# Climate Change and the Urban Forest

## Emerging threats & adaptive strategies for Brooklyn street tree resilience & justice

Emily Bachman - Pratt GCPE - Spring 2020

# Agenda

1. Issue Statement
2. Goal & Objectives
3. Methodology
4. Background
5. Findings
6. Recommendations
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# Issue Statement

Street trees are environmental assets that provide key ecosystem services.

Street trees are unequally distributed across urban environments in correlation with racial and economic segregation of human populations.

**Climate change** poses new threats to street trees and necessitates new approaches to urban forestry to increase **resilience**.

# Goal

To identify, develop, and make the case for street tree management strategies that maximize environmental justice and climate change resilience in Brooklyn, New York.

# Objectives

1. Analyze the distribution of street trees in Brooklyn from an environmental justice perspective.

2. Identify Brooklyn street trees threatened by climate change: sea level rise, flooding, wind, & drought.

3. Explore street tree management best practices to maximize environmental justice and climate change resilience in New York City.

# Methodology

| Objective | Research Questions | Sources | Methods |
|---|---|---|---|
| **1.** Analyze the distribution of street trees in Brooklyn from environmental justice & climate resilience perspectives. | How has the NYC street tree population changed over time? | NYC Parks Street Tree Census (1995, 2005, 2015), MillionTreesNYC, PlaNYC, NYC Parks, & USDA Forest Service Northern Field Station, Brooklyn Public Library Center for Brooklyn History, New York Times Archive | Literature Review<br>Semi-Structured Interviews<br>Statistical Analysis |
| | What are the public health benefits of street trees? | USDA i-Tree Eco v6, Public Health Perspectives; International Journal of Environmental Research and Public Health, Parks & Recreation; Journal of Environmental Management, Arboriculture & Urban Forestry, Landscape & Urban Planning, Landscape Journal | Literature Review |
| | How does street tree distribution vary by NYC Borough and Brooklyn Neighborhood? | NYC Street Tree Census (2015)<br>NYC Planning, NTA Boundaries (2020) | GIS Mapping<br>Statistical Analysis |
| | To what extent does street tree distribution correlate to income and race in Brooklyn? | NYC Street Tree Census (2015)<br>US Census, ACS Economic Data (2016) | Literature Review<br>GIS Mapping |
| | How do NYC street tree species vary in environmental tolerances to climate change threats? | NYC Parks, Approved Street Tree Species List (2019)<br>University of Illinois Extension, Tree Selector (2020) | Literature Review<br>GIS Mapping |

# Methodology

| Objective | Research Questions | Sources | Methods |
|---|---|---|---|
| **2.** Identify street trees threatened by sea level rise, flooding, wind, & drought in Brooklyn. | What are the projected impacts of climate change in NYC? | IPCC, UN, USEPA, USDOE, USDA, US Army Corps of Engineers, NOAA, NYSERDA, PlaNYC, NYC Mayor's Office of Sustainability, & New York Academy of Sciences | Literature Review |
| | How many of each species of tree are in the future flood zone with sea level rise? | NYC Parks, Street Tree Census (2015)<br>NYC Mayor's Office of Sustainability (2013). | GIS Mapping<br>Statistical Analysis |
| | How many Brooklyn street trees are vulnerable to wind, drought, and flooding based on species? | NYC Parks, Street Tree Census (2015)<br>NYC Parks, Approved Street Tree Species List (2019)<br>University of Illinois Extension, Tree Selector (2020) | Literature Review<br>Statistical Analysis |
| **3.** Explore street tree planting & stewardship best practices to maximize environmental justice and climate change resilience in New York City. | What are the leading indicators of street tree survival and health? | USDA Forest Service Northern Field Station, Urban Forestry & Urban Greening, Arboriculture & Urban Forestry | Literature Review<br>Semi-Structured Interviews |
| | What approaches to stewardship exist, and how does stewardship vary across NYC neighborhoods? | TreesNY, Gowanus Canal Conservancy, Lower East Side Ecology Center, GrowNYC | Literature Review<br>Semi-Structured Interviews<br>Citizen Pruner Certification |

Literature Review

Urban Forestry

Street Tree Census

MillionTreesNYC

Environmental Justice

Climate Change Planning

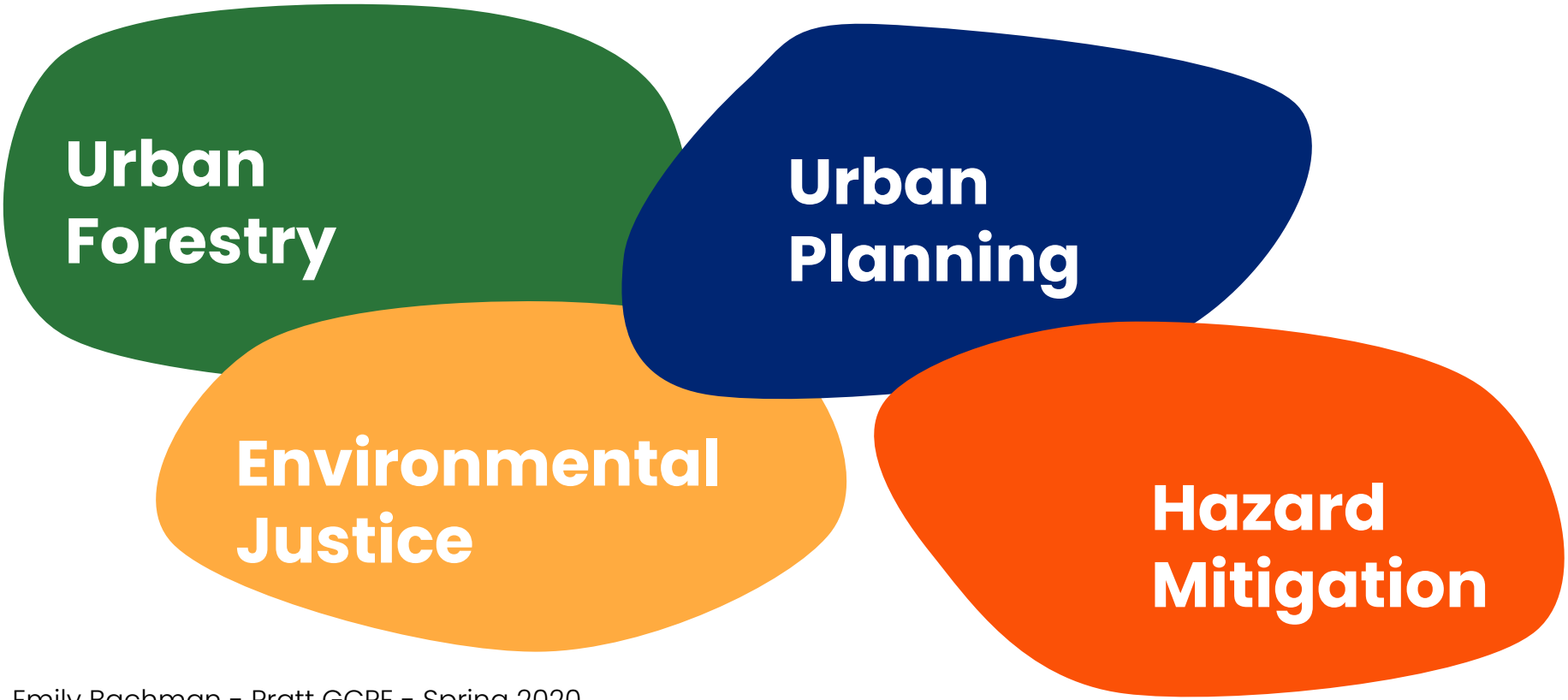
# Background



Source: Stan Honda/AFP/Getty Images via Fast Company, 2015

# Literature Review

Background



# Urban Forestry

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# NYC Street Tree Stakeholders

Background

| Government | Non-Profit | For-Profit | Volunteer |
|---|---|---|---|
| NYC Parks | City Parks Foundation | Business Improvement Districts | Property Owners |
| NYC DEP | New York Restoration Project | Con Edison | Citizen Pruners |
| NYC DOT | Trees New York | Private Landscapers & Contractractors | Individuals |
| DSNY | Gowanus Canal Conservancy | Real Estate Developers | |
| NYC DOITT | GrowNYC Compost Program | | |
| USDA NYC NFS | Lower East Side Ecology Center | | |
| Greenbelt Native Plant Center | Partnerships for Parks | | |
| NYC Service | NYC Compost Project | | |

# Stakeholders - Planting



## Government

- NYC Parks
- NYC DEP
- NYC DOT
- Greenbelt Native Plant Center

## Non-Profit

- New York Restoration Project
- Trees New York
- Gowanus Canal Conservancy

## For-Profit

- Business Improvement Districts
- Private Landscapers & Contractractors
- Real Estate Developers

