Project Report

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1. Topic

The topic of the project is exploring the greenery of the Greater Montreal Area with public trees to inform the public about the changes in trees and green scenery.

2. Problem statement and background

Based on the fact that each individual needs on average seven or eight trees for air (does not include trees regenerated or replanted for the current analysis), the project aims to assess the number of public trees in Montreal Island area for the year in analysis and profile the neighborhoods or boroughs based on characteristics of the green scenery available.

3. Data collection and Handling

a. Data sources

Ville de Montreal - Public trees data set

The data set obtained from Ville de Montreal with information regarding public trees. The data set included 22 variables with 317,844 observations with a time period from 1989 to May 3rd, 2021. The variable types and completeness of the data were indicated as follows: green - data complete, yellow - slightly incomplete data, red - significant incomplete data.

Variable	Variable type	Number of Obs	Information	Used
INV_Type	Categorical	317913	Type of trees: H - off road, R - on road	X
EMP_NO	Numerical	317913	Unique trees number in government database	X
ARROND	Numerical	317913	Numeral of each district/area	X
ARROND_NOM	Characterical	317913	District/area name	X
Rue	Characterical	218281	Name of the road for trees on the road.	
Cote	Categorical	218281	Side of the road (N- North, S - South, E - East, O - West)	

No_civique		171229	Numeral of the resident where the off road trees located	
Emplacement	Character	317913	Type of earth/dirt that the trees are located on. (30 unique values)	X
Coord_X	Numerical	317913	x- coordinate	
Coord_Y	Numerical	317909	y- coordinate	
SIGLE	Character	317913	The shortened latin name of the plant.	
Essence latin	Character	317913	Full Latin name of the plant.	
Essence FR	Character	317913	French name of the plant.	
Essence ang	Character	317913	English name of the plant.	X
DHP	Numerical	317913	Diameter measurement of the trunc of the trees.	X
Date_releve	Date	317242	Date of the latest measurement of DHP.	
Date_plantation	Date	151013	Plantation date of the trees.	
Localisation		217987	Location of the trees from the last corner of the last establishment.	
Code_parc	Numerical	99632	Index number of the park.	
Nom_parc	Character	99632	Name of the park.	
Longitude	Numerical	317909	Longitude geolocation of each tree.	x
Latitude	Numerical	317909	Latitude geolocation of each tree.	x

Note: Number coding for area:

ARROND_NOM	ARROND
Rosemont - La petite-Patrie	3
Ahuntsic - Cartierville	1
Mercier - Hochelaga-Maisonneuve	4
Côte-des-Neiges - Notre-Dame-de-Grâce	7
Villeray-Saint-Michel - Parc-Extension	2
Saint-Laurent	27
LaSalle	13
Rivière-des-Prairies - Pointe-aux-Trembles	9
Le Sud-Ouest	8

Saint-Leonard	12
Le Plateau Mont Royal	5
Verdun	16
Ville-Marie	6
Pierrefonds - Roxboro	25
Anjou	10
Montreal-Est	33

Publication de Montréal en statistiques - Population et démographie, 11 Février, 2022

The population data was obtained from Montréal en statistiques, service du développement économique. The data was published in February 2022, detailing the population and demographic data of the year 2021 by borough. The data was complete with no missing data for any boroughs.

b. Handling

i. Missing observations

There are minimal to significant missing observations in 12 variables. Among the variables used, the variables that have missing observations are: Longitude and Latitude. The two variables each have 4 missing observations. This is not significant and negligible for the project as the missing observations accounted for 0.01% of the total observations. From this, no further procedures to address the missing values for longitude and latitude.

ii. Variable transformation

Ville de Montreal - Public trees

The variable "Emplacement" classified the type of land that each tree/plant was planted on. There were 28 unique types of classification for tree placement. In order to have a more concise analysis, the types of land that have similar characteristics were categorized into a more significant category. Lower case function was applied to the "Emplacement" variable. In addition, a search function (pd.str.contains) was applied to the classifications of the Emplacement variable to create new classifications. The

following eight categories represented the new classification (Please refer to the brackets for subcategories included in the classification):

- ○ Parterre (0): Plant beds, formal garden
- ○ Banquette (3): Seat
- ○ Terre-Plein (7): Open land
- ○ Trottoir (2): Sidewalk
- ○ Parc (1): Park
- ○ Saillie (5): Road extension/protrusion
- ○ Ilot de verdure (4): A patch of green
- ○ Others (6)

Publication de Montréal en statistiques - Population et Démographie, 11 Février 2022

Per inspection of the public trees data from Ville de Montréal, we noted data source limitations regarding the classification of the trees by borough. In fact, while the population dataset includes population data for 34 boroughs, the public trees dataset has available data for only 16 boroughs. From this, we performed procedures to check if the trees in the missing boroughs were accounted for, there were certain cases where the tree from one borough was recorded in the count of another nearby borough; therefore, the count for the original borough was not accounted for. From this, in order to assess accurately the sufficiency of the green scenery based on the residing population, the population was aggregated in accordance to the aggregated count of trees for some nearby neighborhoods. This means that when the count for the original borough was not accounted for, the population for this borough will be aggregated with the borough where the count was accounted. The following procedures were performed:

- Identify the boroughs with missing count data.
- Inspect and select a green scenery in the borough with missing data. Identify a coordinate of a tree, and check the coordinate and classification of boroughs in the public tree dataset.
- Identify the classification of the borough and associate the population of the original borough to the newly identified borough.

Noted from the procedures performed, all of the boroughs with missing tree count data has the tree count data associated with nearby boroughs. Please refer to the dataset population_2021 for the procedures performed.

