Assessing the Plant Species, Mortality Rates and Water Availability under the Canopies in the MillionTreesNYC Plots

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Introduction

In NYC during 2007, Mayor Bloomberg passed the PlaNYC initiative. Its purpose was to prepare New York City for a million additional citizens, strengthen the community, and improve the environment. One of the programs included in this movement was the MillionTreesNYC Project. The purpose of this program is to increase the urban forest throughout the city by planting a million trees over a ten year period (beginning in 2007 and ending in 2017) (P. Timon McPherson et al, 2010). The organization has planted more than half of the million and are continuously working to achieve their goal. They are planning to plant approximately 220,000 street trees, 530,000 in Parks and other agencies, and 250,000 for private partners (*MillionTreesNYC)*.

The urban forest, which consists of street trees and forested land within a city, is vital to NYC's ecosystem; however the perpetual urbanization and limited space make it difficult to manage. The Natural Area Conservancy is the NYC Park's partner in the conservation of 10,000 acres of forests, meadowlands, and wetlands. out of the 29,000 acres of parkland in NYC. The Natural Resource Group's focus is to conserve NYC nature for the benefits of ecosystems and health through proper management, restoration, and advocacy.

Further, trees offer the NYC community a plethora of advantages. For example, trees influence temperature, wind, humidity, rainfall, soil erosion flooding, air quality, scenic quality, and plant/ animal diversity (Dwyer et al, 1992). In addition, trees decrease the need for energy because of the shade they provide (which reduces the amount of radiant energy absorbed, stored, and radiated by built surfaces). Trees convert radiant energy into latent energy, control air temperature with the shade they provide, and facilitate air flow by transporting and diffusing energy, water vapor, and pollutants. Due to the shade, buildings and environments directly underneath tree canopies have a decreased need for alternative air control, such as air conditioning, which in turn decreases energy bills and consumption. (McPherson: Energy Conversation With Trees, 1993)

The urban forest has a great effect on carbon dioxide reduction. The trees carbon dioxide storage and sequestration decrease the effects of the heat island phenomenon by decreasing temperatures. In a study performed in Sacramento, it is clear that trees can manage the carbon dioxide release by all machines and humans; therefore trees are vital to all cities (EG McPherson et al, 1998).

Storm water management is important to maintain in urban settings. Water cannot flow through impervious surfaces, like concrete sidewalks and streets so it is directed into sewage and storm drains. Because of limited space in the drains, overflows result in habitat destruction and hazardous sewer overflows. In order to fix this, scientists are looking at adding trees to decrease water content or add under pavement soil structures to manage the water. (*Storm water Management)* Also, combined sewer outflows (CSOs) have been challenging in cities. A combined sewer system collects rainwater runoff, domestic sewage, and industrial wastewater together. During heavy rainwater or snowmelt, they are designed to overflow into nearby streams, rivers, or other water bodies; contaminating local water sources. (*EPA Combined Sewer Outflows)*The urban forest and soil help improve the effects of CSOs and management of storm water runoff.

Many scientists do not believe that cities can be sustainable. There are little checks on consumption and production which leaves an extremely detrimental ecological footprint (Rees et al, 2008). Increases in the urban forest improves the quality of life for the citizens and would help cities find environmentally stability. Therefore, it is important for citizens to increase the green in their communities.

There are a variety of factors that impact trees' well being including temperature, weather, invasive plants and insects, and available soil (Nowak et al, 2007). Mortality rates are dependent on those variables and fluctuate when there is a natural disaster, like Hurricane Sandy. This event uprooted trees in the MillionTreesNYC plots and caused severe environmental changes in their ecosystems.

Soil Moisture is defined as the water held between soil particles. It influences agricultural processes, runoff, and drought development. It is an important concept to monitor in tree studies because it shows water availability in the soil. In addition, while tree canopies offer a layer of protection to objects underneath them, the impact they have on those species' water availability should be considered

Ecological restoration is the practice of renewing and restoring run-down and damaged ecosystems. There are many natural places in NYC that have been hurt by industrial waste and intense human damage that should be restored by this practice. Also, ecological restoration includes management of invasive and native species. The MillionTreesNYC organization is working to reach their goal to plant a million trees in New York City and manage the plots they have already completed. It is important to continue to watch the growth and effects of the trees on the city. The purpose of this study was to monitor and document the effectiveness of the ongoing restoration project.