## Volunteer

- Property Owners
- Individuals

# Stakeholders - Maintenance

Background

| Government | Non-Profit | For-Profit | Volunteer |
| --- | --- | --- | --- |
| NYC Parks | City Parks Foundation | Business Improvement Districts | Property Owners |
| | New York Restoration Project | Con Edison | Citizen Pruners |
| | Trees New York | Private Landscapers & Contractractors | Individuals |
| | Gowanus Canal Conservancy | Real Estate Developers | |
| NYC DOITT | GrowNYC Compost Program | | |
| | Lower East Side Ecology Center | | |
| | Partnerships for Parks | | |
| NYC Service | NYC Compost Project | | |

# MillionTreesNYC

## Background

**1,000,000 Trees** Planted in NYC

**8 years**
2007-2015


Source: Campbell & Monaco, 2014

# MillionTreesNYC

## Background

| Planting Type | Count |
|---|---|
| Street Trees | 220,000 |
| Parks Reforestation | 380,000 |
| Other Agencies and Zoning Regulations | 100,000 |
| Private Partners | 300,000 |
| **Total** | **1,000,000** |



Source: Source: Campbell & Monaco, 2014

# Street Tree Census

## Background

**Decennial**

1995 - 2005 - 2015

**Open Data**

& Interactive Map

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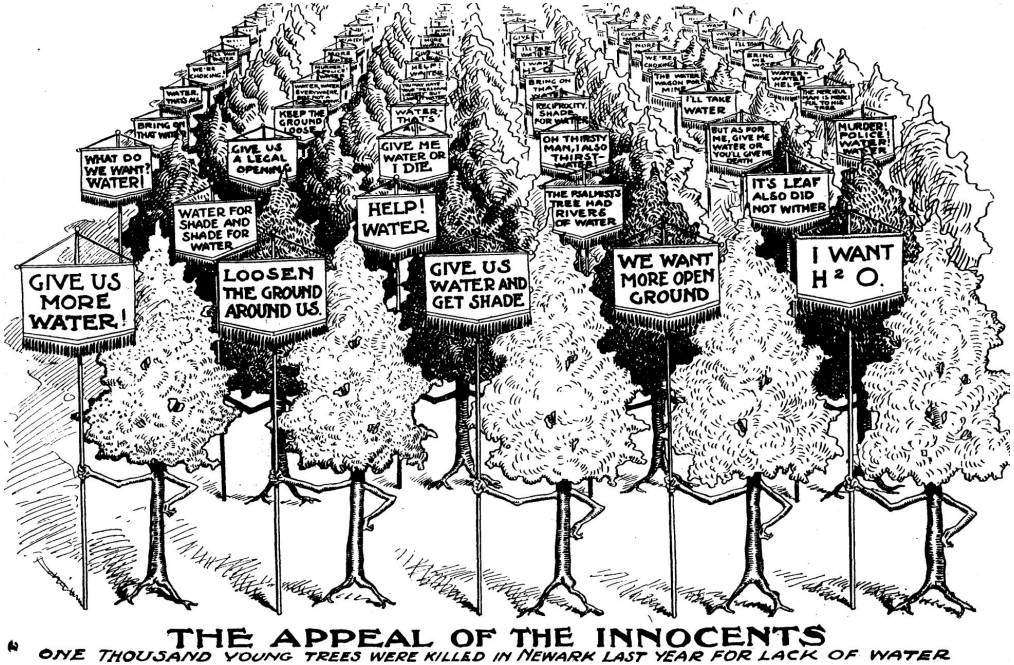
Source: NYC Parks, 2015

# Stewardship

## Background

*(n.): tree care following initial planting.*






Source: Newark Shade Tree Commission (1911)

# Stewardship

## Background

**Branches:** prune dead & damaged branches & branches with narrow crotch angles

**Trunk:** remove wires, stakes, collars, grates and cages.

**Water:** 15 gallons of water 1-2x/week for new trees

**Soil:** cultivate, add compost & mulch

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Source: TreesNY, Citizen Pruner Manual (2019).

# Environmental Justice

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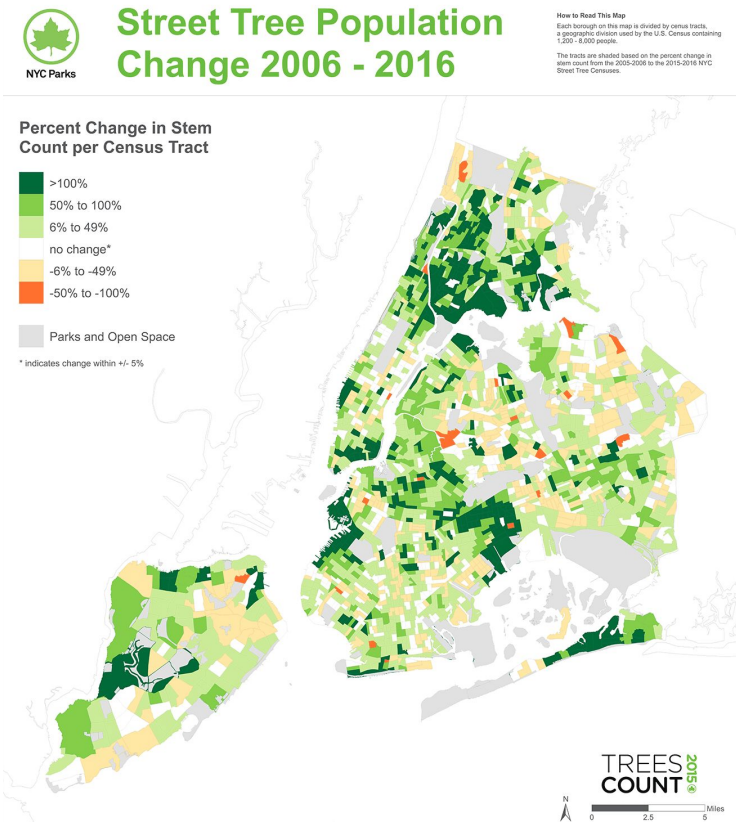
# Environmental Justice

## Background

# Trees for Public Health Neighborhoods

Low Street Tree Count
Low Air Quality
High Poverty
High Childhood Asthma

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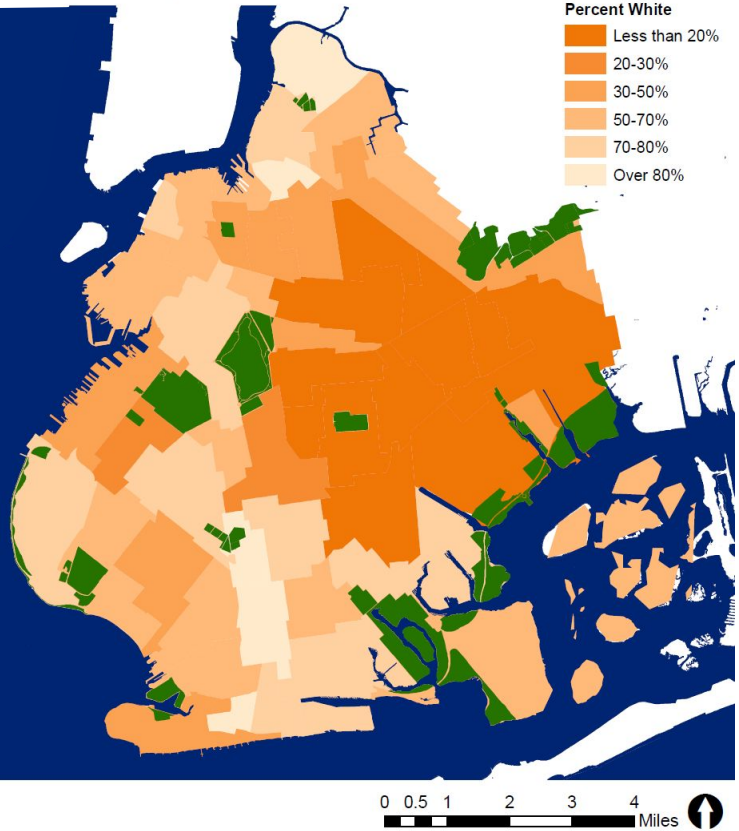
# Racial Segregation

## Background

| Neighborhood Race & Ethnicity | Poverty Rate |
|---|---|
| White Majority | 10.4 |
| White Minority | 20.6 |






Sources: US Census Bureau, ACS (2015), Furman Center (2011) p. 32

# Hazard Mitigation

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*"Well, like they say—if you don't like New York weather, wait twenty years till it's all underwater."*

# Hazard Mitigation: Climate Change Threats to the Urban Forest

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Source: Flake, Emily (August 20, 2018). Two people walk along promenade in New York City. *New Yorker*.