4. Results

The following are the results of the project which are categorized into two main deliverables: visualization deliverables and quantitative deliverables. For further analysis, quantitative deliverables include analysis of tree profile, area differences, and sufficiency of trees for the population. Trees profile analysis aims to inform the overall picture of trees planted on Island of Montreal which includes quantity, types, and characteristics. The area differences analysis compares the differences in tree characteristics (quantitative and qualitative) between the areas or districts of Montreal. Finally, sufficiency of trees analysis reports the adequacy of the quantity of trees planted on the Island of Montreal for the current population.

Visualization deliverables

- Interactive maps/Choropleth map of the most prevalent 5 plants and just maple syrup trees. Please refer to the visualization file at the following link for more information: https://github.com/ngocmphan/arbres_publics

Quantitative deliverables

Trees profile

The population of trees on Montreal Island is 317,913 trees as of May 3rd, 2021. In terms of tree variety, there are 674 types of trees and plants planted in the Greater Montreal Area. The top three trees most planted are Silver Maple, Norway Maple and Red Ash. The Silver maple trees accounted for around 10% of total trees, with Norway Maple at 9%, and Red Ash at 7% respectively. Based on further analysis, we noted the total number of maple trees is 101,591 trees with 59 unique types of maple trees, and accounted for 32% of the total trees planted.

The distribution of the tree's diameter is not a normal distribution, the distribution is skewed to the right [Exhibit 1] which means there is higher concentration of smaller trees with lower DHP measurement than higher DHP measurements. In addition, the median diameter of the tree's population is 23cm and average diameter of the population is 27.5cm [Exhibit 2].

In order to further analyze the variation in size and by tree types, tree types that accounted for more than 50% of the total tree population were taken into consideration. Based on analysis, 50% of the total tree population in Greater Montreal Area can be explained by 12 unique tree types as follows: Skyline Honey Locust, Kentucky coffee tree, Colorado Spruce, Silver Maple, Common Hackberry, Columnare Norway Maple, Siberian Elm, Norway Maple, Red Ash, Thornless Honey Locust, Littleleaf European Liden, Common Honey-Locust. Regarding the size distribution of these 12 tree types, there are six types of trees that have the individual mean diameter larger than 30cm, whereas 4 tree types have DHP diameter between 20 cm and 30 cm, and 2 tree types (Skyline Honey Locust and Kentucky Coffee Tree) have mean diameter less than 20 cm. In addition, out of the six tree types with mean diameter on the higher range, four (Silver Maple, Siberian Elm, Norway Maple, and Littleleaf European Liden) have maximum values extending to more than 90cm, with Silver Maple having the highest maximum value. As the mean and median value of these four tree types are all below 50cm, this indicates that these have considerably bigger trees but are limited in quantity. Please refer to Exhibit 3 for details of the boxplot.

We further analyzed the tree's placement. Based on analysis of the tree's placements, the trees are generally planted on flat areas, sidewalks, parks and areas near benches. In addition, regarding the box plot of the placements, it can be seen that the median line among the eight placements is similar and the majority of the placement box plots are right skewed. This demonstrated that the phenomena where DHP range falls on the lower range from the population boxplot applies to all the tree placements. Furthermore, the flowerbeds/gardens (parterre) are dense and have significant outlier values. This means that while the flowerbeds/gardens distribution include small/medium size trees (0-50cm), there are some outliers that are significantly taller (> 100cm in diameter) [Exhibit 4].

Area differences

For the area differences analysis, 16 neighborhoods from the Montreal Island were taken into consideration with emphasis on green scenery analysis and profiling the areas based on the green scenery characteristics. Based on preliminary analysis, the three neighborhoods with the most trees are Rosemont - La Petite-Patrie, Ahuntsic - Cartierville, and Mercier - Hochelaga. The neighborhoods with the least number of trees are Montreal-Est, Anjou, and Pierrefonds - Roxboro. [Exhibit 5] We further analyzed the tree types most abundant in individual

neighborhoods and noted that most of the top three trees identified for the majority of the neighborhoods fall into 12 tree types that accounted for 50% of total tree population. Two neighborhoods that have the top three most abundant tree types for that specific neighborhood outside of the 12 popular tree types are Anjou, Lasalle and Montreal-Est. [Exhibit 6]

For further understanding of the green scenery in different neighborhoods, comparison of the trees' size and profiling of the neighborhoods were conducted. Regarding the trees' size by neighborhood, the neighborhoods with the mean diameter higher than 30 cm and among the highest ones are Ahunstic - Cartierville and Cote des Neiges - Notre Dame de Grâce. Regarding the mean diameter of neighborhoods between 20 cm and 30 cm, 11 out of 16 neighborhoods fall into this category indicating that the majority of the neighborhood is between this range. The three neighborhoods with mean lower than 20 cm are Ville Marie, Anjou and Montreal Est. Note that the Montreal Est and Anjou are already listed as neighborhoods with the least number of trees based on analysis above. The neighborhoods with long tails above 100 cm indicating high maximum values are Ahunstic-Cartierville, Mercier - Hochelaga-Maisonneuve, Côte-des-Neiges - Notre-Dame-de-Grâce, and Saint Laurent. In addition, the means of these neighborhoods are higher than the medians indicating that the distribution of the trees' diameter is skewed to the right with higher smaller trees and lower bigger trees, however, bigger trees with significantly bigger diameter. [Exhibit 7]

We performed clustering, an unsupervised learning technique in order to explore patterns in the green scenery identified in different neighborhoods. Based on k-means clustering, four labeling clusters were identified with seven key elements noted. [Exhibit 8]

First cluster (cluster zero) is characterized by a high number of formal gardens that are on the roads with some limited plants planted on sidewalks and open lands. These cluster plants are not usually displayed in Ville Marie.