The questions that this study focused on are: what will the mortality rate of specific species be, have the tree's canopies influenced the plants under their cover, specifically how did it affect the water access to the tree and non tree species that were part of the sub-canopy; and what were the differences in regeneration rates from 2009, 2010 until now?

The hypotheses of this experiment are the water available to all species under the trees' canopies in the plots will be less than the water available to any species in an open area, the importance values for all of the tree species will have increased from 2009 to 2013 , and the herbaceous covering will be greater in 2013 (present) than in 2010 (when first surveyed).

Materials and Methods

Two twenty meter by twenty meter plots, 101-1 and 124-1, were considered in this study. In these plots, trees were planted as part of the MillionTreesNYC project in 2008 and 2009. 101-1 and 124-1 were surveyed for sapling mortality and site characteristics in 2009; and herbaceous cover in 2010. My findings in this study were compared to the 2009 and 2010 data to sight the effectiveness of the MillionTreesNYC project.

Measurements

The 2009 Site Witness Map was used to find the corners of each plot and its center with specific locations of marker trees and coordinates. Then, I drew plot boundary lines from each corner in order to mark the mark the appropriate area for the study. From there I was able to determine which species should be considered in my study; saplings with their trunks within the boundaries were only considered. First, my mentor and I gathered all information about living saplings, including the species names recorded and if the trees were dead or alive. If dead then we recorded their apparent cause of death ; plant uprooted (UR) or broken stem (BS). If the tree was alive then caliper was measured at 6 inches from the base of the tree for all trees that were 1 meter or great in height. Also, if they were alive then I stated whether the Leader Stem was dead or alive; if dead then we recorded if more or less is dead. If the Leader stem was alive then we estimated if more than one half of the leaves were damaged (LD) and if more than one half of the leaves were discolored (LC).

This is an example of the chart that all of this information was recorded: (Figure 1)

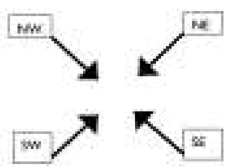
Individual	Species - Common or Scientific Name	Survival - 1 for Live, 0 for Dead	If Dead →	Cause of Death	If Alive →	Diameter cm*	Leader Stem – 1 for Live, 0 for Dead	If Leader ALIVE	If Leader DEAD
1				UR BS				LD LC	Less 1/2 Dead More 1/2Dead

In this study, 10 meter herbaceous transects were taken from each of the four corners of each plot. Using the line intercept method, the distance plant species covered underneath or above the tape measure if they were less than one meter tall was recorded. Every meter on the transect line was broken down into a different section, beginning with the 0-1 meter because it was closest to the center of the plot.

This is an example of the log used to record herbaceous layer and seedling: (Figure 2)

Individual	Species - Common or Scientific Name	Survival - 1 for Live, 0 for Dead	If Dead →	Cause of Death	If Alive →	Diameter cm*	Leader Stem – 1 for Live, 0 for Dead	If Leader ALIVE	If Leader DEAD
1				UR BS				LD LC	Less 1/2 Dead More 1/2Dead

This is a depiction of the herbaceous transect set ups: (Figure 3)

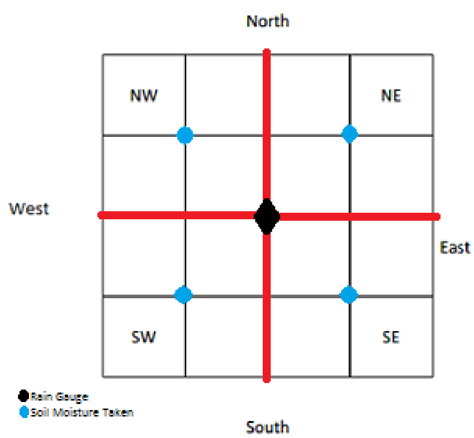


In addition to the herbaceous transects, I estimated the three non-tree plant species that covered the greatest area in each plot. Also, any additional species in the plots were listed along with whether they were common or uncommon.

Next, the site characteristics were recorded. These included hydrologic features (pond, stream, perennial, ephemeral, flood debris, gully, and sheet erosion), Soil Surface Cover (leaf litter, woody debris, rocky outcrop, bare soil, and built structure), and Human Impacts (garbage, plant damage, built structure, official trail, informal trail, tire tracks, and campfire). In addition, the slope was taken for each plot in percent and degrees using a clinometer. Then, insect herbivory or animal impacts in the plot were taken in percent cover. Lastly, all adjacencies to the plot within fifty meters were documented, like roads, official trails, informal trails, parking lots, buildings, forest, lawn, and any others.

