	0.1007	0.2257371
Nonnative Richness (Tree)	34049	0.02871	-0.2978594
Average CC (Groundcover)	20466	0.1101	0.2199013
Maximum CC (Groundcover)	21021	0.1497	0.1987243
Native Abundance (Groundcover)	29968	0.3038	-0.1422908
Nonnative Abundance (Groundcover)	29708	0.34	-0.1323829
Native Richness (Groundcover)	19668	0.06791	0.2503206
Nonnative Richness (Groundcover)	24960	0.7271	0.04859984

Note: p-values < 0.05 indicate a significant relationship between the independent variable (Percent Remnant Forest Cover) and the dependent variable. Rho indicates the strength and polarity of the relationship within a range of 1 to -1, with larger values indicating a stronger relationship.

Generalized Linear Models were run to examine further the strength and direction of significant relationships identified by the Spearman's Correlation Tests. The test statistics (z-values) and p-values are reported for each dependent variable; p-values below 0.05 indicate statistically significant relationships. Four dependent variables showed significant correlations with Percent Remnant Forest Cover: Native Richness, Average CC (Tree), Native Richness (Tree), and Native Richness (Groundcover). All four relationships are positive. Five variables showed significant correlations with Distance to Remnant Forest Edge (m): Native Richness, Average CC (Tree), Maximum CC (Tree), Nonnative Abundance (Tree), Nonnative Richness (Tree). The relationships with Native Richness, Average CC (Tree), and Maximum CC (Tree) are positive. The relationships with Nonnative Abundance (Tree) and Nonnative Richness (Tree) are negative (Table 9).

Table 9: Summary of Results from Generalized Linear Models (GLMs), used to further examine the strength and direction of significant relationships identified by Spearman's Correlation Tests.

Dependent Variable	Predictor	z-value	p-value
Average CC	Percent Remnant Forest Cover	0.934	0.350
Maximum CC	Percent Remnant Forest Cover	1.159	0.246
Native Richness	Percent Remnant Forest Cover	2.897	0.0038
Average CC (Tree)	Percent Remnant Forest Cover	1.970	0.0489
Native Richness (Tree)	Percent Remnant Forest Cover	2.141	0.0323
Native Richness (Groundcover)	Percent Remnant Forest Cover	2.666	0.0077
Average CC	Distance to Edge	1.041	0.298
Maximum CC	Distance to Edge	0.897	0.370
Native Richness	Distance to Edge	2.327	0.020
Average CC (Tree)	Distance to Edge	2.659	0.00784
Maximum CC (Tree)	Distance to Edge	2.272	0.0231
Nonnative Abundance (Tree)	Distance to Edge	–2.508	0.0121
Nonnative Richness (Tree)	Distance to Edge	–2.600	0.00932

Note: p-values < 0.05 indicate a significant relationship between the independent variable and dependent variable. Rho indicates the strength and polarity of the relationship, with values closer to 0 indicating a weaker relationship.

Native Richness (Figure 16) differs among sites based on the percentage of the plot within remnant forest patches. Sites with higher Percent Remnant Forest Cover exhibit higher rates of overall Native Richness. In contrast, sites with little or no overlap with remnant forest patches have less diverse plant communities, which support fewer native species. The upward slope of the fitted trend line illustrates this positive relationship, indicating that increased remnant forest cover is associated with plant communities that possess higher overall Native Richness.