Second cluster (cluster one) is characterized by high numbers of formal gardens, on the streets, with plants that are not planted on sidewalks or open lands. The cluster holds some low numbers of coffee trees and honey locust trees.

Third cluster (cluster two) is characterized by a high number of coffee trees and no honey locust trees. The trees are usually planted on the streets, especially on sidewalks, some on open lands. This cluster has a high possibility of appearing in Ville Marie.

Fourth cluster (cluster three) is characterized by a high number of honey locust trees and no coffee trees. The trees are planted on the streets, especially on sidewalks and some on open land. These trees belonging to this cluster can appear in Ville Marie.

Sufficiency of trees populated

For sufficiency of trees analysis, we first need to understand how many trees are needed per person for air. With general analysis, an individual needs approximately seven or eight trees for air. From this, we obtained the population of Montreal Island and determined the number of trees sufficient for the population, and divided the number of trees available to the required number of trees. We performed the test of sufficiency by neighborhood. In addition, person per tree analysis was also performed and analysis of the sufficiency for neighborhoods with the highest population.

We obtained the total population of Montreal Island for 2021 as per the year the trees dataset is obtained. The total population for Montreal Island 2021 is 2,025,928, thus the total trees required are around 15 million trees. From this, the sufficiency of trees in percentage is 2.1% with 6 people per tree.

The sufficiency by area is calculated by dividing trees planted by the area to the population needs. Based on each adult requires 8 trees for sufficient oxygen needs; however, the rate of 7.5 trees is used for calculation as this does not take into account the needs from other age groups. The population needs are based on the population from each borough multiplied with 7.5 trees.

Limitation of the sufficiency calculation inherits the limitation from the trees dataset. As the trees dataset has issues with the classification of the trees into respective neighborhoods, the population of the neighborhood is adjusted to appropriately address this issue. From this, some neighborhoods have aggregated population, which means the population of one neighborhood can include the population of another one.

All boroughs do not have enough trees sufficient for the population in each area. Please refer to exhibit [Exhibit 9]. The highest sufficiency rate among the boroughs is 3% meaning that the trees planted are only sufficient for 3% of the population needs for that respective borough. The three highest sufficiency rates are: Ahuntsic - Cartierville, Rosemont - La Petite-Patrie, and Le Sud-Ouest; the three lowest sufficiency rates: Pierrefonds - Roxboro, Montreal-Est, and Anjou.

Another descriptive statistics was used to understand more on the green scenery between boroughs: Person per tree. Please refer to exhibit [Exhibit 10] below for the Person per tree table. Similarly to sufficiency rates, the three highest people per tree boroughs are: Ahuntsic - Cartierville, Rosemont - La Petite-Patrie, and Le Sud-Ouest. The highest person per tree is Ahuntsic - Cartierville borough with around 4 persons per tree.

5. Discussion

Based on our understanding of the findings in tree profile, area differences, and sufficiency of trees populated, we will discuss the implication of each section. Regarding the tree profile, we noted that around 50% of the trees have a diameter less than 23 cm or 9 inches. From this, based on Silver Maple statistics, a tree with 9 inches in diameter or around 28 inches in circumference is around 27 years old. Although not all the trees have the same statistics, we can assume this baseline that 50% of the trees are less than or around 27 years old, which dates back to 1995. We understood that half of the population includes old trees. Note that for the 12 tree types that accounted for more than 50% of the total tree population, 6 tree types have diameter larger than 30 cm or 12 inches, thus having the approximate of around 36 years old which dates back to 1986.

Based on our area differences findings, we noted that Pierre-Roxboro, Anjou and Montreal-Est boroughs have the least number of trees among the 16 boroughs. However, we noted that boroughs with mean diameter lower than 20 cm are Ville-Marie, Anjou and Montreal-Est. In addition, Ville-Marie has a diameter median of around 15 cm or 5 inches, which indicates that 50% of the trees planted are less than or around 18 years old. Furthermore, the average diameter of Ville-Marie trees is near 20 cm, which is higher than the median of the borough indicating there are limited trees with bigger diameter in the borough. From this, we could suggest that although Ville-Marie borough does not have issues with the number of trees planted, the size of the tree is smaller than other boroughs. For Anjou and Montreal-Est, the number of trees are limited, with the size of the trees being slightly less than 20 cm in diameter. In addition, there are no trees with a bigger diameter (bigger than 20 cm in diameter) in Anjou and Montreal Est. For the majority of the boroughs (13 out of 16 boroughs) have DHP average between 20 cm and 40 cm as discussed with most of the median is near the mean indicating insignificant amount of trees with bigger diameter. This suggests that most of the boroughs have trees around 25 years old. This indicates the positive sign in trees' longevity and green scenery of the majority of the boroughs.

Based on the sufficiency of trees populated analysis, there are not enough trees for the population residing in Montreal Island. From the perspective of each borough analysis, the highest sufficiency rate is only 3.3%, which is higher than the overall Montreal sufficiency of 2.1%. The two boroughs with the most concerning sufficiency rate are Montreal Est and Anjou with 0.02% and 0.005% respectively. Considering Montreal Est and Anjou have the lowest number of trees among the 16 boroughs, this would require the government to increase efforts on planting more trees. In general, an effort to increase the number of trees would be necessary to ensure that the number of trees is adequate for the population.

The limitations of the project are the data accuracy and completeness of the public trees dataset, which include the erroneous classification of boroughs, the lack of accurate count for the boroughs, and human error in measuring and recording the DHP. Although some of the

erroneous classifications were mitigated with the data transformation in the population dataset for sufficiency rate calculation, this would still affect the accuracy of the sufficiency rate of each borough.