# Wind

## Background

**Tropical Storm Isaias** August 4, 2020

**3,300** Trees fell

**7,400** Trees Damaged

**10,739** Work Orders

**Con Edison** @ConEdison · Aug 4

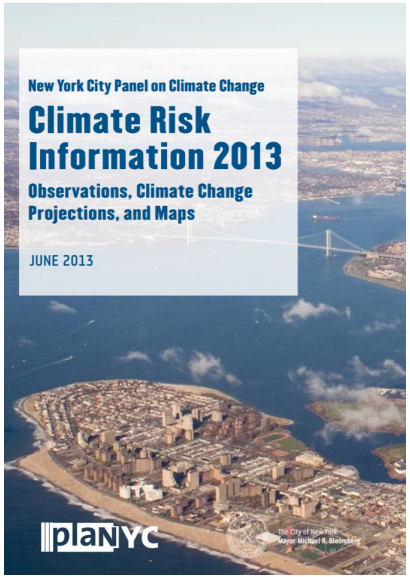
#TropicalStormIsaias is barreling into the New York area and has caused damage to our system, resulting in outages. Our crews are assessing the damage and will restore power as soon and as safely as possible. spr.ly/6018G58Or



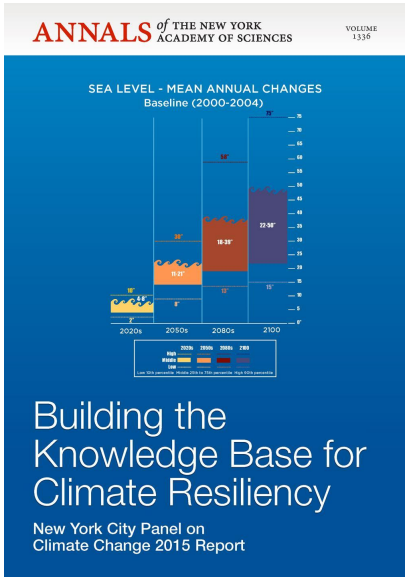

Sources: Culliton, K.(2020), ConEd (2020)

# Future Projections

Background

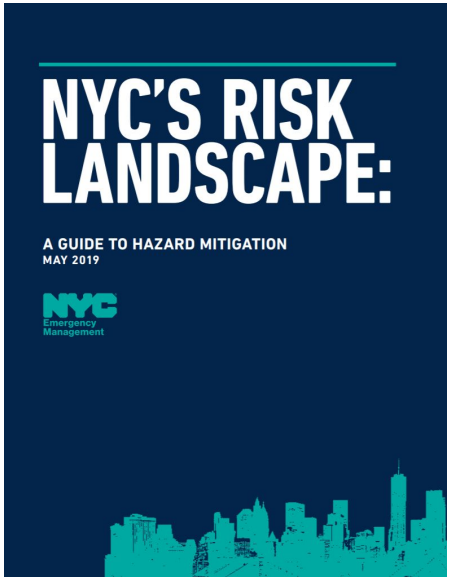



2013




2013


2014




2019



Sources: NYCEM (2019) Hazard Mitigation, p. 35; NYC NPCC (2013)

# New York City, 2080

## Background

**Average Temperature Increase** 5.3 - 8.8°F Increase in Mean Annual Temperatures

**Extreme Heat** 3x Increase in Heat Waves (6 per year)

**Cold Snaps** 50% Decrease in Extreme Cold Events

**Sea Level Rise** 18 - 39 Inch Increase in Local Sea Level

**Tropical Storms** Increased Frequency and Severity of:

- **Coastal Storm Surge**
- **Heavy Rainfall & Flooding**
- **Extreme Winds**

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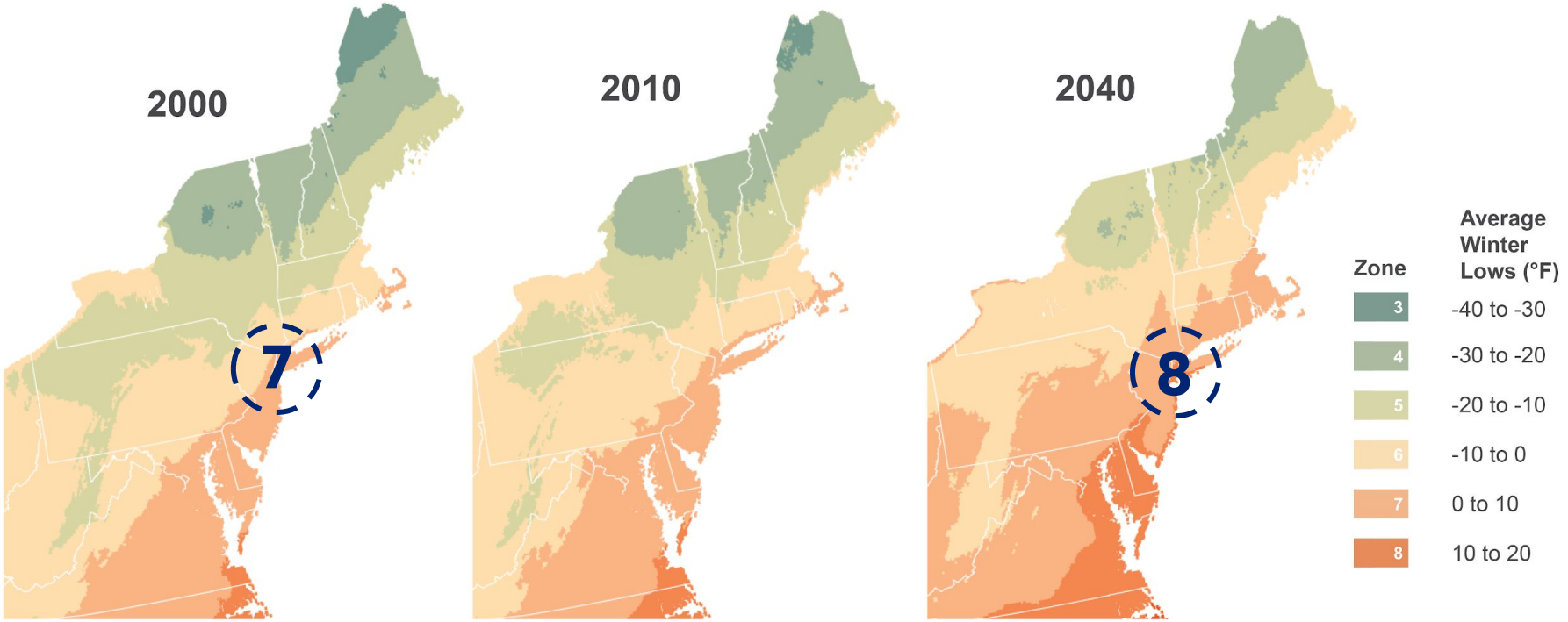
Sources: NYCEM (2019) Hazard Mitigation, p. 35; NYC NPCC (2013)

# USDA Plant Hardiness Zones

Background

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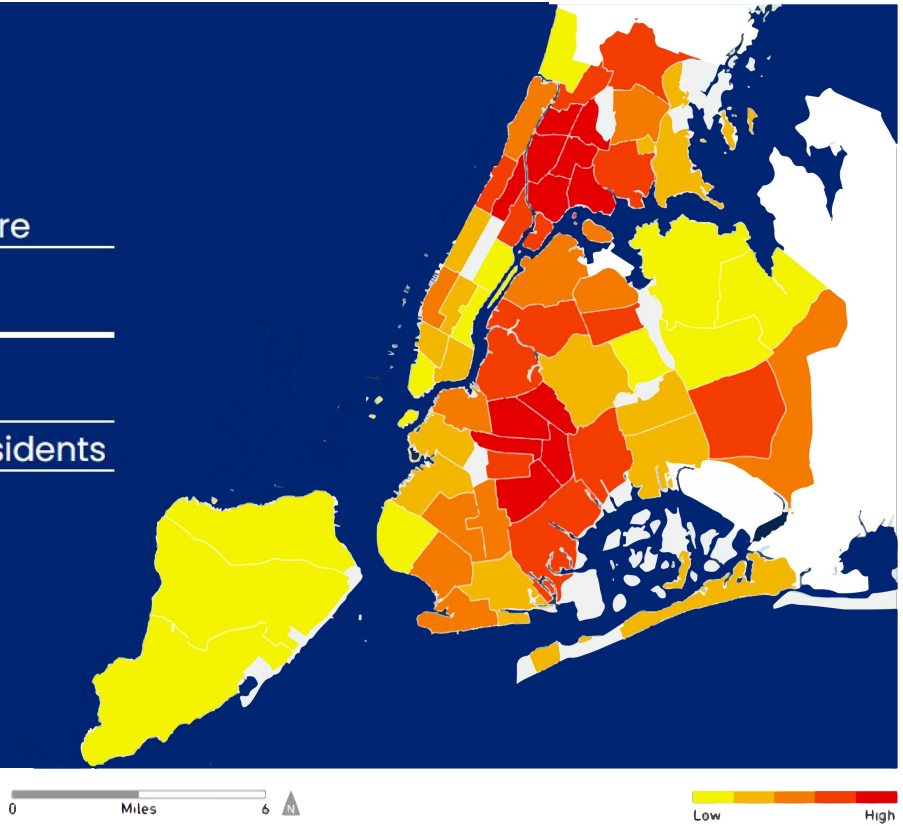
Sources: NYT (2019) & NOAA (2017)