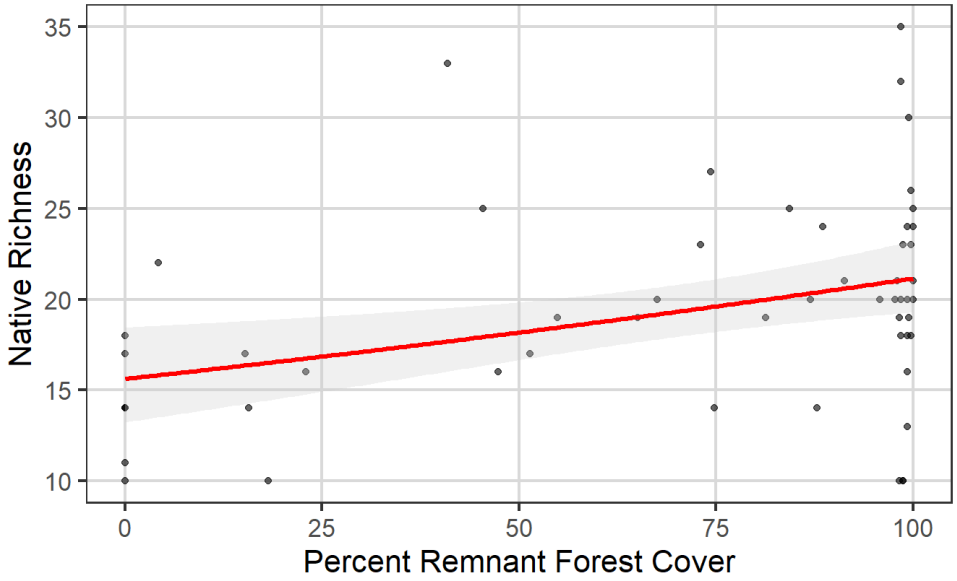

Figure 16: Relationship between native species richness and percent remnant forest cover.

Average CC values of trees (Figure 17) differ among sites based on the percentage of the plot within remnant forest patches. Sites with higher Percent Remnant Forest Cover are comprised of tree species with higher Average CC values and greater ecological fidelity. In contrast, sites with little or no overlap with remnant forest patches contain trees with lower Average CC values, reflecting species that are generally less conservative. The upward slope of the fitted trend line illustrates this positive relationship, indicating that increased remnant forest cover is associated with trees that possess higher Average CC values.

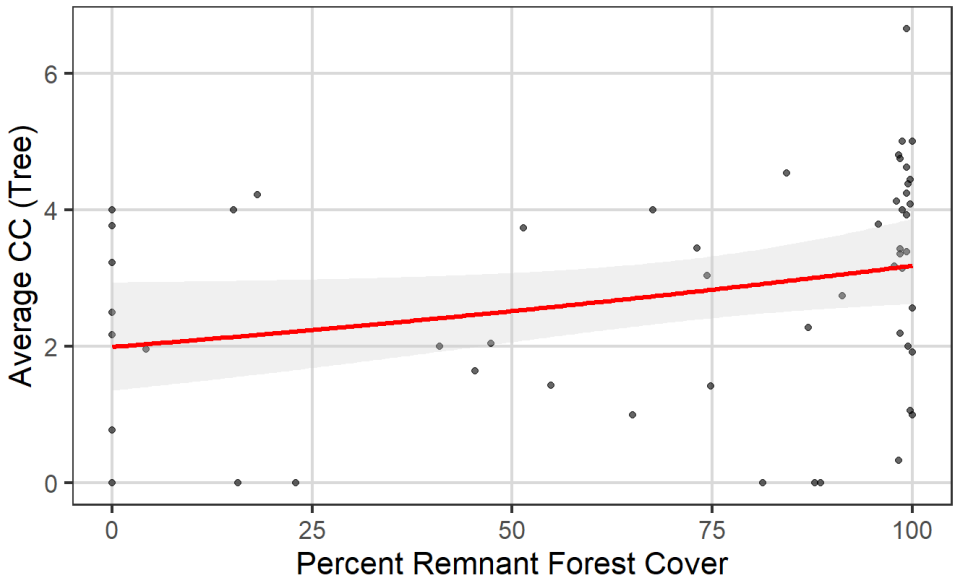

Figure 17: Relationship between average conservation coefficient (CC) values of trees and percent remnant forest cover.

Native Richness of trees (Figure 18) differs among sites based on the percentage of the plot within remnant forest patches. Sites with higher Percent Remnant Forest Cover exhibit higher rates of Native Richness amongst trees. In contrast, sites with little or no overlap with remnant forest patches have less diverse plant communities, which support fewer native tree species. The upward slope of the fitted trend line illustrates this positive relationship, indicating that increased remnant forest cover is associated with plant communities that possess higher native tree richness.