6. References

Arbres publics sur le territoire de la Ville. Ville de Montréal. Data updated on May 03, 2021. Retrieved from: https://donnees.montreal.ca/ville-de-montreal/arbres

Population data. Ville de Montreal, Publication.

http://ville.montreal.qc.ca/portal/page?_pageid=6897,68149724&_dad=portal&_schema=PORTAL
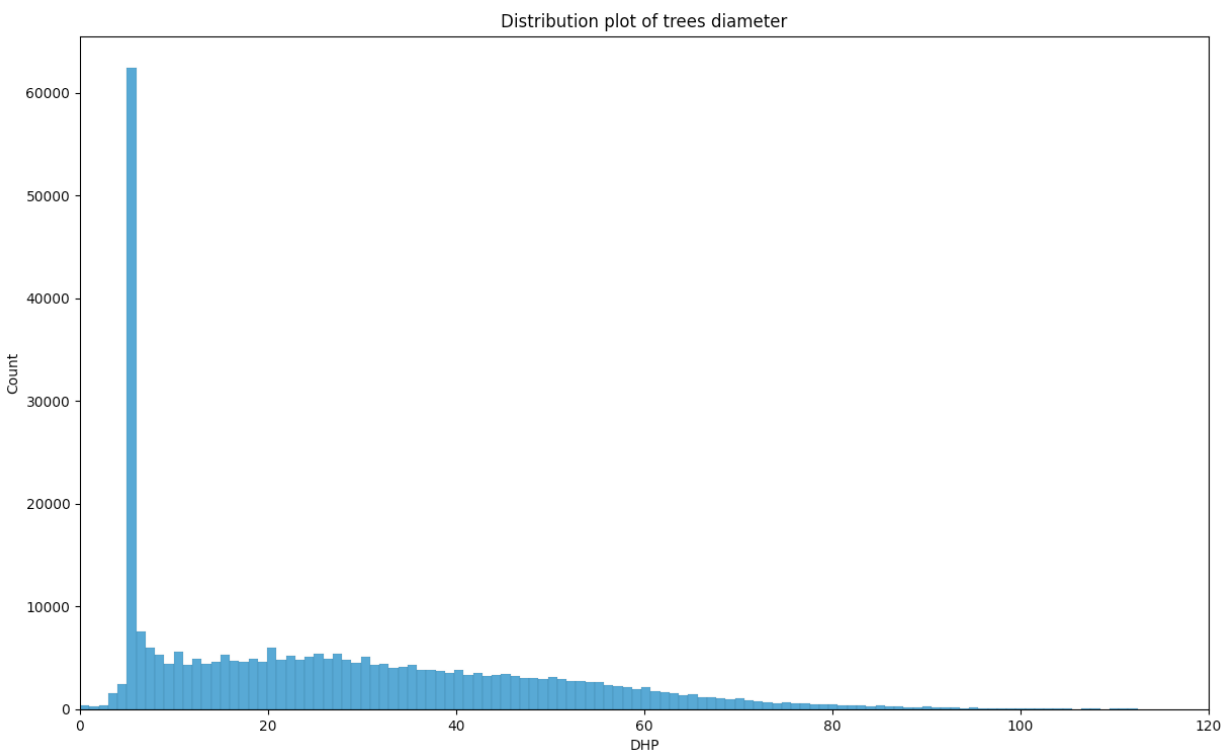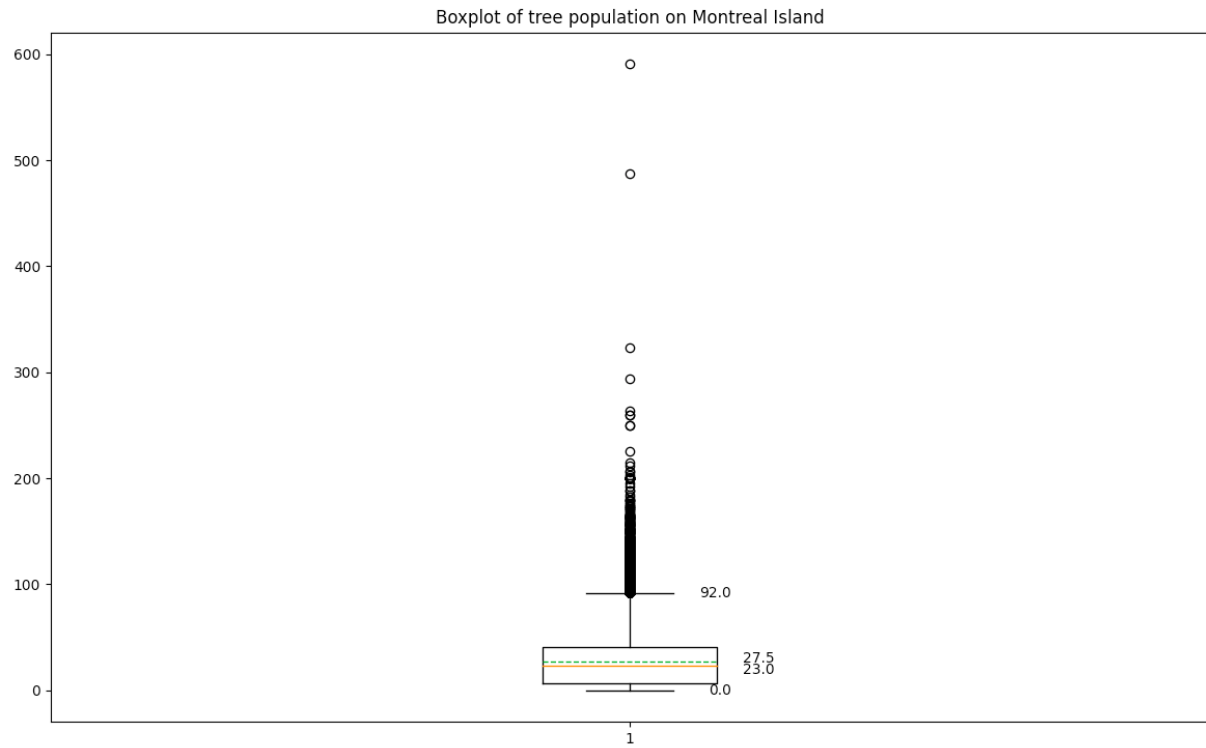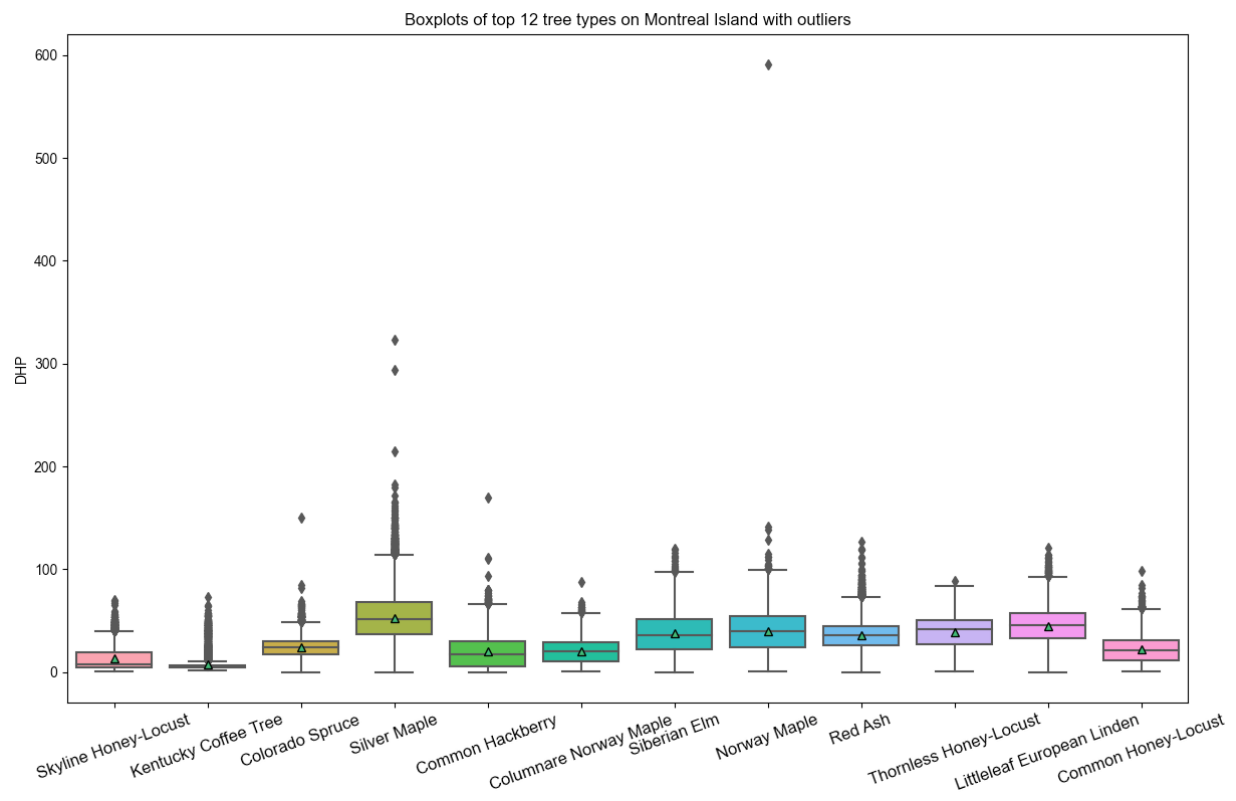
7. Exhibit