# Heat Waves

Background

## Heat Vulnerability Index

| | |
|---|---|
| **Environmental Factors** | Daytime Surface Temperature |
| | Percentof Green Space |
| **Social Factors** | Poverty |
| | Percent non-Latinx Black Residents |
| | Access to Air Contidioning |




 Sources: NYC Emergency Management (2019), NYC Health Department (2019)

# Urban Planning

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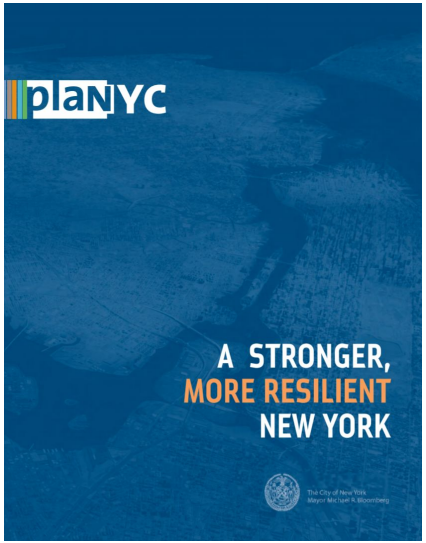
# NYC Planning

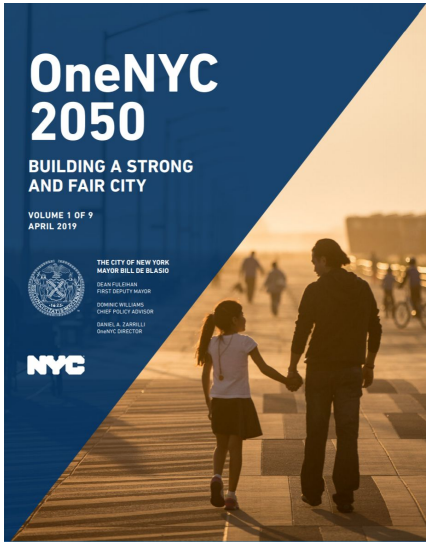
## Background


2007




2013


2015




2019

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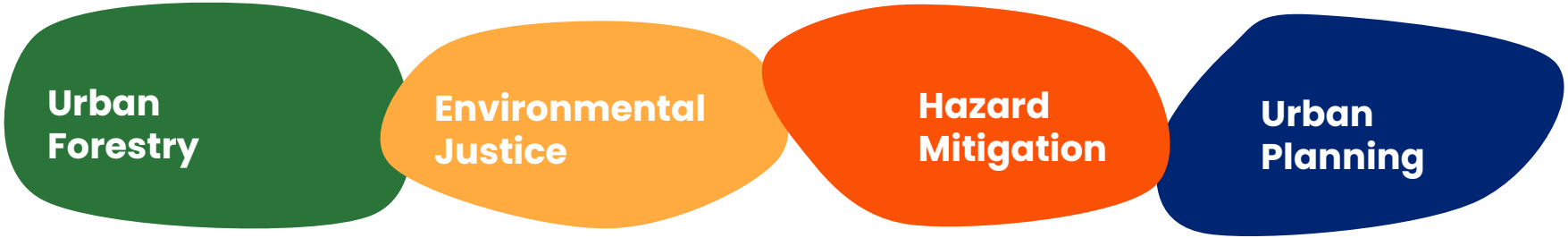
Sources: NYCEM (2019) Hazard Mitigation, p. 35; NYC NPCC (2013)