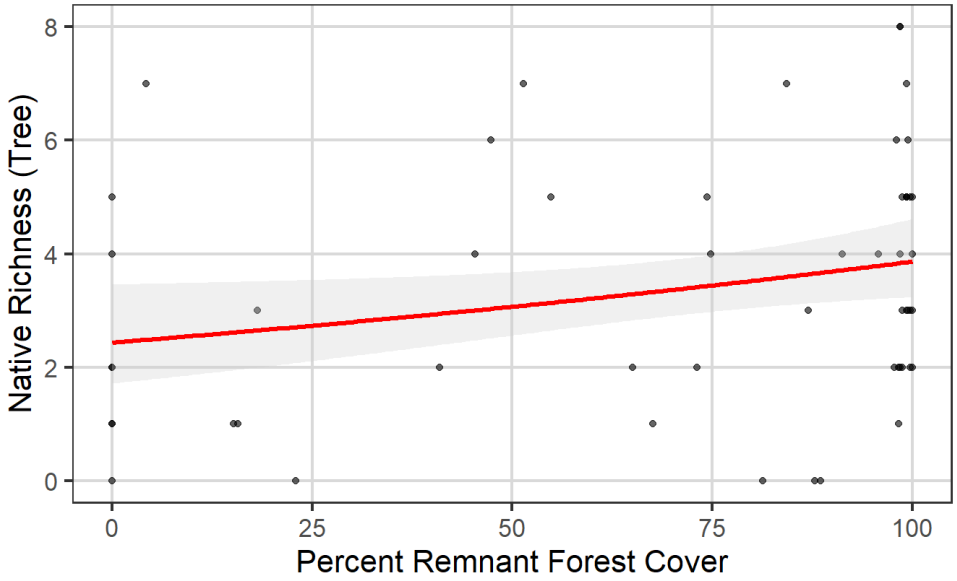

Figure 18: Relationship between native species richness of trees and percent remnant forest cover.

Native Richness amongst groundcover species (Figure 19) differs among sites based on the percentage of the plot within remnant forest patches. Sites with higher Percent Remnant Forest Cover exhibit higher rates of Native Richness in the groundcover layer. In contrast, sites with little or no overlap with remnant forest patches have less diverse plant communities, which support fewer native groundcover species. The upward slope of the fitted trend line illustrates this positive relationship, indicating that increased remnant forest cover is associated with plant communities that possess higher Native Richness in the groundcover layer.

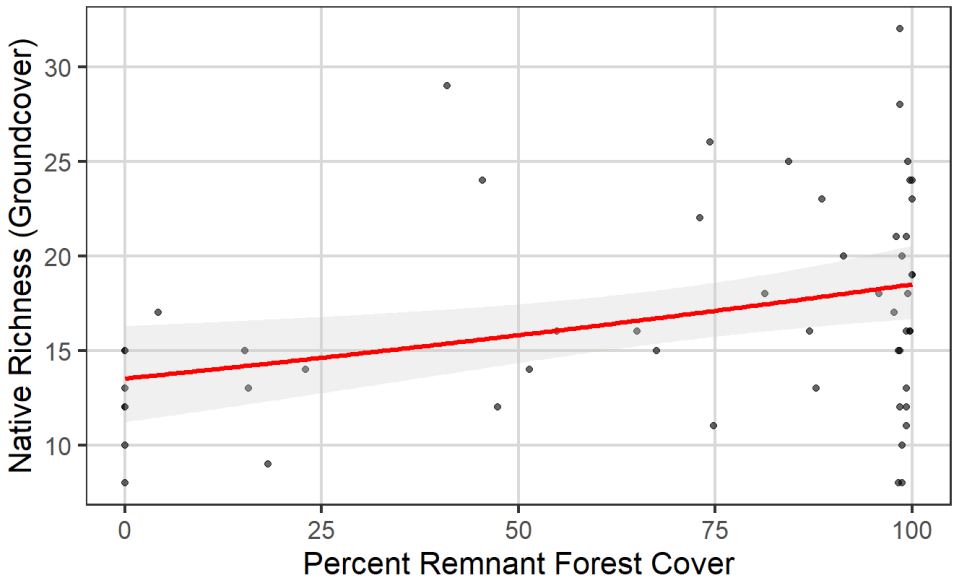

Figure 19: Relationship between native species richness in groundcover plants and percent remnant forest cover.

Native Richness (Figure 20) differs between sites based on distance from or within remnant forest patches. Sites with a shorter Distance to the Remnant Forest Edge exhibit higher rates of overall Native Richness. In contrast, sites located furthest from remnant forest patches have less diverse plant communities, which support fewer native species. The upward slope of the fitted trend line illustrates this positive relationship, indicating that increased proximity to remnant forest patches is associated with plant communities that possess higher overall Native Richness.