Exhibit 1

Distribution plot of trees diameter

Exhibit 2

Boxplot of tree population on Montreal Island

Exhibit 3

Boxplots of top 12 tree types on Montreal Island with outliers

Boxplots of top 12 tree types on Montreal Island without outliers

Exhibit 4

Box plot of different trees placements

Exhibit 5

Bar chart of number of trees by neighborhood
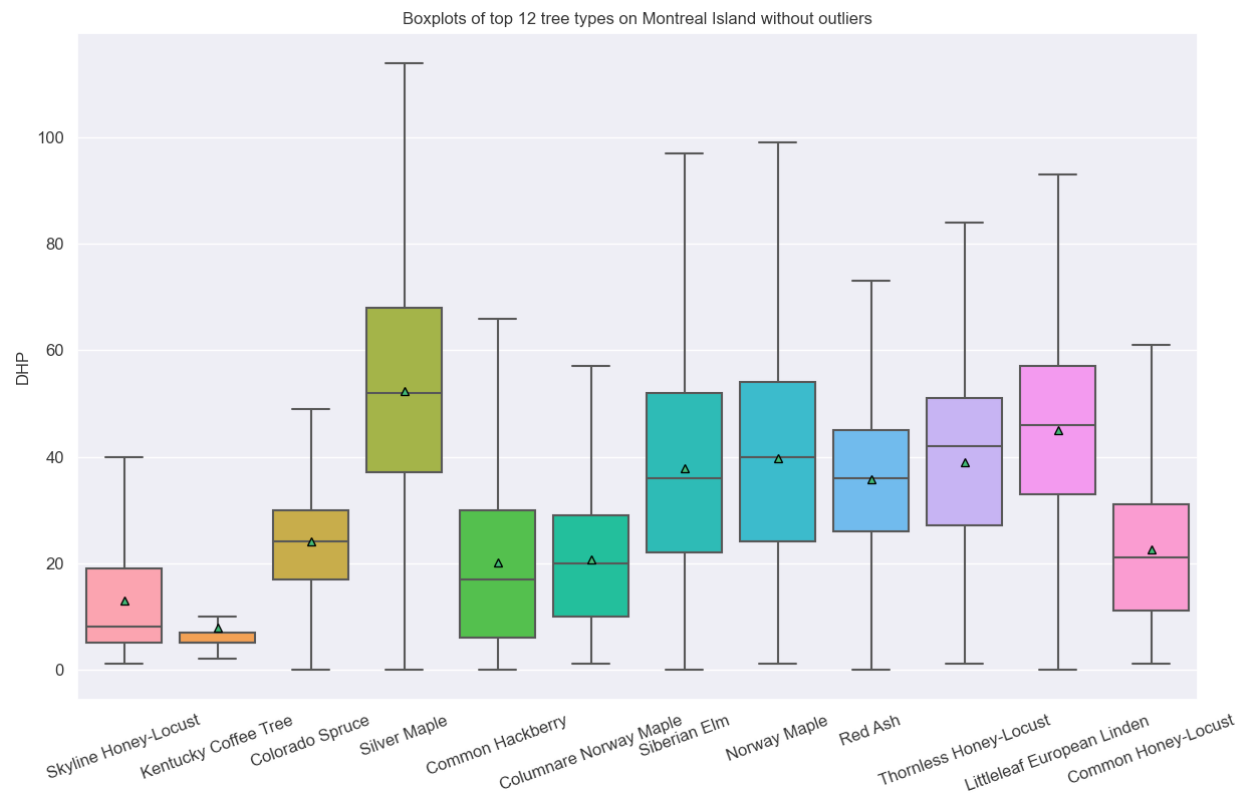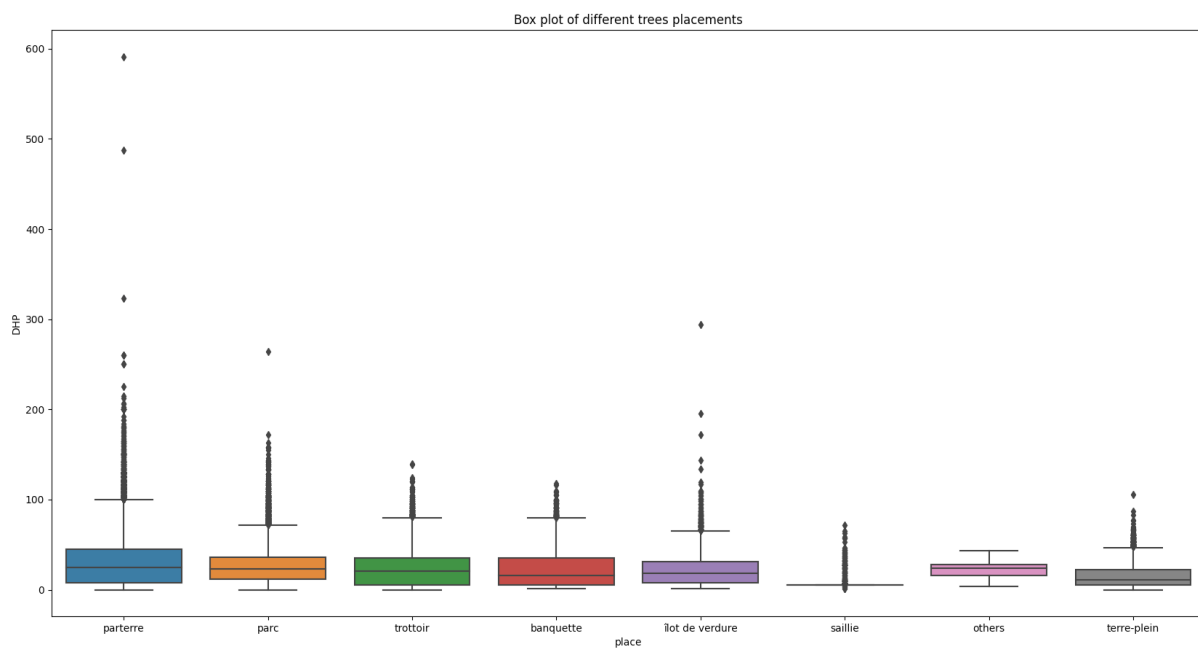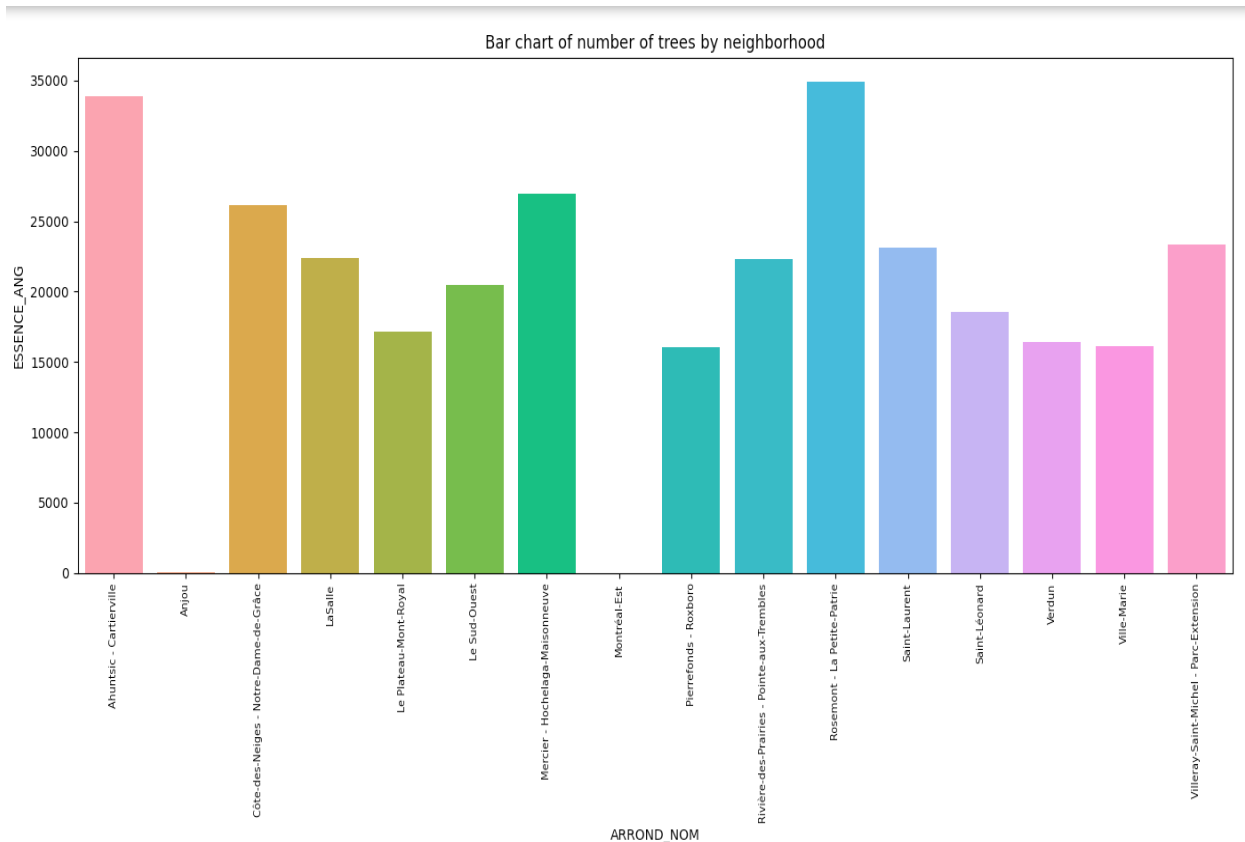
Exhibit 6