# Literature Review

Background




## What's Missing?

### Climate Change Adaptation and Resilience for Urban Trees

Street Tree Count & Density

Species Diversity

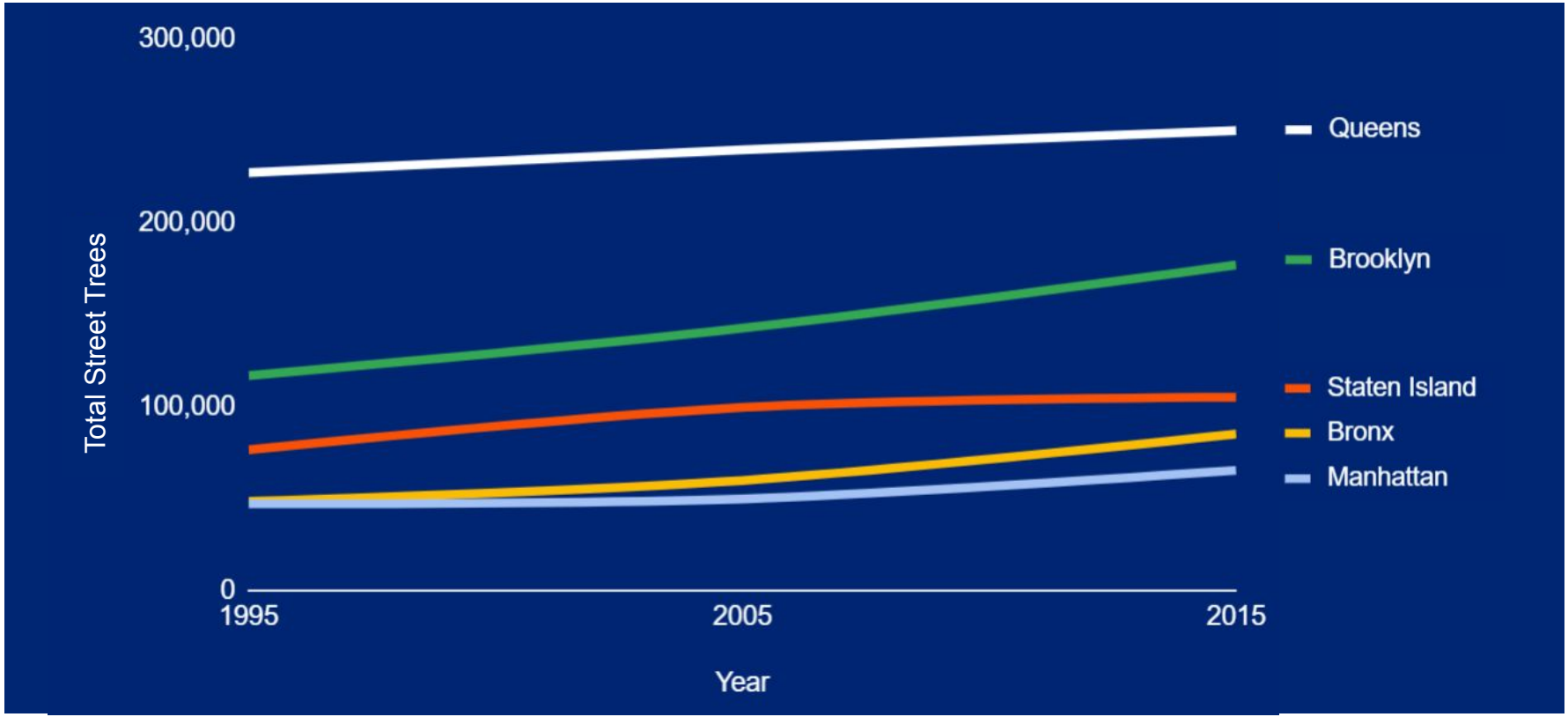
Environmental Tolerance

Climate Change Resilience

# Findings

# Street Tree Count, 1995-2015

Findings

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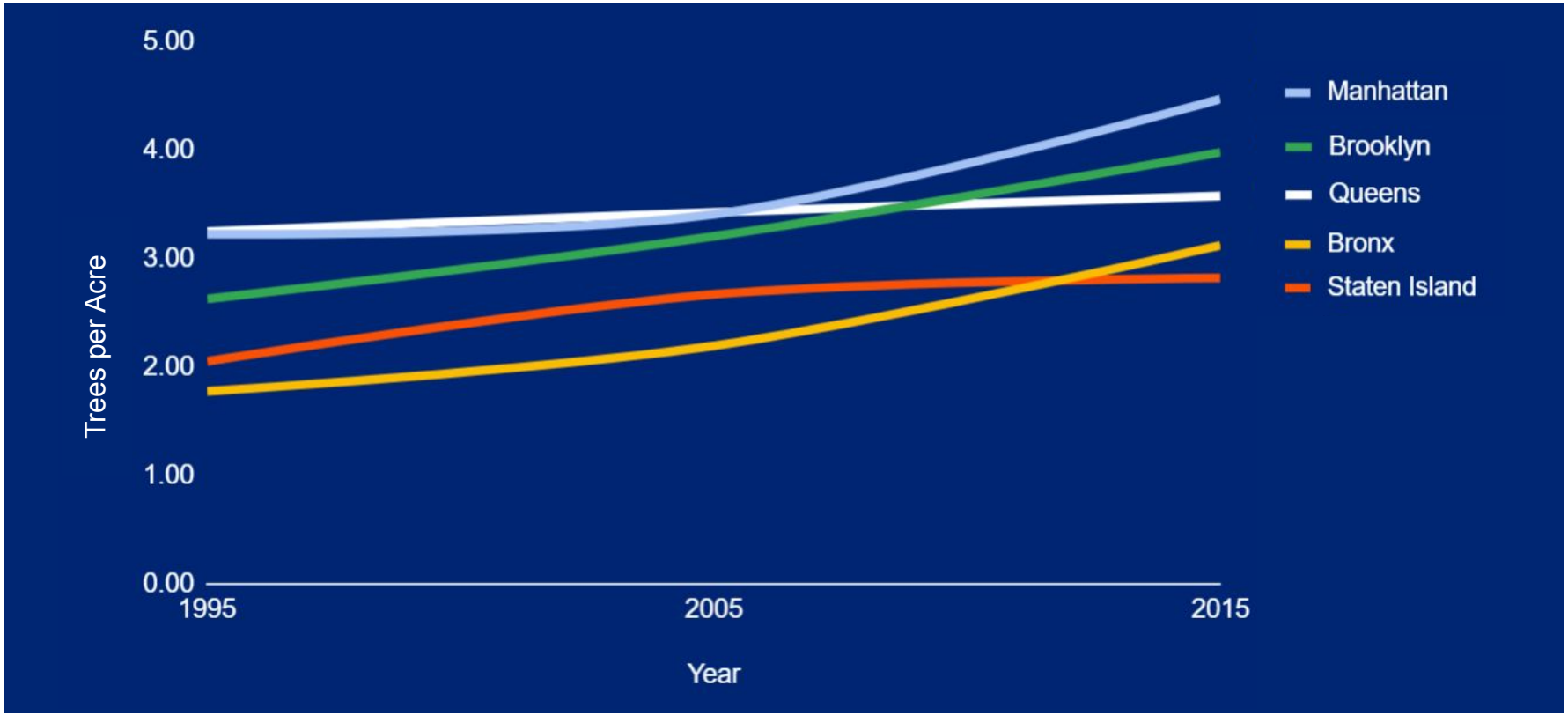
Sources: NYC Street Tree Census (1995, 2005, 2015), NYC Planning (2019)

# Street Tree Density, 1995-2015

Findings

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Sources: NYC Street Tree Census (1995, 2005, 2015), NYC Planning (2019)

# Open Space & Street Trees

## Findings

| Borough | Population per Acre | Percent Area Open Space | Open Space Acres per 1,000 Residents | Trees per Acre | Trees per 1,000 Residents |
|---|---|---|---|---|---|
| Manhattan | 97 | 14% | 1.5 | 4.5 | 46 |
| Bronx | 41 | 20% | 4.8 | 3.1 | 77 |
| Brooklyn | 46 | 9% | 2.1 | 4.0 | 86 |
| Queens | 27 | 10% | 3.7 | 3.6 | 133 |
| Staten Island | 10 | 13% | 12.6 | 2.8 | 277 |
| **Grand Total** | **35** | **12%** | **3.3** | **3.5** | **100** |

Sources: NYC Street Tree Census (2015), US Census Bureau ACS (2016), NYC Planning (2019), NYC Parks Open Space (2014)

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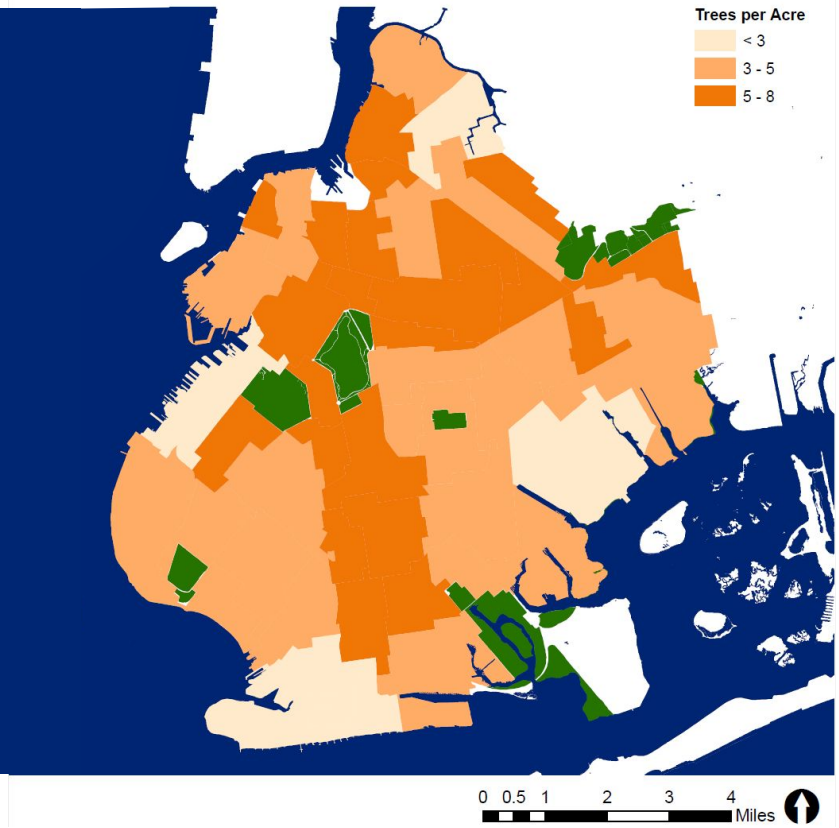
# Brooklyn Street Tree Density

Findings

**4** Trees per Acre

**86** Trees per 1,000 Residents

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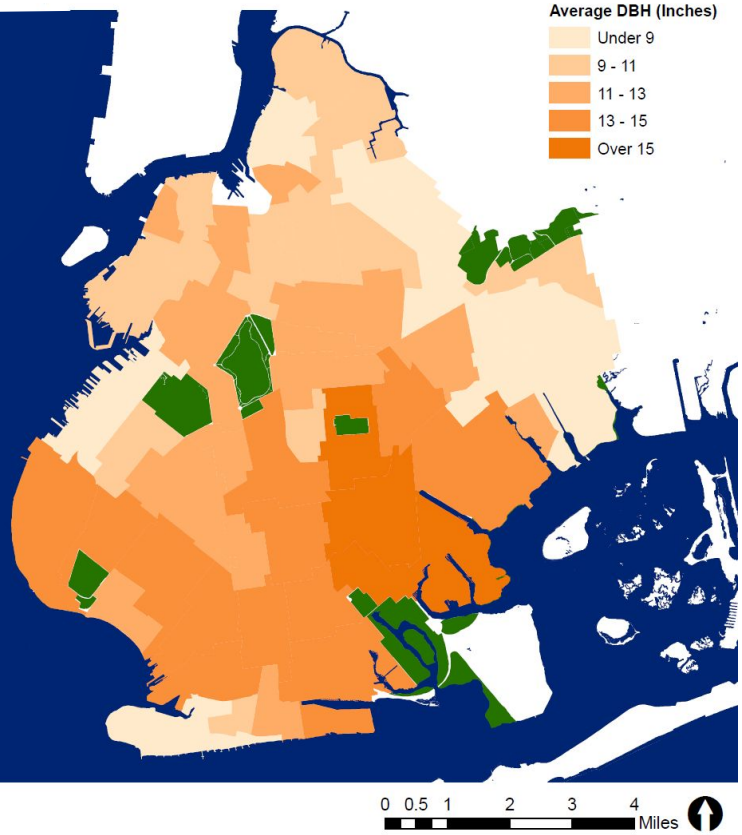
Source: Source: NYC Parks, 2015

# Tree Maturity

Findings

# 11.7 inches

Average Brooklyn Street Tree Diameter at Breast Height (DBH)

