The Ecological Resilience Landscape of New York City

A Thesis

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Abstract

Urban ecosystems like urban parks and street trees provide ecosystem services that serve as nature-based solutions to the issues of climate change resiliency and adaptation in cities. Previous research has focused on the nature of ecosystem services and their effects on urban resiliency. However, there has been less studies on understanding how resilient these urban ecosystems themselves are to climate change, and therefore whether they can continue to provide services that cities rely on for well-being.

Plant functional traits have been used to study the impact of climate change on ecosystem functioning and services in a nonurban context. In this study, we extend this traits-based approach to urban contexts and evaluate specific response traits to climate change with an emphasis on heat and drought. Using New York City as a case study, we use street tree species databases in conjunction with species-specific response traits data to spatially analyze the ecological resiliency of the city. This study will inform local resiliency planning and adaptation by identifying areas vulnerable to climate change due to the lack of resiliency traits present.

Introduction

Cities are increasingly responsible for the health and well-being of the majority of the human population. In 1990, 43% of the world's population lived in urban areas (2.3 billion) and in 2015 this has grown to 54% (4 billion).[1] It is projected that by 2050, 66% of the world's population will be urban, an increase in both relative and absolute numbers of urban population.[2] This rapid urbanization poses a challenge for sustainable development of cities that will only be exacerbated by the coming threats of climate change. Climate change resiliency and adaption in cities needs to be at the forefront of urban planning.

Urban ecosystems provide ecosystem services that serve as nature-based solutions to the issues of climate change resiliency and adaptation in cities. Street trees are an urban ecosystem that provide services such as pollution control, climate regulation, storm and waste water management, physical and mental health benefits, wildlife habitats, and scenic beauty.[3][4][5] These services are important for climate change resiliency of cities and have been studied extensively. However, there has been less studies on understanding how resilient street trees themselves are to climate change. Without proper studies on tree resiliency that can inform sustainability planning, problems arise for the city infrastructure and limits the potential ecosystem services that the city relies on for well-being.[6]

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[1] World Cities Report 2016: Urbanization and Development. (2016). Retrieved from https://unhabitat.org/books/world-cities-report/
[2] ibid
[3] Akbari, H., Pomerantz, M., & Taha, H. (2001). *Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas*doi://doi.org/10.1016/S0038-092X(00)00089-X
[4] Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., . . . Van, D. B. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*(6630), 253-260. doi:10.1038/387253a0
[5] Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: The role of the green infrastructure. *Built Environment (1978-), 33*(1), 115-133. doi:10.2148/benv.33.1.115
[6] Pretzsch, H., Biber, P., Uhl, E., Dahlhausen, J., Rötzer, T., Caldentey, J., . . . Pauleit, S. (2015). Crown size and growing space requirement of common tree species in urban centres, parks, and forests. *Urban Forestry & Urban Greening, 14*(3), 466-479. doi:10.1016/j.ufug.2015.04.006

Plant functional traits have been used to study the impact of climate change on ecosystem functioning and services in a nonurban context.[7][8][9][10] In this study, I will use a traits-based approach in an urban context to evaluate specific response traits to climate change with an emphasis on heat, drought, and extreme weather events. Using New York City as a case study, I combine street tree species databases with species-specific response traits data to spatially analyze the ecological resiliency of the city. This study will inform local resiliency planning and adaptation by identifying areas vulnerable to climate change due to the lack of resiliency traits present.

Methodology

Case Study: New York City

The climate of New York City (NYC) is experiencing changes- annual temperatures are increasing, storm surges are more frequent and intense, and the sea level is rising.[11] These patterns will continue to worsen due to the increasing concentration of greenhouse gases (GHG) in the atmosphere. For these reasons, the climate change factors that I look at for NYC are heat and storm

[7] Adler, P., Salguero-Gómez, R., Compagnoni, A., Hsu, J., Ray-Mukherjee, J., Mbeau-Ache, C., & Franco, M. (2014). Functional traits explain variation in plant life history strategies. *Proceedings of the National Academy of Sciences of the United States of America, 111*(2), 740. doi:10.1073/pnas.1315179111