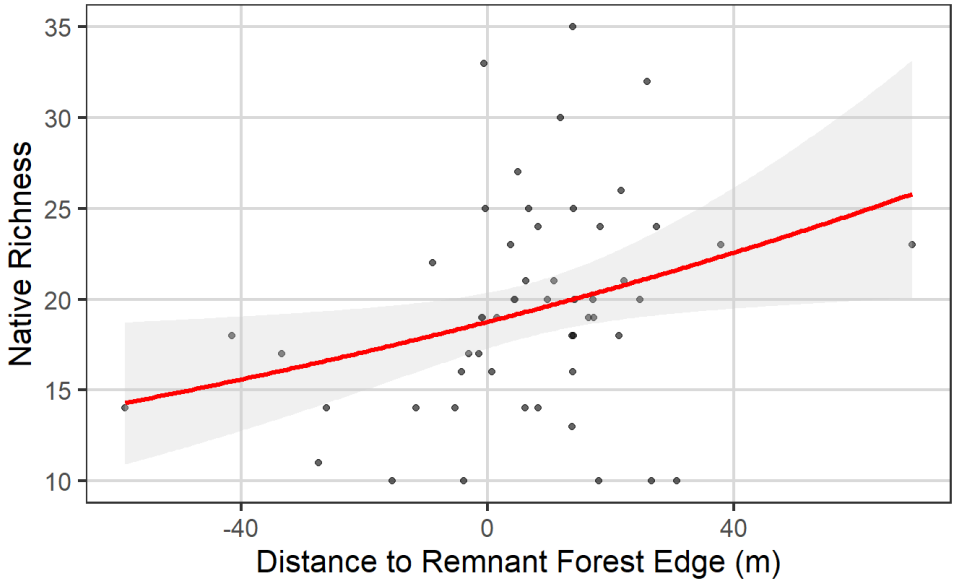

Figure 20: Relationship between native species richness and distance to remnant forest edge.

Average CC values of trees (Figure 21) differ between sites based on distance from or within remnant forest patches. Sites with a shorter Distance to Remnant Forest Edge are comprised of tree species with higher Average CC values and greater ecological fidelity. In contrast, sites located furthest from remnant forest patches contain trees with lower Average CC values, reflecting species that are generally less conservative. The upward slope of the fitted trend line illustrates this positive relationship, indicating that increased proximity to remnant forest patches is associated with trees that possess higher Average CC values.

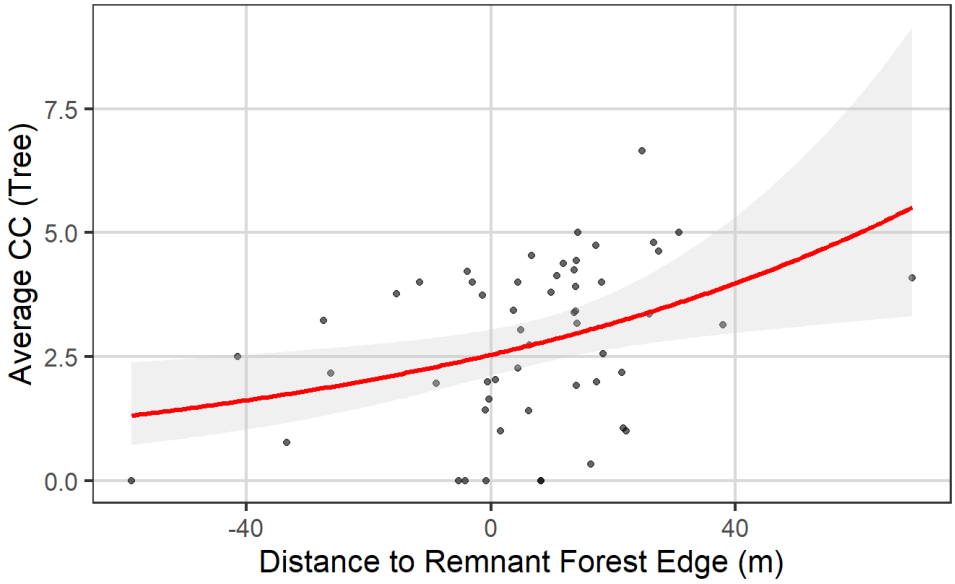

Figure 21: Relationship between average conservation coefficient (CC) values of trees and distance to remnant forest edge.