The second part of the study included recording soil moisture in four subplots within the larger plots and recording rain measurements using rain gauges. The 124-1 and 101-1 plots were separated into four ten meter by ten meter sections, and then at the center of the plots the soil moisture was recorded with the HydroSense II instrument that reads water content by percent per us.. Also, rain gauges were placed in the center of 124-1 and 101-1 in order to monitor the water availability under the tree canopy. A rain gauge was also placed in an open field in order to monitor the water content directly.

This illustrates where the measurements were taken in relation to the plot: (Figure 4)



Data Analysis

The 2009 sapling mortality data of 101-1 and 124-1 was compared to the 2013 data in order to compute the regeneration rates and mortality rates of species in the plots. The Regeneration Rates were calculated by percent for each species using the formula:

$$Regeneration\ Rate = \frac{\textbf{2013 number of Saplings} - \textbf{2009 number of Sapling}}{\textbf{2013 number of Sapling}}\ \textbf{x 100}$$

Also, I calculated the number of trees per year that regenerated for each species over the four year span. The mortality rates were calculated by percent for those trees using the formula:

$$Mortality\ Rate = \frac{\textbf{Number of Saplings recorded Dead in 2013}}{\textbf{2013 number of Sapling}}$$

The leader stem mortality rates were calculated using the formula above. Following, the importance values for each species were calculated for 2013 and 2009 using the formula:

$$IV = \text{Relative Density} + \text{Relative Frequency}$$

In order to analyze the herbaceous transects, the cover of each species were added together then converted into a percentage using the formula:

$$\text{Ave. \% Ground Cover} = \frac{\textbf{total \% ground cover by species (cm)}}{\textbf{1m segment}}$$. (McDonnell et. al.)

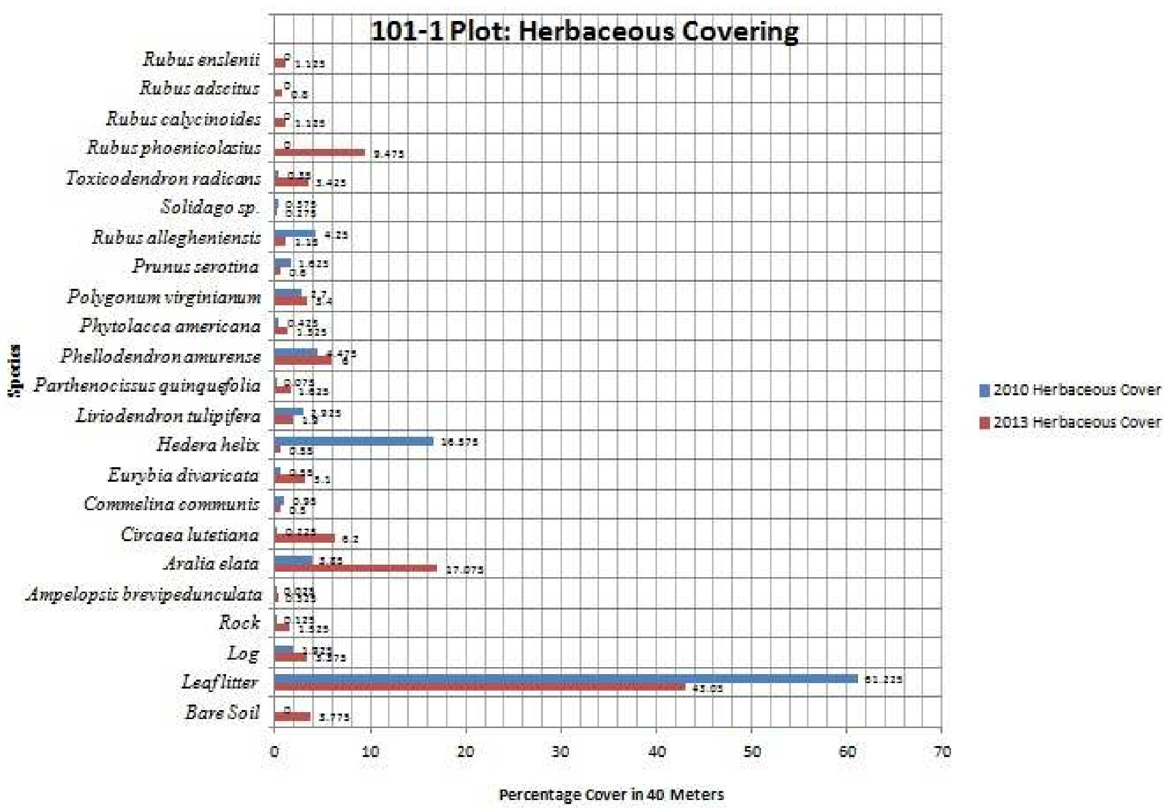
Also, the herbaceous cover of each species of the 40 meter transects were holistically analyzed to find a percentage of each species' ground cover in 2013 and 2010.