[8] Kraft, N. J. B., Crutsinger, G. M., Forrestel, E. J., & Emery, N. C. (2014). Functional trait differences and the outcome of community assembly: An experimental test with vernal pool annual plants. *Oikos, 123*(11), 1391-1399. doi:10.1111/oik.01311

[9] Soudzilovskaia, N., Elumeeva, T., Onipchenko, V., Shidakov, I., Salpagarova, F., Khubiev, A., . . . Cornelissen, J. (2013). Functional traits predict relationship between plant abundance dynamic and long-term climate warming. *Proceedings of the National Academy of Sciences of the United States of America, 110*(45), 18180. doi:10.1073/pnas.1310700110

[10] Skelton, R., West, A., & Dawson, T. (2015). Predicting plant vulnerability to drought in biodiverse regions using functional traits. *Proceedings of the National Academy of Sciences of the United States of America, 112*(18), 5744. doi:10.1073/pnas.1503376112

[11] IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer

surges (wind and heavy precipitation). I also look at drought because urban environments in general experience harsher droughts than nonurban ones and the droughts will become more severe with hotter climates.[12]

Trait data

I assembled a matrix of 8 traits based on the climate change factors of heat, drought, and storm surges (Table 1) for NYC's top 14 tree species. In order to figure out what the top 14 tree species were, I used the NYC open data Street Tree Census file and using R, arranged the dataset in terms of highest to lowest tree count. I removed *Prunus,* although it ranked #7 for most common street tree, it is a genus name and not a species so I removed it from the analysis. The trees used in the study are responsible for 72% of all of NYC's street trees.

To find the relevant traits, I conducted a literature review on what traits are most tolerant to heat, drought, and storm surges. Studies that I included are a mixture of urban and nonurban trees, park and forest trees. I used the TRY and Citree databased to extract quantitative data for the traits. I used the University of Florida Environmental Horticulture database to extract qualitative data. Some traits that were found extremely relevant to climate change did not have values or descriptions in any database: root depth, leaf density, wood fiber wall thickness, wood vessel density, and photosynthetic water use efficiency. "Wood density" and "plant woodiness" were used as proxies for wood thickness. University of Florida had conflicting results with the Citree

[12] Scheuer S, Haase D, Volk M (2017) Integrative assessment of climate change for fast-growing urban areas: Measurement and recommendations for future research. PLOS ONE 12(12): e0189451. https://doi.org/10.1371/journal.pone.0189451

database in terms of qualitative data, but Citree was chosen over because it was the more recent data.

Spatial and Statistical analysis

I created rankings for the traits using Jenks Natural Breaks. All traits are weighted the same. Traits with high tolerance (read: resiliency) are allocated number 3, traits with medium are allocated 2, and traits with low are allocated 1. All the individual traits were added and scored on a climate change resilience index. I then created an index just for drought resilient traits, using the traits: drought tolerance, plant woodiness, wood density, and leaf area to dry mass ration (SLA). I also did so for heat: leaf thickness, height, and heat tolerance; and storm surges: SLA, plant woodiness, wood density, height, spread, breakage, and pest resistance. Please see Appendix for in depth description of traits and references. Note: The indices are not additive since certain traits are relevant for more than one climate change factor.

I then used ArcGIS online to map the resiliency indices created from the scoring. . I put anything under 0.55 as low ranking, 0.55-0.7 as medium, and > 0.7 as high. I overlaid the storm surges map with flood zones. I overlaid the heat indices map with a heat map.

Results

Trait data

The tree species used in the analysis make up 72% of all street trees in NYC (466905 trees) (see Figure 1 and 2).

There are 8 traits used in this analysis for climate change resiliency (Figure 3). There are 4 traits for drought resiliency, 3 traits for heat resiliency, and 6 traits for storm surge resiliency (Tables 2-4).

The top tree species in NYC are relatively good at drought and heat resiliency, and relatively poor at storm surge resiliency (See Figures 4-6).

For climate change resiliency, the highest scored species is Pyrus calleryana (ranked 3rd most common tree) and the lowest scored is Styphnolobium japonicum (ranked 9 most common), with most trees higher than 0.55 (the low threshold).

For drought resiliency, the highest is Pyrus calleryana and the lowest is Quercus palustris (ranked 4th most common), with most trees higher than 0.55.