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Source: Source: NYC Parks, 2015

# Tree Species Diversity

Findings

**132** Species Present

**41** Species Approved for Street Tree Planting in NYC

| Common Name | Scientific Name | Percent of Population | Approved Species? |
|---|---|---|---|
| London planetree | *Platanus x acerifolia* | 19.7% | N |
| Honeylocust | *Gleditsia triacanthos var. inermis* | 9.5% | Y |
| Pin Oak | *Quercus palustris* | 7.0% | Y |
| Japanese Zelkova | *Zelkova serrata* | 5.4% | Y |
| Callery Pear | *Pyrus calleryana* | 5.1% | N |
| Littleleaf Linden | *Tilia cordata* | 5.0% | Y |
| Unknown | *Unknown* | 4.3% | -- |
| Norway maple | *Acer platanoides* | 3.9% | N |
| Sophora | *Styphnolobium japonicum* | 3.4% | Y |
| Cherry | *Prunus* | 3.2% | Y |
| Ginkgo | *Ginkgo biloba* | 3.2% | Y |
| American Linden | *Tilia americana* | 2.3% | Y |
| Green Ash | *Fraxinus pennsylvanica* | 2.1% | N |
| Swamp White Oak | *Quercus bicolor* | 1.5% | Y |
| American Elm | *Ulmus americana* | 1.5% | N |
| Northern Red Oak | *Quercus rubra* | 1.4% | Y |
| Red Maple | *Acer rubrum* | 1.3% | N |
| Silver Linden | *Tilia tomentosa* | 1.3% | Y |
| Sweetgum | *Liquidambar styraciflua* | 1.1% | Y |

# Tree Species Diversity

Findings

**52%** Top 6 Species Share of Total Population

**20%** London Planetree

| Common Name | Scientific Name | Percent of Population | Approved Species? |
|---|---|---|---|
| **London planetree** | *Platanus x acerifolia* | 19.7% | N |
| **Honeylocust** | *Gleditsia triacanthos var. inermis* | 9.5% | Y |
| **Pin Oak** | *Quercus palustris* | 7.0% | Y |
| **Japanese Zelkova** | *Zelkova serrata* | 5.4% | Y |
| **Callery Pear** | *Pyrus calleryana* | 5.1% | N |
| **Littleleaf Linden** | *Tilia cordata* | 5.0% | Y |
| **Unknown** | *Unknown* | 4.3% | -- |
| **Norway maple** | *Acer platanoides* | 3.9% | N |
| **Sophora** | *Styphnolobium japonicum* | 3.4% | Y |
| **Cherry** | *Prunus* | 3.2% | Y |
| **Ginkgo** | *Ginkgo biloba* | 3.2% | Y |
| **American Linden** | *Tilia americana* | 2.3% | Y |
| **Green Ash** | *Fraxinus pennsylvanica* | 2.1% | N |
| **Swamp White Oak** | *Quercus bicolor* | 1.5% | Y |
| **American Elm** | *Ulmus americana* | 1.5% | N |
| **Northern Red Oak** | *Quercus rubra* | 1.4% | Y |
| **Red Maple** | *Acer rubrum* | 1.3% | N |
| **Silver Linden** | *Tilia tomentosa* | 1.3% | Y |
| **Sweetgum** | *Liquidambar styraciflua* | 1.1% | Y |

# Environmental Tolerance

## Findings

| Common Name | Scientific Name | Wet Tolerant | Salt Tolerant | Drought Tolerant | Wind Tolerant |
|---|---|---|---|---|---|
| Ginkgo | *Ginkgo biloba* | N | Y | Y | Y |
| Honeylocust | *Gleditsia triacanthos var. inermis* | Y | Y | Y | Y |
| Coffeetree | *Gymnocladus dioicus* | N | N | Y | N |
| Sweetgum | *Liquidambar styraciflua* | Y | Y | N | N |
| Dawn Redwood | *Metasequoia glyptostroboides* | Y | N | Y | N |
| Swamp White Oak | *Quercus bicolor* | Y | N | Y | N |
| Shingle Oak | *Quercus imbricaria* | N | N | N | N |
| Pin Oak | *Quercus palustris* | N | N | Y | Y |
| Willow Oak | *Quercus phellos* | N | N | Y | N |
| Northern Red Oak | *Quercus rubra* | N | Y | N | N |
| Fastigiata Oak | *Quercus spp. 'Fastigiata'* | N | N | N | N |
| Bald Cypress | *Taxodium distichum* | Y | Y | Y | N |
| American Linden | *Tilia americana* | N | N | N | N |
| Littleleaf Linden | *Tilia cordata* | N | N | N | N |
| Silver Linden | *Tilia tomentosa* | N | Y | N | N |
| Crimean Linden | *Tilia x euchlora* | N | N | N | N |
| Japanese Zelkova | *Zelkova serrata* | N | N | Y | Y |



Source: NYC Parks (2019). Approved Species List

# Environmental Tolerance

Findings

| Climate Change Impacts | Street Tree Threats | Environmental Tolerances |
|---|---|---|
| Extreme Heat | Increased Risk of Drought | Drought |
| Sea Level Rise | Groundwater Flooding & Salination | Wet<br>Salt |
| Coastal Storm Surge | | |
| Heavy Rainfall & Inland Flooding | Stormwater Runoff & Combined Sewage Overflow | Wet |
| Extreme Winds | Downed Limbs & Uprooted Trees | Wind |



Source: NYC Parks (2019). Approved Species List

# Drought Tolerance

## Findings

| Common Name | Scientific Name | Count | Percent of Total | Drought Tolerant |
|---|---|---|---|---|
| Pin Oak | *Quercus palustris* | 12,343 | 7% | N |
| Littleleaf Linden | *Tilia cordata* | 8,903 | 5% | N |
| Sophora | *Styphnolobium japonicum* | 5,989 | 3% | N |
| Cherry | *Prunus* | 5,706 | 3% | N |
| American Linden | *Tilia americana* | 4,023 | 2% | N |
| Swamp White Oak | *Quercus bicolor* | 2,714 | 2% | N |
| American Elm | *Ulmus americana* | 2,587 | 2% | N |
| Red Maple | *Acer rubrum* | 2,384 | 1% | N |
| Kentucky Coffeetree | *Gymnocladus dioicus* | 1,176 | 1% | N |
| Dawn Redwood | *Metasequoia glyptostroboides* | 1,130 | 1% | N |
| Willow Oak | *Quercus phellos* | 802 | 0% | N |

**30%** Brooklyn Street Trees Lacking Drought Tolerance


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# Wind Tolerance

## Findings

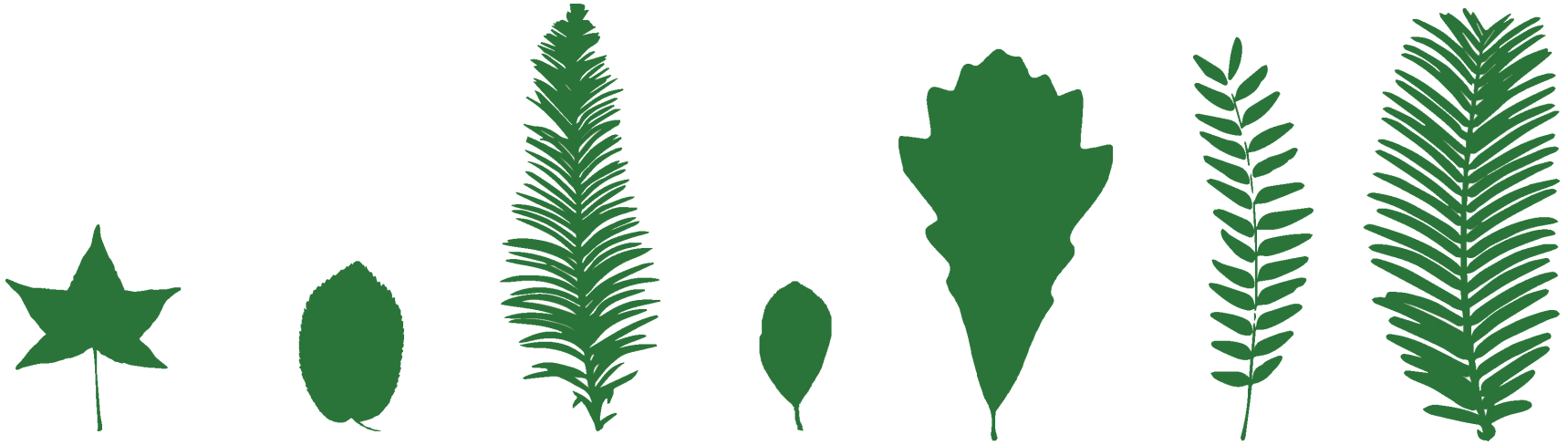
**30%** Brooklyn Street Trees lacking wind tolerance