Maximum CC values of trees (Figure 22) differ between sites based on distance from or within remnant forest patches. Sites with a shorter Distance to the Remnant Forest Edge contain tree species with higher CC values and greater ecological fidelity. In contrast, sites located furthest from remnant forest patches contain trees with lower CC values, reflecting species that are generally less conservative. The upward slope of the fitted trend line illustrates this positive relationship, indicating that increased proximity to remnant forest patches is associated with trees that possess higher Maximum CC values.

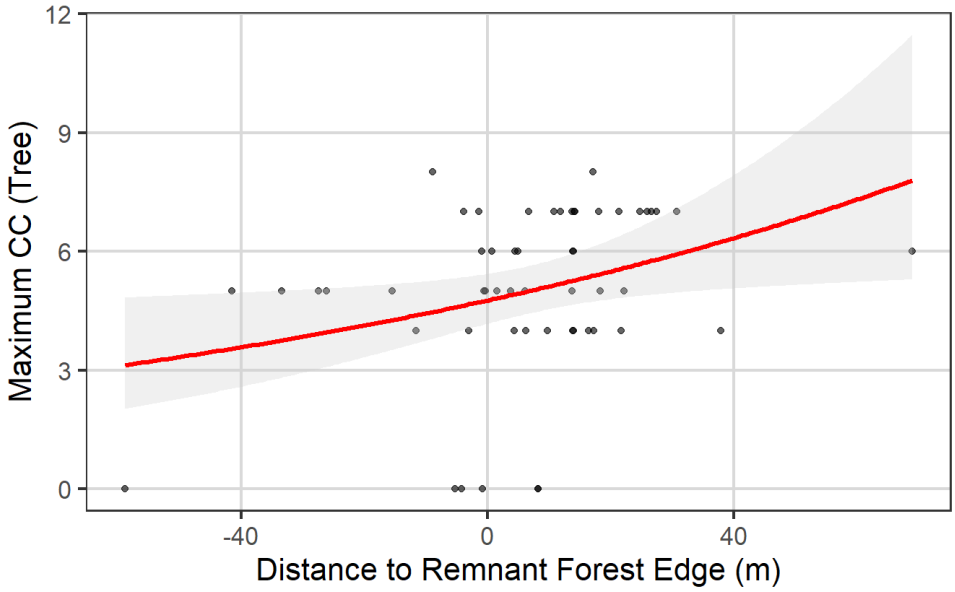

Figure 22: Relationship between maximum conservation coefficient (CC) values of trees and distance to remnant forest edge.

Nonnative Abundance of trees (Figure 23) differs between sites based on distance from or within remnant forest patches. Sites with a shorter Distance to Remnant Forest Edges exhibit lower Nonnative Abundance amongst trees. In contrast, sites located furthest from remnant forest patches have higher Nonnative Abundance and contain fewer native trees. The downward slope of the fitted trend line illustrates this negative relationship, indicating that decreased proximity to remnant forest patches is associated with plant communities that possess higher Nonnative Tree Abundance.