For heat resiliency, the highest is Pyrus calleryana and the lowest is Acer platanoides (ranked 5 most common), with the majority of trees higher than 0.55 but a fair amount scoring 0.55.

For storm surge resiliency, the highest is Pyrus calleryana and the lowest is Platanus x acerifolia (ranked 1st most common tree). The majority scored higher than 0.55 here as well.

Spatial and Statistical analysis

Lower Brooklyn and upper Queens seem to be relatively vulnerable to climate change resiliency in terms of street trees (Map 1).

Generally, NYC trees are well adapted to drought. However, some trees are more adapted than others. There does not seem to be any particularly vulnerable areas in terms of drought resilience (Map 2).

The heat resiliency map demonstrates areas of vulnerability: lower Brooklyn, deep Queens, and Staten Island (Map 3). The heat map also demonstrates these areas have relatively warmer temperatures (Map 5).

Unlike the drought and heat maps that suggest a adequate level of resiliency, the storm surge map demonstrates that there are a lot of vulnerable areas that are in need of attention to climate change adaption.

Discussion

Results analysis

The drought and heat resiliency maps do not show anything out of the ordinary- traits suggest that the trees in NYC are well adapted to those conditions. This is perhaps because urban conditions tend to be hotter (urban heat island effect) and drier than nonurban conditions and therefore trees chosen to be planted in urban areas exhibit resiliency for these environments.[13][14][15] It is important to keep in mind that trees that exhibit better resiliency to these conditions than others (Pyrus calleryana versus Tilia americana) should be promoted because these conditions will only be getting worse.[16] It is important to mention it is not recommended to plant only the most resilient

[13] Oke, T. R. (1988). The urban energy balance. *Progress in Physical Geography, 12*(4), 471-508. doi:10.1177/030913338801200401

[14] Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Boone, C. G., Groffman, P. M., Irwin, E., . . . Warren, P. (2011). Urban ecological systems: Scientific foundations and a decade of progress. *Journal of Environmental Management, 92*(3), 331-362. doi:10.1016/j.jenvman.2010.08.022

[15] Jochner, S., & Menzel, A. (2015). Urban phenological studies - past, present, future. *Environmental Pollution, 203*, 250.

[16] IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer

species but the most resilient species (plural) in order to maintain biodiversity, which is extremely important for resiliency.[17]

It is intriguing to analyse the resiliency of NYC's street trees to storm surges in the final map (Map 4). As mentioned above, NYC will experience an increase in sea level rise and coastal flooding frequency from storms; however, the results from map 5 suggest that the trees do not have a strong capacity to adapt to these extreme events. This perhaps makes sense because these events are not an urban phenomenon, and until recently due to climate change the frequency and intensity of these events were not cause for alarm. NYC needs to take the threat of extreme events seriously and better prepare the city to withstand the coming threats.

Assumptions and limitations

This study was a pilot project because a proper framework had not be established prior and time was a limiting factor. However, at the end, a framework was developed that could be undertaken in a next phase and results demonstrate that focus needs to be given to the study of ecological resiliency. I will list some important limitations and assumptions that need to be taken into consideration for future studies.

1. This study looked at morphological traits. This is because physiological trait data is less accessible and would require more time and expertise to analyse for the trait species selected. This lacking of physiological trait data does weaken the study because plants adapt to environmental conditions in a morphological as well as physiological way.

[17] Kowarik, I. (2011). Novel urban ecosystems, biodiversity, and conservation. *Environmental Pollution, 159*(8), 1974-1983. doi:10.1016/j.envpol.2011.02.022

2. Some traits had conflicting effects; for example: wood density is a positive trait for storm surge resilience as well as a negative trait in case flexibility was not taken into account. Data on flexibility was lacking and since more studies suggested it was a resilient trait, that is how I scored it. Another example is tree height: tall trees show resiliency to warmer temperatures and less resiliency to storm surges. Proper threshold data on a middle ground of resiliency could be useful to combat the opposing effects.
3. Quantitative data on roots was significantly lacking from the databases. This is a huge weak point because root depth is an important trait for all three environmental resiliency adaptations.
4. The literature review conducted to select climate change important traits included majority nonurban studies and assumptions were made that tree species in an urban context behaved similarly. This is because there is a general lack of street tree/urban tree functional trait literature.
5. The databases have missing data on units and methods of data collection, weakening the validity of their data.
6. Finally, in order to have a fully encompassing ecological resiliency map and database, not just functional traits need to be considered but the site in which the trees are planted as well. Soil conditions, pavement, and infrastructure play a part in tree resiliency.