**19** Wind-tolerant species approved for street tree planting in NYC

| Common Name | Scientific Name | Count | Percent of Total | Wind Tolerant |
|---|---|---|---|---|
| Callery Pear | *Pyrus calleryana* | 9,081 | 5% | N |
| Littleleaf Linden | *Tilia cordata* | 8,903 | 5% | N |
| Cherry | *Prunus* | 5,706 | 3% | N |
| American Linden | *Tilia americana* | 4,023 | 2% | N |
| Green Ash | *Fraxinus pennsylvanica* | 3,808 | 2% | N |
| American Elm | *Ulmus americana* | 2,587 | 2% | N |
| Northern Red Oak | *Quercus rubra* | 2,468 | 1% | N |
| Silver Linden | *Tilia tomentosa* | 2,373 | 1% | N |
| Sweetgum | *Liquidambar styraciflua* | 2,027 | 1% | N |
| Silver Maple | *Acer saccharinum* | 1,375 | 1% | N |
| Purple-leaf Plum | *Prunus cerasifera* | 1,198 | 1% | N |
| Eastern Redbud | Cercis canadensis | 796 | 0% | N |

# Flood Tolerance

## Findings



Sweetgum
*Liquidambar styraciflua*

Serviceberry
*Amelanchier sp.*

Dawn Redwood
*Metasequoia glyptostroboides*

Black Gum
*Nyssa sylvatica*

Swamp White Oak
*Quercus bicolor*

Honeylocust
*Gleditsia triacanthos var. inermis*

Bald Cypress
*Taxodium distichum*

**7** Wet-tolerant tree species approved for street tree planting in NYC

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# Coastal Flood Tolerance

## Findings

**28%** Wet & Salt-tolerant Brooklyn Street Trees

**63%** Brooklyn Street Trees Lacking Flood Tolerance

**7** Wet-tolerant tree species approved for street tree planting in NYC

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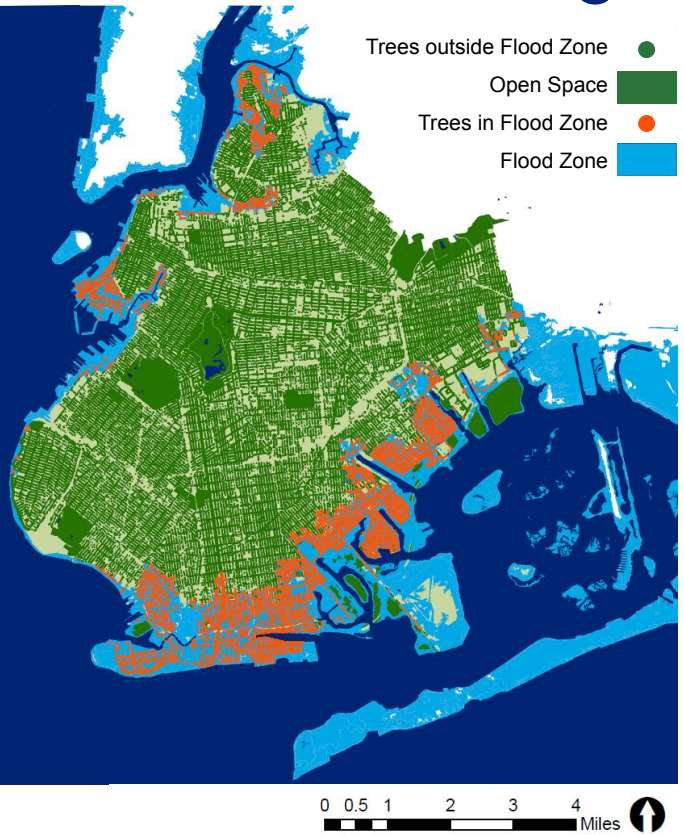
# Street Trees in Flood Zone

## Findings

**26,550** Brooklyn Street Trees in 2050 Flood Zone

**15%** Brooklyn Street Trees facing salt-water flooding

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# Flood Tolerance in Flood Zone

Findings

**70%** Trees intolerant to saltwater flooding in Brooklyn Flood Zone

**18,585**

Potential Tree Mortality due to Sea Level Rise + Storm Surge


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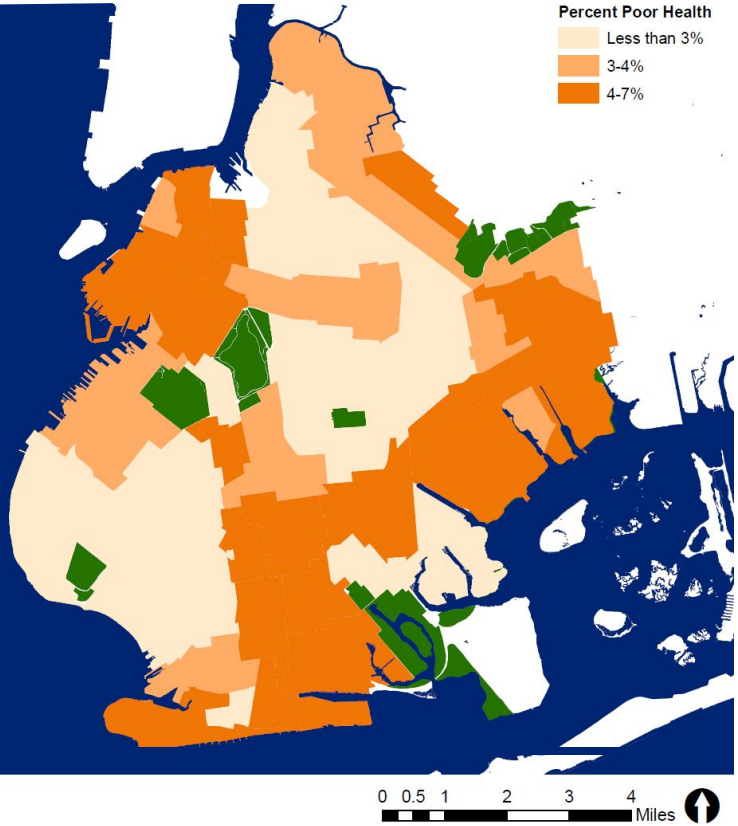
# Tree Health

## Findings

**2x** Dead Street Trees & Stumps (2015) in Hurricane Sandy flood zone (2013)




Source: NYC Parks, 2015

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# Recommendations

# Recommendations

| Climate Change Impacts | Street Tree Threats | Street Tree Adaptation Opportunity |
|---|---|---|
| Extreme Heat | Increased Risk of Drought | Stewardship - Watering, Compost & Mulch Application<br>Design - Expand Tree Pits, Passive Watering (gator bags) |
| Sea Level Rise<br>Coastal Storm Surge | Groundwater Flooding & Salination | Planting - Flood & Salt-Tolerant Species<br>Design - Rain Gardens, Above-Ground Planters<br>Stewardship - Soil Aeration & Compost Application |
| Heavy Rainfall & Inland Flooding | Stormwater Runoff & Combined Sewage Overflow | Planting - Flood-Tolerant Species<br>Design - Expand Tree Pits, Bioswales, Above-Ground Planters<br>Stewardship - Soil Aeration & Compost Application |
| Extreme Winds | Downed Limbs & Uprooted Trees | Planting - Wind-Tolerant Species<br>Design - Expand Tree Pits<br>Stewardship - Pruning |

# Recommendations

## 1. Planting

a. Expand Approved Species List
b. Enact Street Tree Flood Zoning Code
c. Succession Planning for Threatened Mature Trees

## 2. Design

a. Enhance Existing Tree Pits to Increase Stormwater Runoff Capacity
b. Expand Street Green Infrastructure beyond Tree Pits

## 3. Stewardship

a. Prioritize Stewardship using Species-specific Vulnerabilities
b. Mandate Parks Department Composting & Soil Stewardship
c. Institutionalize Stewardship Funding in Capital Budget
d. Invest in community-based stewardship groups in EJ neighborhoods