Lastly, the water availability under the tree canopy of the plots vs. the open field was analyzed using a percentage. In order to examine the readings, the percentage of water was collected in the plots underneath the canopies in comparison to the water collected in the open field. The soil moisture readings were averaged and considered with the water collection data to give more of a sense of each plot's water availability at ground level.

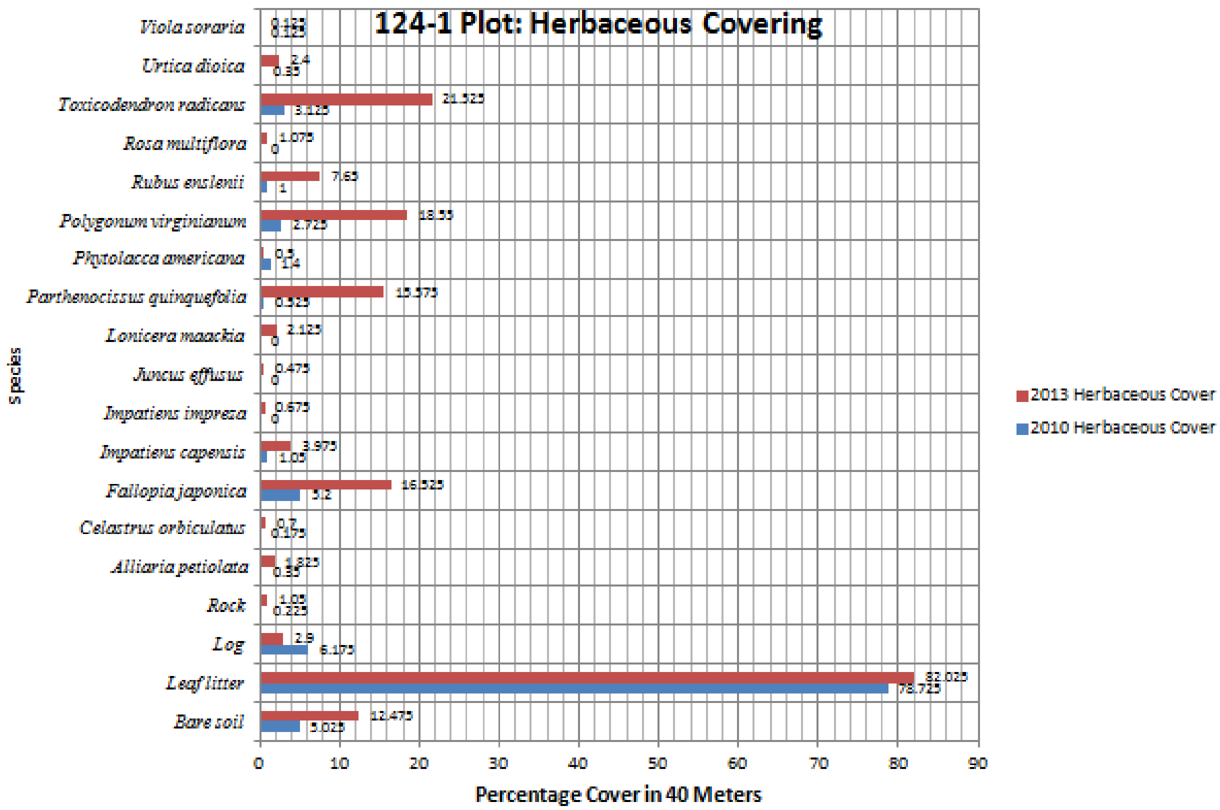
Results

Tree Seedling/ Herbaceous Cover

All Species that did not cover more than one percent of the plot or did not have a change in percent greater than 0.8 are not pictured in this data chart. The a biotic factors in this graph include rock, log, leaf litter, and bare soil. The other species listed are biotic. (Graph 1)