Borough name	First	Second	Third
Ahuntsic - Cartierville	Silver Maple	Red Ash	Littleleaf European Linden
Anjou	White Elm x	Eastern Cottonwood x	White Ash x
Côte-des-Neiges - Notre-Dame-de-Grâce	Silver Maple	Norway Maple	Littleleaf European Linden
LaSalle	Silver Maple	Eastern Cottonwood x	Norway Maple
Le Plateau-Mont-Royal	Silver Maple	Norway Maple	Skyline Honey-Locust
Le Sud-Ouest	Red Ash	Silver Maple	Skyline Honey-Locust
Mercier - Hochelaga-Maisonneuve	Red Ash	Silver Maple	Norway Maple
Montréal-Est	White Elm x	Bur Oak x	None

Pierrefonds - Roxboro	Red Ash	Norway Maple	Silver Maple
Rivière-des-Prairies - Pointe-aux-Trembles	Silver Maple	Norway Maple	Red Ash
Rosemont - La Petite-Patrie	Red Ash	Silver Maple	Norway Maple
Saint-Laurent	Norway Maple	Silver Maple	Littleleaf European Linden
Saint-Léonard	Norway Maple	Siberian Elm	Silver Maple
Verdun	Norway Maple	Red Ash	Colorado Spruce
Ville-Marie	Skyline Honey-Locust	Kentucky Coffee Tree	Silver Maple
Villeray-Saint-Michel - Parc-Extension	Silver Maple	Red Ash	Littleleaf European Linden