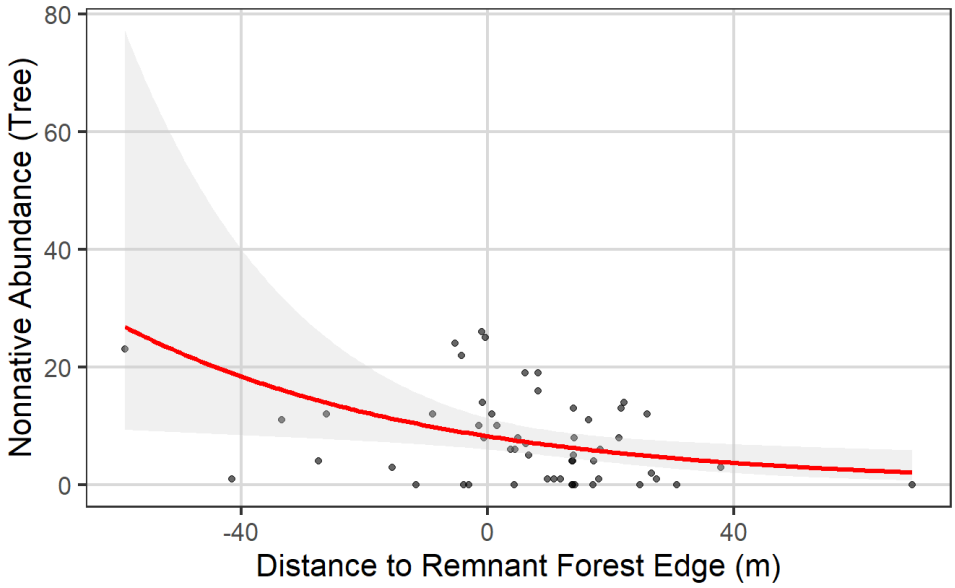

Figure 23: Relationship between nonnative tree abundance and distance to remnant forest edge.

Nonnative Richness of trees (Figure 24) differs between sites based on distance from or within remnant forest patches. Sites with a shorter Distance to Remnant Forest Edges exhibit lower rates of Nonnative Richness amongst trees. In contrast, sites furthest from remnant forest patches have higher Nonnative Richness and support fewer native tree species. The downward slope of the fitted trend line illustrates this negative relationship, indicating that decreased proximity to remnant forest patches is associated with plant communities that possess higher Nonnative Tree Richness.

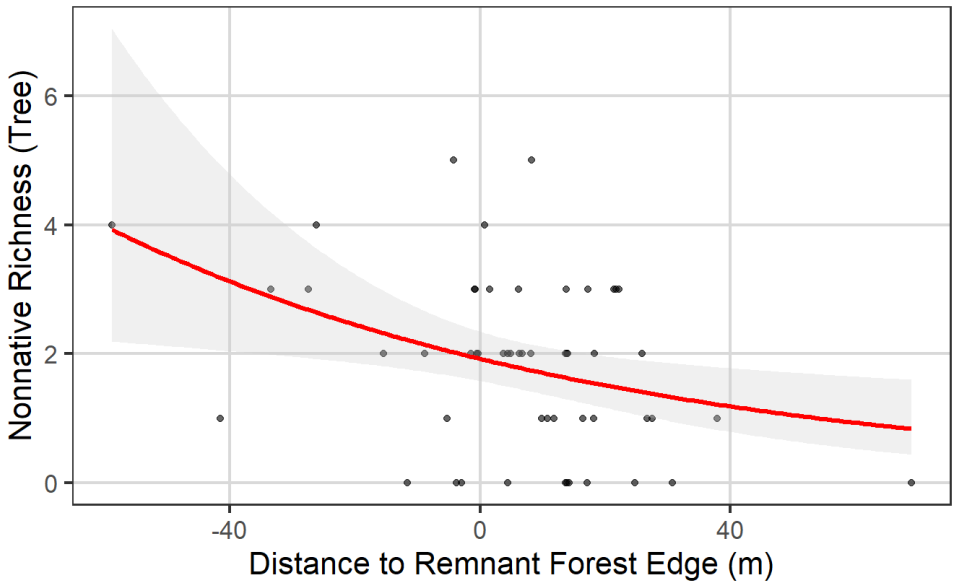

Figure 24: Relationship between nonnative species richness of trees and distance to remnant forest edge.

4. Discussion

Examining the results of statistical analysis provides insight into compositional and structural differences between remnant and secondary forests in urban areas. In addition, it highlights factors that most influence the abundance and diversity of native plant species in these urban forest ecosystems. Statistical analysis highlights that the dependent variable most strongly influenced by differences between remnant forest patches and secondary growth within this context was overall native species richness. Native Richness demonstrated significant relationships with Remnant Forest Position (Binary), Percent Remnant Forest Cover, and Distance to Remnant Forest Edge. These results align with previous research, which found that remnant forests in urban areas had a lower proportion of nonnative species than secondary forests (Zipperer, 2002). While not specific to urban forests, research examining post-agricultural sites also found that nonnative plant species had not stabilized 80 years after disturbance (Holmes & Matlack, 2019). This trend is reflected in the secondary forests at the G. Ross Lord Park, as historical mapping shows they were still used for agricultural purposes in 1954, 71 years prior to the 2025 data collection. While previous research demonstrated that nonnative plant abundance in these post-agricultural secondary forests declined over time, it concluded that a subset of shade-tolerant species would remain as a long-term component of forest ecosystems (Holmes & Matlack, 2019).