All Species that did not cover more than one percent or did not have a change in percent greater than 0.475 are not pictured in this data chart. The a biotic factors in this graph include rock, log, leaf litter, and bare soil. The other species listed are biotic (Graph 2)



Sapling Regeneration and Mortality

101-1 Native Species Regeneration Rates (Table 1)

Plot	Species	Percent of Regeneration	Regeneration in tree per year
101-1	Betula Lenta	7.142857143	0.25
101-1	Liriodendron Tulipfera	98.7804878	20.25
101-1	Quercus	93.93939394	7.75
101-1	Fagus Sylvatica	100	0.25
101-1	Carya Ovalis	100	0.75
101-1	Carpinus Caroliniana	100	0.5
101-1	Fraxinus Americana	100	1
101-1	Fraxinus Pennsylvanica	100	1.75
101-1	Ben Linden	100	0.25
101-1	Nyssa Sylvatica	100	1.25
101-1	Prunus Serotina	100	7.25
101-1	Quercus Velutina	100	0.5
101-1	Quercus Alba	100	0.25
101-1	Weedy Apple	100	0.25
101-1	Viburnum Dentatum	100	0.5
101-1	Liquidambar Styraciflua	100	0.25
101-1	Quercus Bicolor	100	0.5
101-1	Quercus Rubra	100	0.25
101-1	Acer Rubrum	100	0.25

101-1 Invasive Species Regeneration Rates (Table 2)

Plot	Species	Percent of Regeneration	Regeneration in tree per year
101-1	Aralia Eleta	100	8
101-1	Morus Alba	100	2.5
101-1	Acer Platenoides	100	1.25
101-1	Paulownia	100	0.75
101-1	Phellodendron Amurense	100	11
101-1	Weedy Cherry	100	1.75

101-1 Mortality Rates (Table 3)

All Species in bold lettering are invasive species.

Plot	Species	Rate by Percent	Mortality in tree per year
101-1	Fraxinus Pennsylvanica	100	0.25
101-1	Betula Lenta	6.667	0.25
101-1	Liriodendron Tulipfera	10.86956522	2.5
101-1	Prunus Serotina	3.3333	0.25
101-1	**Weedy Cherry**	22.2222	0.5

101-1 Leader Stem Mortality Rates (Table 4)

Plot	Species	Rate by Percent	Leader stem dead per year
101-1	Nyssa Sylvatica	20	0.25

124-1 Native Species Regeneration Rates (Table 5)

Plot	Species	Percent of Regeneration	Regeneration in Tree per year
124-1	Acer Rubrum	0	0
124-1	Acer Saccharum	88.889	2
124-1	Amelanchier Canadensis	100	0.25
124-1	Betula Lenta	76.92307692	2.5
124-1	Carpinus Caroliniana	100	0.25
124-1	Fraxinus Americana	100	1.5
124-1	Fraxinus Pennsylvanica	0	0
124-1	Liquidambar Styraciflua	100	0.75
124-1	Liriodendron Tulipfera	43.333	9.75
124-1	Ostrya Virginiana	100	0.25
124-1	Platanus Occidentalis	100	0.25
124-1	Quercus Bicolor	33.333	0.25
124-1	Quercus Rubra	100	1.5
124-1	Quercus Velutina	100	0.75

124-1 Invasive Species Regeneration Rates (Table 6)

Plot	Species	Percent of Regeneration	Regeneration in tree per year
124-1	Acer Platnoides	100	1.25
124-1	Ailanthus Altissima	100	0.25
124-1	Weedy Cherry	100	0.5
124-1	Japanese Zelkova	100	0.25