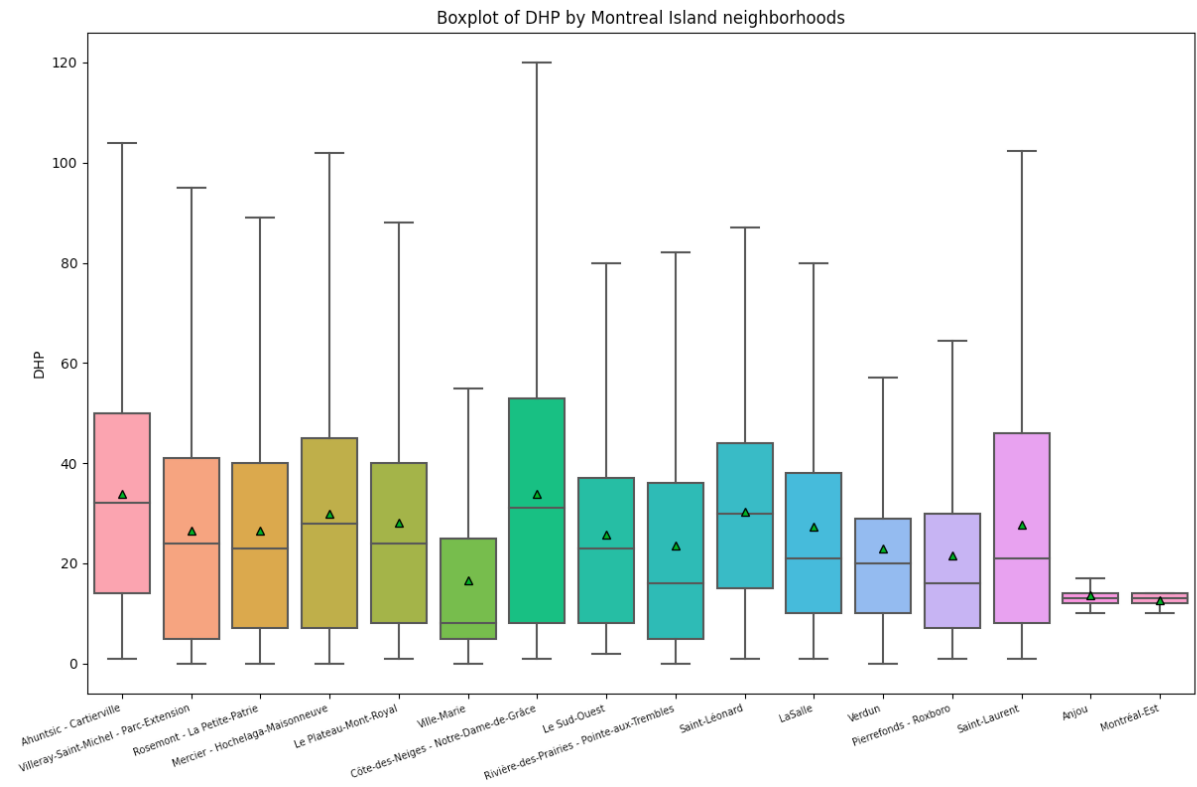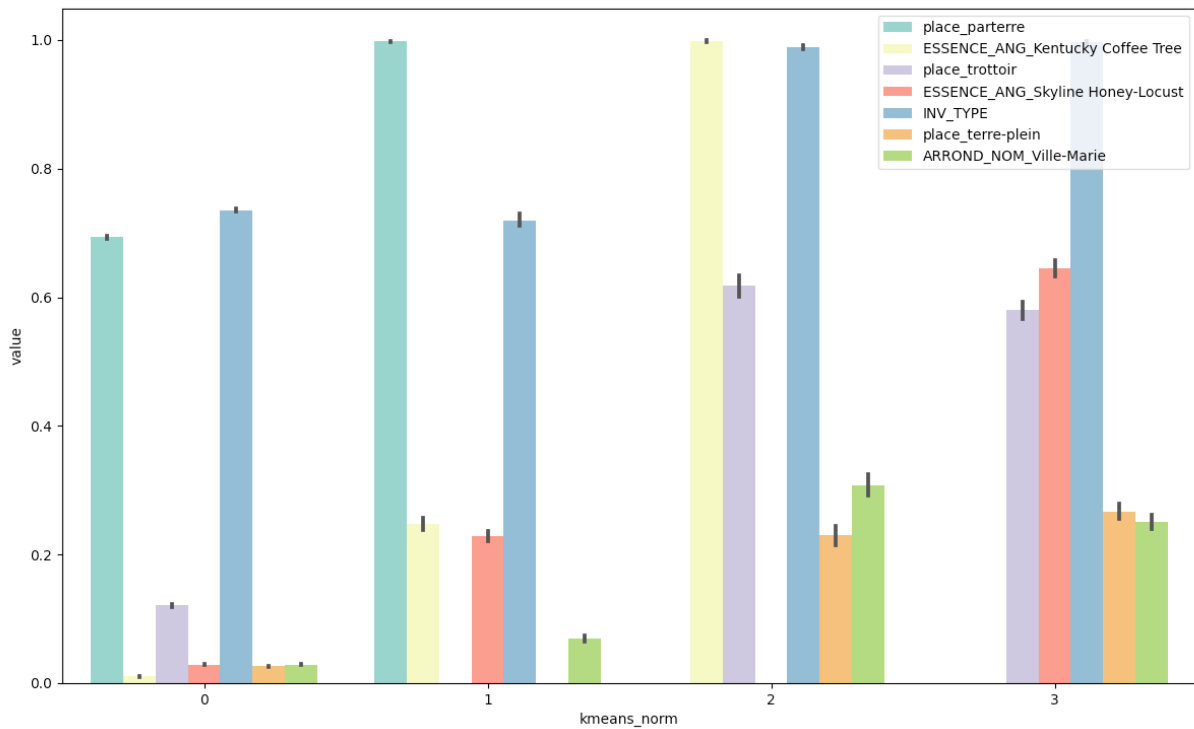X: Not in the group of most 12 popular trees.

Exhibit 7

Boxplot of DHP by Montreal Island neighborhoods

Exhibit 8

Exhibit 9

Borough name	Sufficiency rate (%)
Ahuntsic - Cartierville	3.336
Rosemont - La Petite-Patrie	3.281
Le Sud-Ouest	3.23
Saint-Léonard	3.116
Verdun	3.108
Saint-Laurent	3.016
Rivière-des-Prairies - Pointe-aux-Trembles	2.758
Mercier - Hochelaga-Maisonneuve	2.553
LaSalle	2.323
Le Plateau-Mont-Royal	2.159
Ville-Marie	2.05
Villeray-Saint-Michel - Parc-Extension	1.634

Côte-des-Neiges - Notre-Dame-de-Grâce	1.474
Pierrefonds - Roxboro	0.981
Montréal-Est	0.015
Anjou	0.005

Exhibit 10

Borough name	Person per tree
Ahuntsic - Cartierville	3.996
Rosemont - La Petite-Patrie	4.063
Le Sud-Ouest	4.128
Saint-Léonard	4.278
Verdun	4.29
Saint-Laurent	4.421
Rivière-des-Prairies - Pointe-aux-Trembles	4.834
Mercier - Hochelaga-Maisonneuve	5.223
LaSalle	5.741
Le Plateau-Mont-Royal	6.176
Ville-Marie	6.505
Villeray-Saint-Michel - Parc-Extension	8.159
Côte-des-Neiges - Notre-Dame-de-Grâce	9.048
Pierrefonds - Roxboro	13.597
Montréal-Est	878.8
Anjou	2543.706