Conclusion

This explorative study produced a strong framework and pointed out limitations in the research of ecological resiliency of street trees. Results demonstrated that the city of New York needs to allocate attention to the climate change resiliency of certain vulnerable areas (lower Brooklyn, Queens) as well as a storm surge resiliency throughout the city.

I would like to say a special thank you to my supervisor, Timon McPhearson, whom's guidance helped me throughout the project, as well as the general team at the Urban Systems Lab.

Appendix:

Graphs

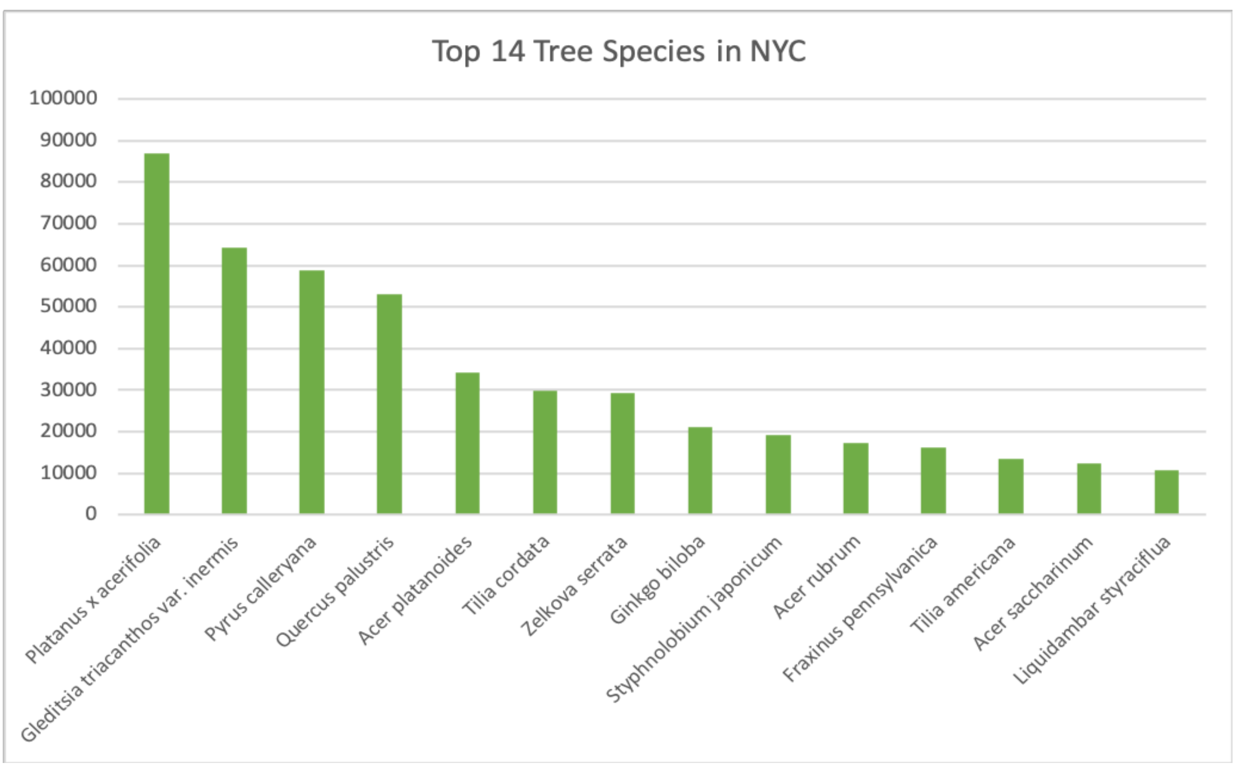


Figure 1: Bar graph of top 14 species (excluding Prunus genus)