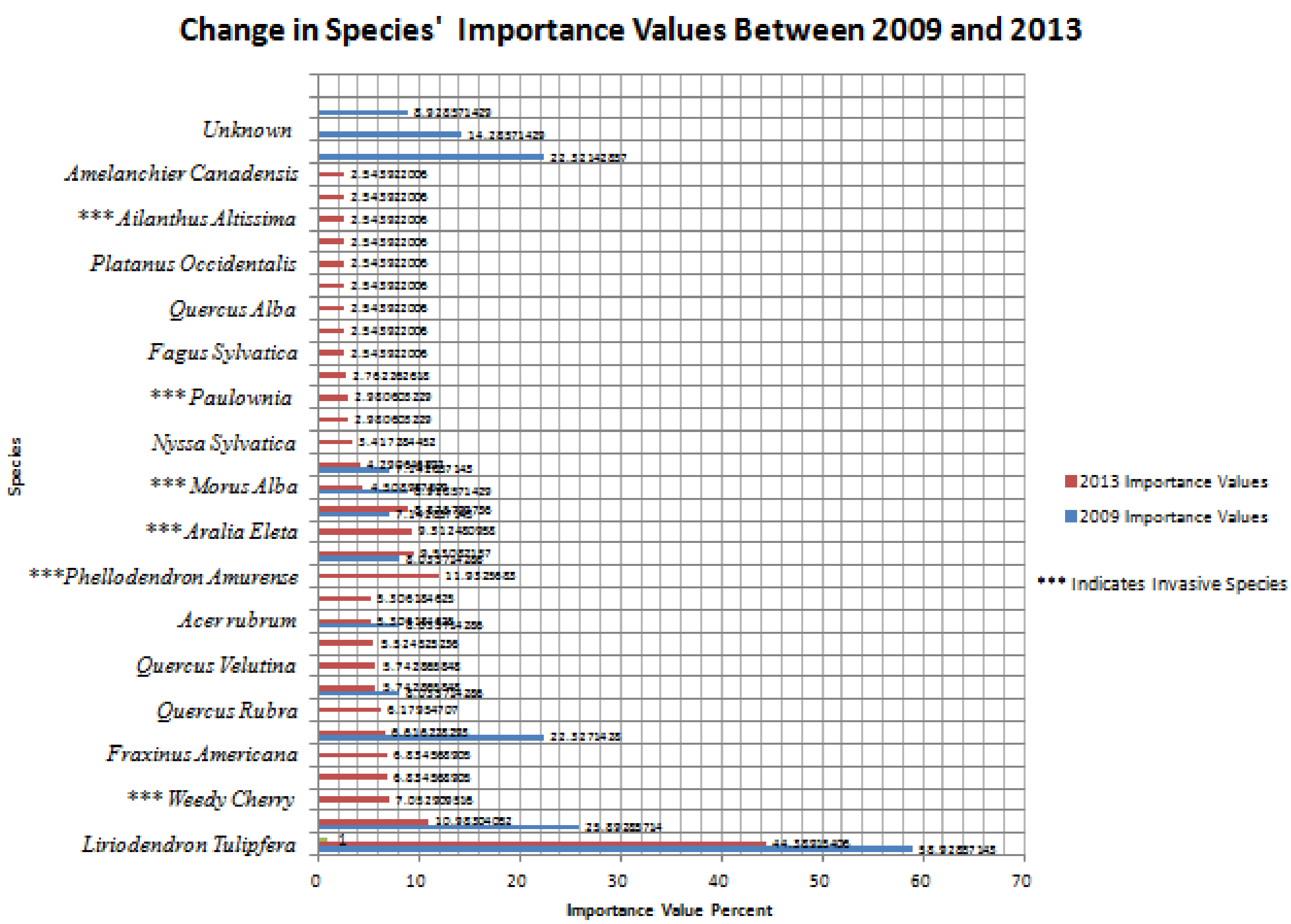
124-1 Mortality Rates

Plot	Species	Rate by Percent	Tree mortality per year
124-1	Betula Lenta	7.142857	0.25

124-1- Leader Stem Mortality Rates (Table 7)