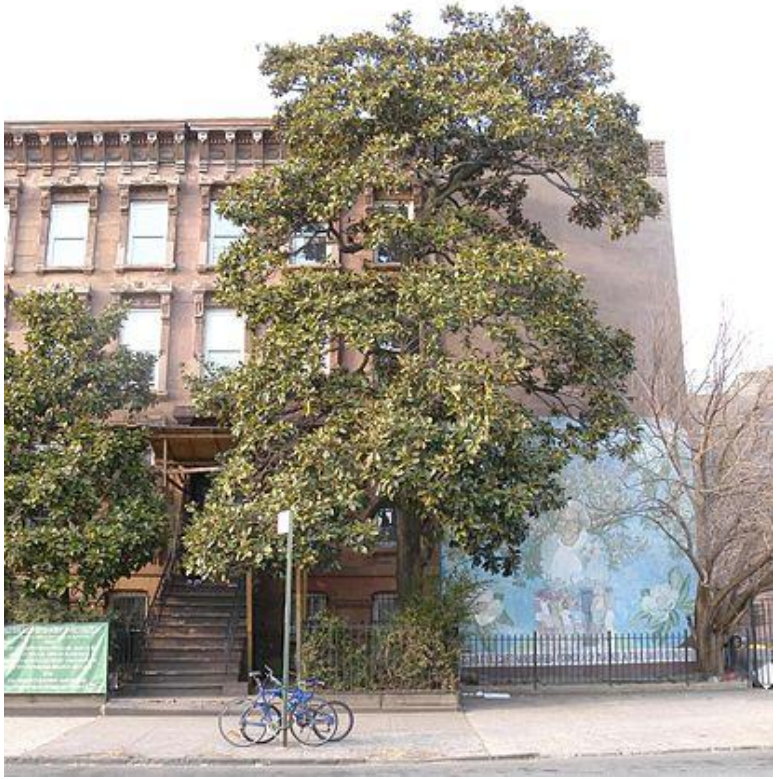
# 1. Planting

# Recommendations

## a. Increase Approved Species

Add species from USDA Growing Zones 7 & 8 to reflect changing climate:

| Common Name | Scientific Name | Growing Zones |
|---|---|---|
| **Southern Magnolia** | *Magnolia grandiflora* | 7-9 |
| **Southern Red Oak** | *Quercus falcata* | 7-9 |
| **Deodar Cedar** | *Cedrus deodara* | 7-8 |
| **Common Persimmon** | *Diospyros virginiana* | 7-10 |
| **Fig** | *Ficus carica* | 7-11 |





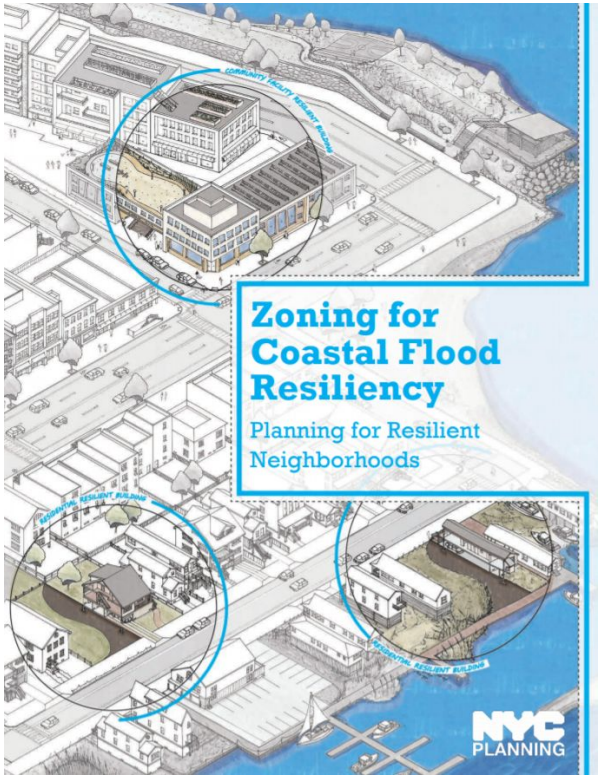
Sources: Jim Henderson via WikiCommons (2009), Casey Trees (2015).

# 1. Planting

Recommendations

## b. Tree Flood Zoning Code

Require all new street tree plantings in flood zone to be species with known saltwater tolerance.

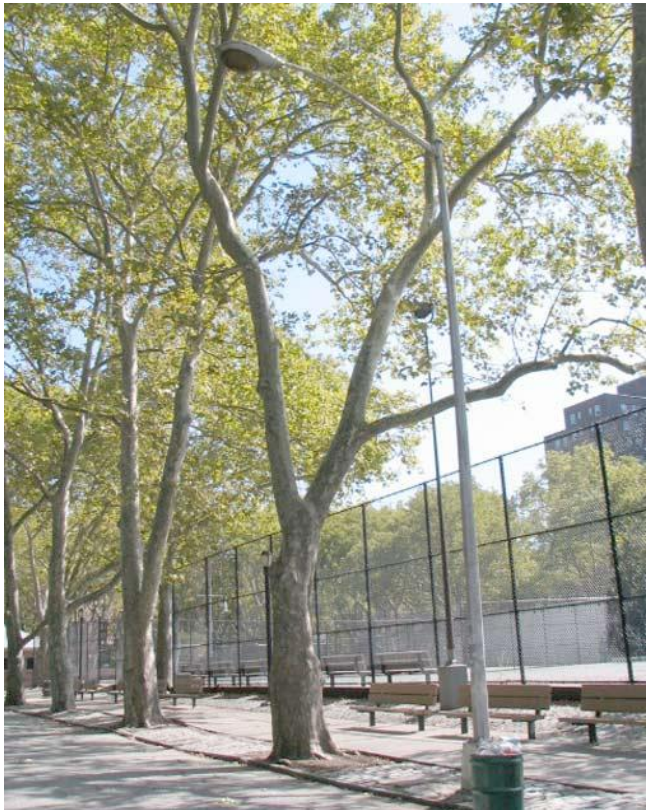


# 1. Planting

Recommendations

## c. Succession Planning

Plant young, climate-resilient tree species between mature at-risk trees before they die.





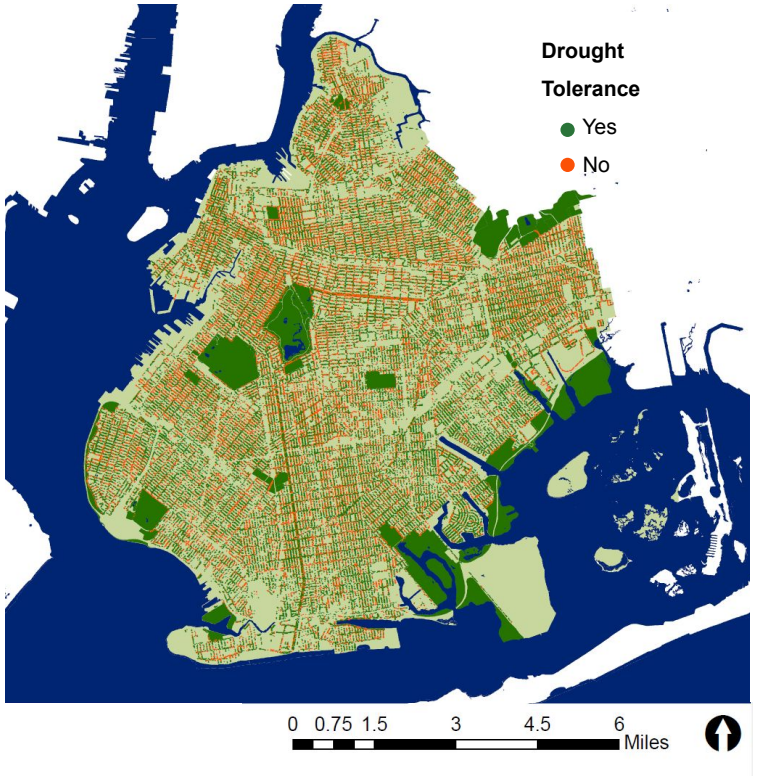
Source: Forgotten New York, 2012

# 3. Stewardship

# Recommendations

## a. Prioritize Stewardship

Use species-specific vulnerabilities and climate threats to identify highest risk trees in high heat vulnerability neighborhoods where stewardship efforts are needed most.



# 3. Stewardship

Recommendations

## b. Mandate Parks Composting & Soil Stewardship

Integrate NYC Parks into Citywide Zero Waste Goals by Mandating all Parks' leaf and yard-waste be composted on parks property. Set target soil stewardship goals to ensure compost is used to improve soil in street tree pits.

# 3. Stewardship

## Recommendations

### c. Institutionalize Stewardship Funding in NYC Capital Budget

Protect planting investments by moving Parks maintenance from General Fund to Capital Budget, reducing risk of budget cuts.



Source: Wall Street Journal, 2020

# 3. Stewardship

Recommendations

## c. Invest in Community-Based Stewardship in Environmental Justice Neighborhoods

Fund community-led green jobs in “Trees for Public Health” neighborhoods where young trees require stewardship to grow into healthy mature trees for the next generation.




Source: Gowanus Canal Conservancy, 2020

# Table of Contents

# Thank you!