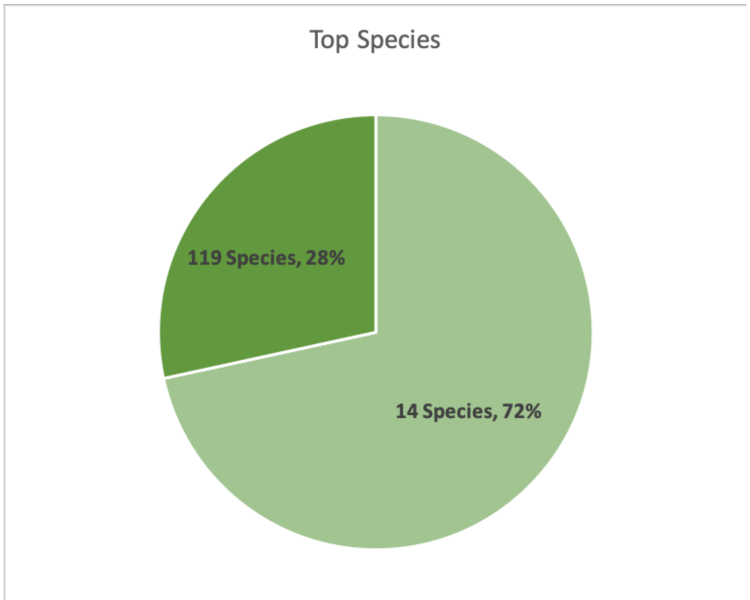


Figure 2: Pie chart of the top 14 species compared to the other 119 species

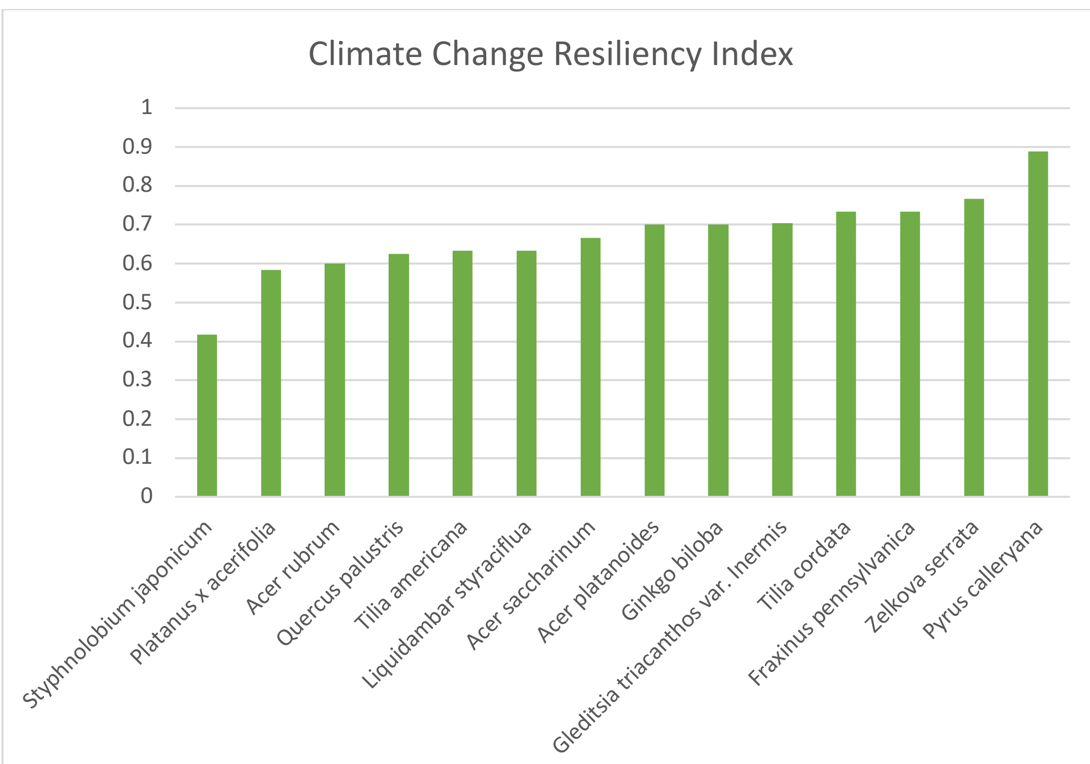


Figure 3: Bar graph of climate change resilient tree species

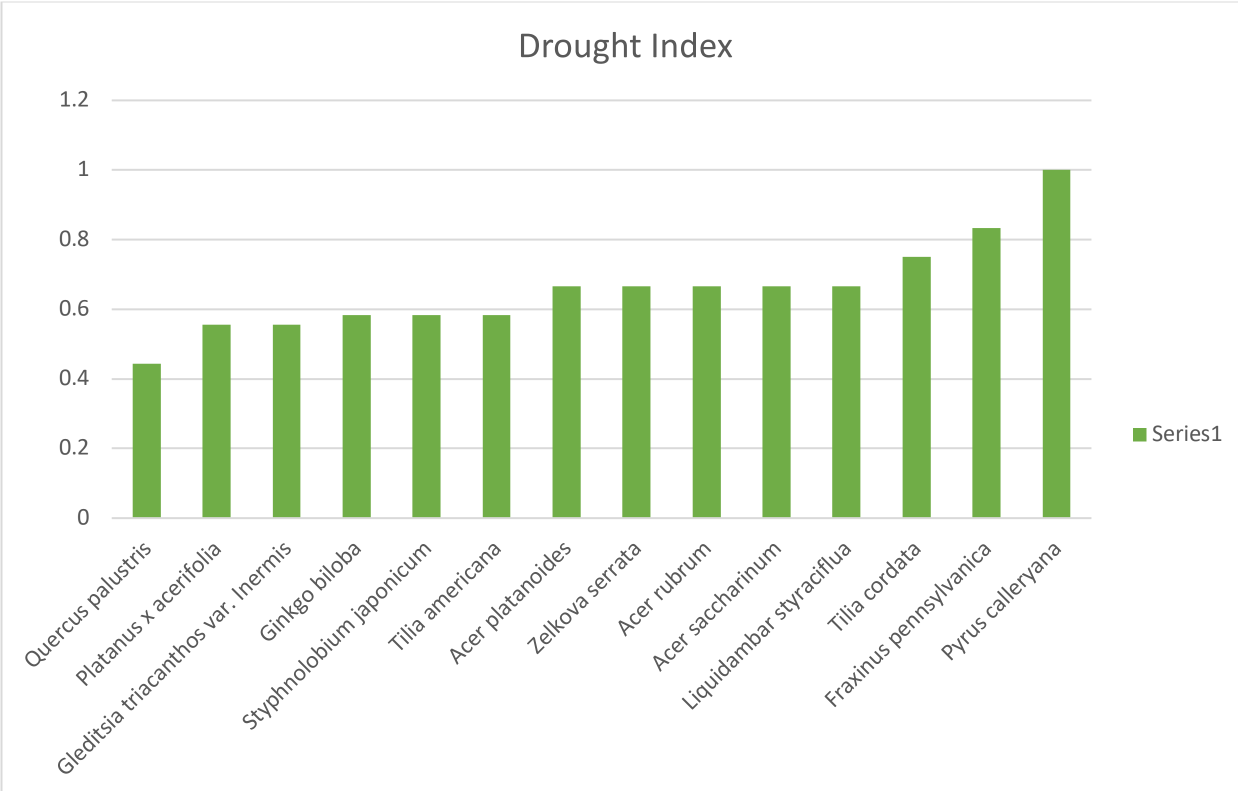


Figure 4: Bar graph of drought resilient tree species

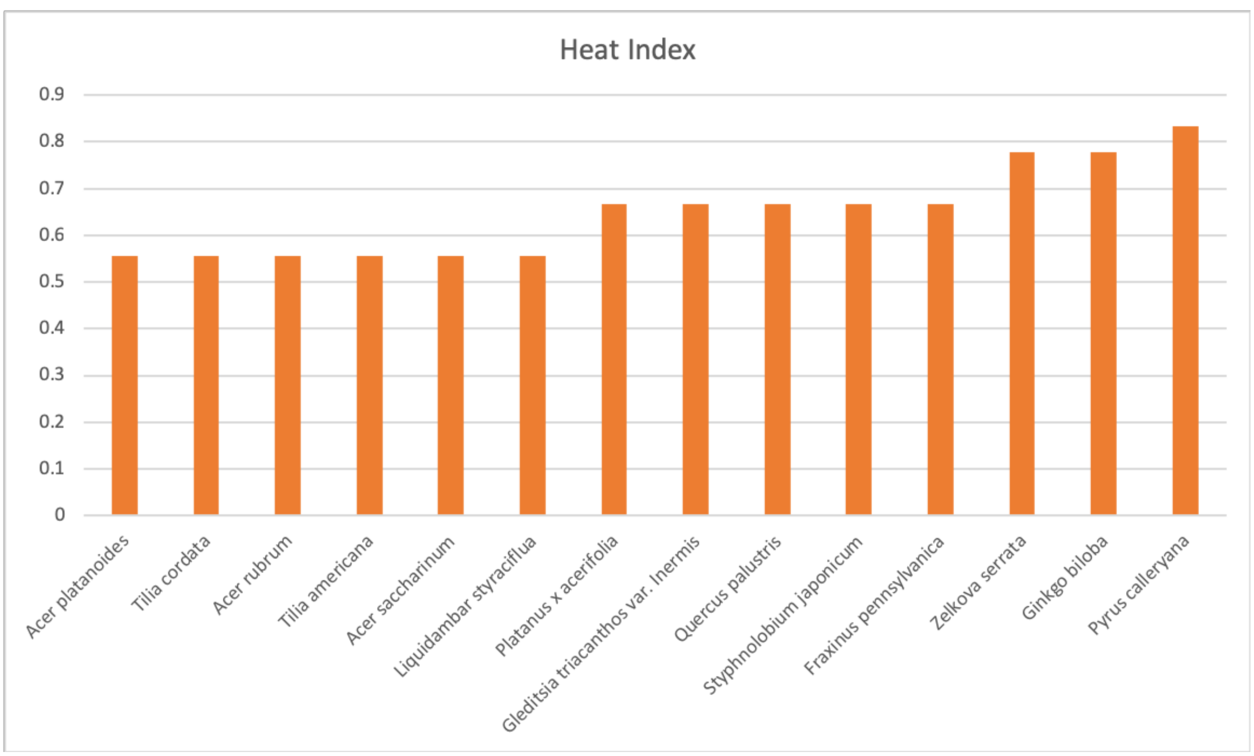


Figure 5: Bar graph of heat resilient tree species

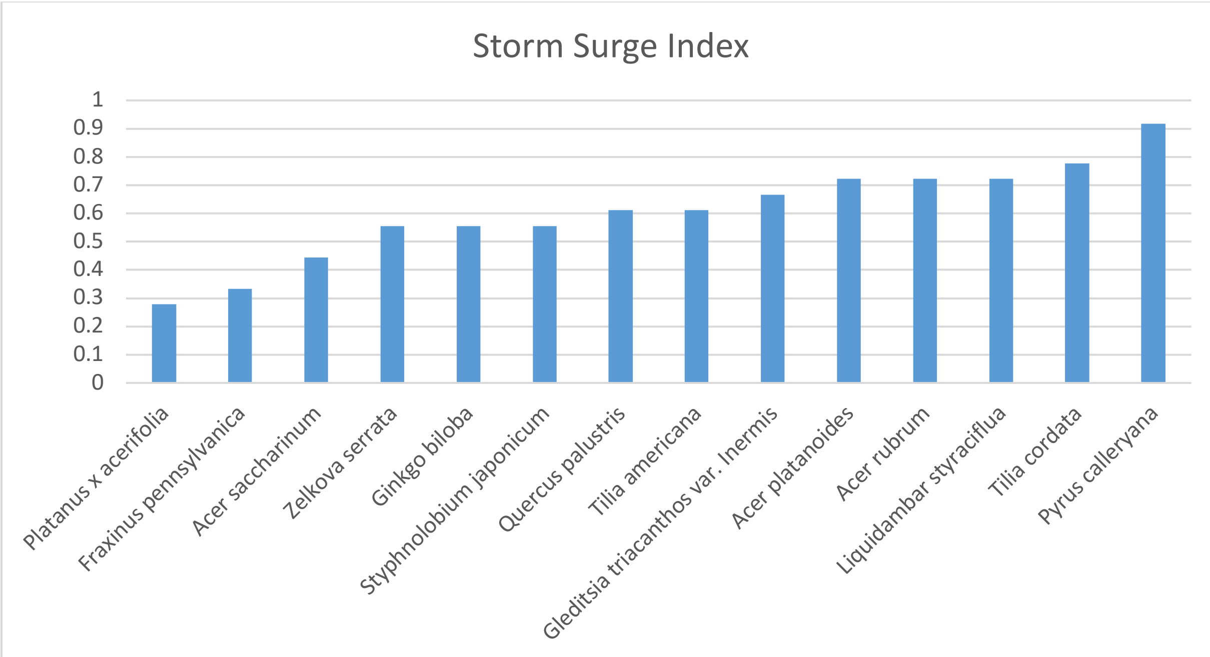


Figure 6: Bar graph of storm surge resilient tree species

Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	Column10	Column11	Column12	Column13	Column14