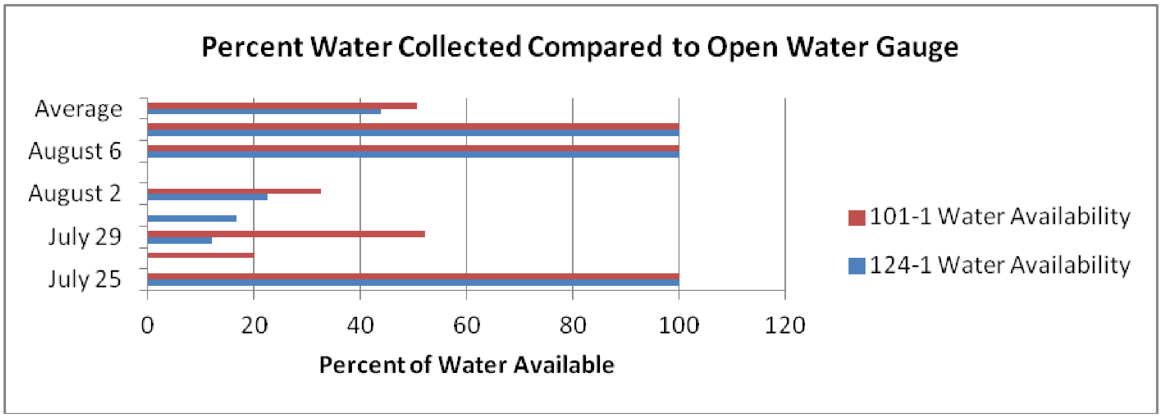
Plot	Species	Rate by Percent	Leader stem dead per year
124-1	Betula Lenta	7.69	0.25

Sapling Importance Value (Graph 3)



Water Availability and Soil Moisture

The water available in the plots was divided by the water in the open water gauge are shown in this graph to show the difference in water availability between the plots. (Graph 4)



Soil Moisture Averages (Table 8)

Plot	**Corner**	**Percent Water in Soil**	**per us**
124-1	NE	12.3875	1.864875
124-1	NW	32.3625	2.414625
124-1	SE	11.925	1.846625
124-1	SW	9.1625	1.762375
101-1	NE	6.7625	1.566875
101-1	NW	14.225	1.7565
101-1	SE	12.7875	1.870125
101-1	SW	15.45	1.935875
124-1	Average	16.459375	1.972125
101-1	Average	9.845	1.782344

Discussion

Over the past four years the 101-1 and 124-1 plots have altered entirely, from sapling species to herbaceous density. There were many new species introduced to the plots, some resulted from the sapling and herbaceous regeneration. On Graph 3, it highlights how the calculated importance values of the native species of the area have decreased while invasive species' importance values have increased. The invasive saplings have impact the plots include *Phellodendron Amurense*, *Aralia Elata* (especially in plot 101-1), *Morus Alba*, *Acer Platanoides,* and a Woody Cherry *sp*. My hypothesis "the importance values for all of the tree species will have increased from 2009 to 2013" was both supported and refuted by the data because the importance values of many species, especially invasive species, increased; however the importance values of many native species decreased.

Herbaceous Cover increased significantly in both plots, more so for 124-1 than 101-1. There were additional species that were introduced in both plots, however many species appeared to thrive, which is projected in the transect readings. Plot 101-1 was mainly dominated by *Aralia Elata*, Wineberry, and *Circaea Lutetiana*. Plot 124-1was mainly dominated by *Toxicodendron Radicans, Polygonum Virginianum, Parthenocissus Quinquefolia*, and *Fallopia Japonica*.

In addition, water availability was significantly lower underneath the canopy of the trees. One reason for these values may have been because the sub-canopies of saplings hovered directly over the openings of the rain gauges. Overall, my hypothesis that the water availability is much lower at ground level in the plots than in an open area was supported and this fact may impact which species thrive in the plots. Also, the soil moisture readings gave an estimation of the water content in the soil beneath the canopies. The water content value changed dramatically based on where the reading was taken. For example, the Northwest corner of plot 124-1 was directly adjacent to a river which definitely increased the soil's water content. Although, when averaged together it gave a well rounded perspective to the water availability in the soil.

Conclusions and Future Work

This study analyzed the effects of an NYC urban reforestation project. My findings indicate that invasive tree species are increasing in importance values and are steadily dominating the plots. Native species regenerated at positive rates even though their importance values decreased, meaning they are holding their place in the ecosystem. Also, the mortality rates and leader stem mortality rates were extremely scarce between the years of 2009 and 2013.

Water Availability in the dense forest plots was much smaller than that of the open area. This influences the species that can thrive in the environment and what animals may reside in these areas. Forest restoration scientists should be aware of the effects that concentrated planting has on the environment. Scientists should research to see if the lack of water has a negative impact on the environment and if trees need to be spaced out and to what extent when planted.

This experiment is important for future NYC urban restoration projects because it serves as a reference for species and importance values of saplings in MillionTreesNYC plots. These accounts provide information about invasive species and native species scientists should focus on maintaining throughout the city.

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