Based on the Kruskal-Wallis tests, Overall Native Richness initially appeared to have a significant relationship with Remnant Forest Position (Categorical). However, a post-hoc Dunn test was used to determine the difference between the three spatial groups, forest interior, forest edge, and outside forest, and provided no significant results. Interestingly, the comparison that presented borderline significance (p-value: 0.056) was between forest edge and outside forest, and the comparison that presented completely non-significant results (p-value: 1.00) was between forest edge and forest interior. These comparisons imply that despite spatial differences there is little ecological variance within remnant forest patches. This conclusion is further supported by Remnant Forest Position (Categorical)'s lack of significant relationships with any of the dependent variables. This is particularly notable when compared against Remnant Forest Position (Binary), which demonstrated significant relationships with three dependent variables: Average CC, Native Richness, and Average CC (Tree).

Given that the G. Ross Lord Park is located adjacent to major city roads and built-up commercial areas and is regularly utilized for recreational activities, it is notable that the impact of edge effects is not reflected in these findings. Previous research has identified patch size as the characteristic of remnant forest patches with the most significant impact on compositional dissimilarity, finding that urban forests with larger remnant forest patches have higher taxonomic diversity and less compositional turnover in woody plants (Yang et al., 2021). This may indicate that, given the relatively small and fragmented nature of remnant forest patches, the entire study area is vulnerable to edge effects. Alternatively, significant results may emerge with larger sample sizes. Notable borderline significance, such as the weak negative relationship (p-value: 0.054, Rho: -0.26) between Nonnative Abundance (Tree) and Percent Remnant Forest Cover, suggests nonnative tree invasions may be occurring at remnant forest edges. It is ecologically

reasonable to assume that remnant forest interiors will act as refuges for native plants, while remnant forest edges will allow invasive trees to establish. Therefore, the differences between the two groups are worth further exploration in future years.

Beyond their positive connection with overall native species richness, the results of the statistical analysis indicate that remnant forest patches have stronger ecological health than secondary forests. By assigning a coefficient of conservatism (CC) to each plant species identified during data collection, various measures of floristic quality were determined for each plot. Average CC had a significant relationship with Remnant Forest Position (Binary), Maximum CC (Tree) had a significant relationship with Distance to Remnant Forest Edge, and Average CC (Tree) had significant relationships with Remnant Forest Position (Binary), Percent Remnant Forest Cover, and Distance to Remnant Forest Edge. The enhanced floristic quality within remnant forest patches reflects superior ecological health and resilience. Not only does it indicate that remnant forest patches in the G. Ross Lord Park contain more native plants, but also that these plants are of higher conservation value. Plant species with higher floristic quality are likely to be better adapted to local conditions and more tolerant to disturbances. These results align with and build upon the previous perception of remnant forests as urban biodiversity hotspots (Russo et al., 2025).

Finally, the results highlighted distinct differences between the varying plant strata. While Native Richness showed significant results when including plants recorded across all four height-based stratifications, many of the dependent variables included only plants in the groundcover layer (< 0.5m in height). Out of these, Native Richness (Groundcover) only demonstrated a significant relationship with Percent Remnant Forest Cover. Conversely, several of the dependent variables that only included tree species (diameter breast height > 5cm) demonstrated strong significance. As stated above, Native Richness (Tree), Average CC (Tree), and Maximum CC (Tree) all demonstrated positive relationships with different remnant forest indicators. These results demonstrate that remnant forest patches possess higher native tree diversity and that the trees present are of higher conservation value. Tree species also represented the only significant relationships identified involving nonnative species, with negative relationships between Distance to Remnant Forest Edge and both Nonnative Abundance (Tree) and Nonnative Richness (Tree). This means that areas farthest from remnant forest patches are allowing for the introduction of more nonnative trees. We can assume that the strong contrast between the trees in remnant and secondary forests, especially compared with plants in the groundcover layer, is due to their longer lifespans and successional trajectories.

4.1 Limitations

The primary limitation of the study is that data collection was restricted to only one park, the G. Ross Lord Park, within Toronto's ravine network. Therefore, further research is required to better understand the differences between remnant forest patches and secondary growth across the entire city. While plots were located throughout the park, select areas were inaccessible due to difficult terrain and are not represented in the data. Data collection was carried out between the months of June and August, meaning that ephemeral plants that bloom in early spring may

not have been captured. Similarly, all data used in this study was collected during a single field season and may not fully capture yearly variations in vegetation cover brought about by weather patterns, recreational usage, and other disturbance. Large portions of the G. Ross Lord Park have undergone construction activities between 2023 and 2025. The increased disturbance and reduced public access associated with these activities may have impacted forest structure and species composition in the park. Resampling these established plots in future years will provide insight into the impact of construction activities and increase the confidence that findings from 2025 are representative of long-term trends. Finally, remnant forest patches and secondary growth were identified using only historical mapping from 1954. Accessing images of the area from prior decades would further enhance our understanding of historical land use in the park.

5. Recommendations

1. Prioritize Protection of Remnant Forest Patches

Remnant forest patches in the G. Ross Lord Park demonstrate higher rates of native plant diversity, greater floristic quality, and lower abundance and diversity of nonnative tree species. These areas of remnant forest should be a priority for conservation activities occurring in the park, with special emphasis on the interior remnant forest. Protection may include discouraging public access and recreational use, and installing boot-brush stations to prevent the spread of invasive plant species. Given their ecological importance, remnant forest patches should be a priority for invasive species management. Remnant forest patches should also be prioritized for monitoring tree crown indicators of poor health.

2. Implement Targeted Invasive Species Management at Remnant Forest Edges

Remnant forest edges are often highly susceptible to invasion from nonnative plant species, particularly if adjacent to roads, trails, or built-up areas. Invasive species management should prioritize removal activities in these areas to protect their ecological integrity. For further information on management strategies for the most abundant invasive plant species located in the G. Ross Lord Park, refer to the Master of Forest Conservation capstone by Nathalie Wood titled, Invasive Plant Abundance and Spatial Distribution in an Urban Ravine: Vegetation Trends and Management Implications in G. Ross Lord Park, Toronto.

3. Carry Out Assisted Regeneration of Tree Species in Secondary Forests

Secondary forests have lower native tree diversity and poorer floristic quality. Planting native canopy and subcanopy species in these areas would accelerate succession and help create a more resilient, healthier forest ecosystem. Recommended tree species are those with medium to high floristic quality that have demonstrated an ability to establish themselves across the G. Ross Lord Park. These species include Sugar Maple (*Acer saccharum ssp. saccharum*), Black Walnut (*Juglans nigra*), Silver Maple (*Acer saccharinum*), American Beech (*Fagus grandifolia*), Red Oak (*Quercus rubra*), and Black Maple (*Acer saccharum ssp. nigrum*).

4. Implement and Expand Long-Term Monitoring

Vegetation Sampling Protocol (VSP) should be carried out on five-year intervals to ensure information on ecosystem structure, composition, and health is current. Any newly established plots should emphasize monitoring in remnant forest patches. Future monitoring could expand to incorporate other metrics, such as measuring soil health indicators and performing water quality assessments. This could inform a wide array of interventions if deemed necessary, including the application of soil amendments or the implementation of erosion control measures. Monitoring of small mammal and insect populations could also serve as indicators of ecosystem health. Conducting additional vegetation sampling in late April would help identify ephemeral plant species that bloom in early spring.

6. Conclusion

This project provides insight into the condition of Toronto's urban ravine network by assessing the ecological characteristics of the G. Ross Lord Park. By comparing species composition, native and nonnative plant dynamics, and floristic quality throughout the park, the results demonstrate significant differences between remnant forest patches and secondary forests. Remnant forests displayed higher rates of native species richness, greater floristic quality, and lower abundance and richness of nonnative tree species, indicating stronger ecological health and resilience. These findings align with previous research, which identifies remnant forests as biodiversity hotspots within urban areas and highlights their role in providing crucial ecosystem services. Conversely, secondary forests showed lower rates of native plant diversity and poorer floristic quality, reflecting the impacts of past agricultural land use.

These results highlight the need for targeted, evidence-based management actions in the G. Ross Lord Park. Protecting remnant forest patches, implementing targeted invasive species management at remnant forest edges, and supporting assisted regeneration in secondary forests will help promote long-term ecosystem resilience. Continued long-term monitoring will be essential to understanding ongoing ecological change and evaluating the effectiveness of conservation and restoration activities. This project contributes to a growing body of research emphasizing the importance of understanding the dynamics of urban forests, particularly given their increasing vulnerability.

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