Traits	Leaf area per leaf dry mass (SLA or 1/LMA): undefined if petiole and rachis are in- or excluded (RATIO)	Leaf Thickness (LENGTH UNIT)	Stem dry mass per stem fresh volume (stem specific density, SSD, wood density) (Wood density PROXY)	Plant Woodiness (PROXY)	Height	spread	Drought Tolerant	Heat Tolerant	Breakage	Pest resistance	score	/total	Ratio
Species													
Platanus x acerifolia	NA	NA	1	1	1	1	3	3	3	1	14	24	0.583333333
Gleditsia triacanthos var. Inermis	NA	1	1	1	2	2	3	3	3	3	19	27	0.703703704
Pyrus calleryana	NA	NA	NA	NA	3	3	3	2	3	2	16	18	0.888888889
Quercus palustris	NA	NA	1	1	2	2	2	2	2	3	15	24	0.625
Acer platanoides	2	2	2	2	1	2	2	2	3	3	21	30	0.7
Tilia cordata	2	2	3	2	1	2	2	2	3	3	22	30	0.733333333
Zelkova serrata	3	2	1	1	2	1	3	3	2	3	23	30	**0.766666667**
Ginkgo biloba	2	3	1	1	1	1	3	3	3	3	21	30	0.7
Styphnolobium japonicum	1	NA	2	1	2	1	3	NA	1	3	10	24	**0.416666667**
Acer rubrum	1	3	2	3	1	3	2	1	1	3	18	30	**0.6**
Fraxinus pennsylvanica	3	1	1	3	2	1	3	3	2	1	22	30	**0.733333333**
Tilia americana	2	2	1	2	1	2	2	2	2	3	19	30	0.633333333
Acer saccharinum	3	2	1	1	1	1	3	2	1	3	20	30	**0.666666667**
Liquidambar styraciflua	1	1	1	3	1	2	3	3	3	3	19	30	**0.633333333**

Table 1: Traits matrix for climate change resiliency

Traits	Leaf area per leaf dry mass (SLA or 1/LMA): undefined if petiole and rachis are in- or excluded (RATIO)	Stem dry mass per stem fresh volume (stem specific density, SSD, wood density) (Wood density PROXY)	Plant Woodiness (PROXY)	Drought Tolerant	grade	total	score
Species							
Platanus x acerifolia	NA	1	1	3	5	9	0.55555556
Gleditsia triacanthos var. Inermis	NA	1	1	3	5	9	0.55555556
Pyrus calleryana	NA	NA	NA	3	3	3	1
Quercus palustris	NA	1	1	2	4	9	0.44444444
Acer platanoides	2	2	2	2	8	12	0.66666667
Tilia cordata	2	3	2	2	9	12	0.75
Zelkova serrata	3	1	1	3	8	12	0.66666667
Ginkgo biloba	2	1	1	3	7	12	0.58333333
Styphnolobium japonicum	1	2	1	3	7	12	0.58333333
Acer rubrum	1	2	3	2	8	12	0.66666667
Fraxinus pennsylvanica	3	1	3	3	10	12	0.83333333
Tilia americana	2	1	2	2	7	12	0.58333333
Acer saccharinum	3	1	1	3	8	12	0.66666667
Liquidambar styraciflua	1	1	3	3	8	12	0.66666667

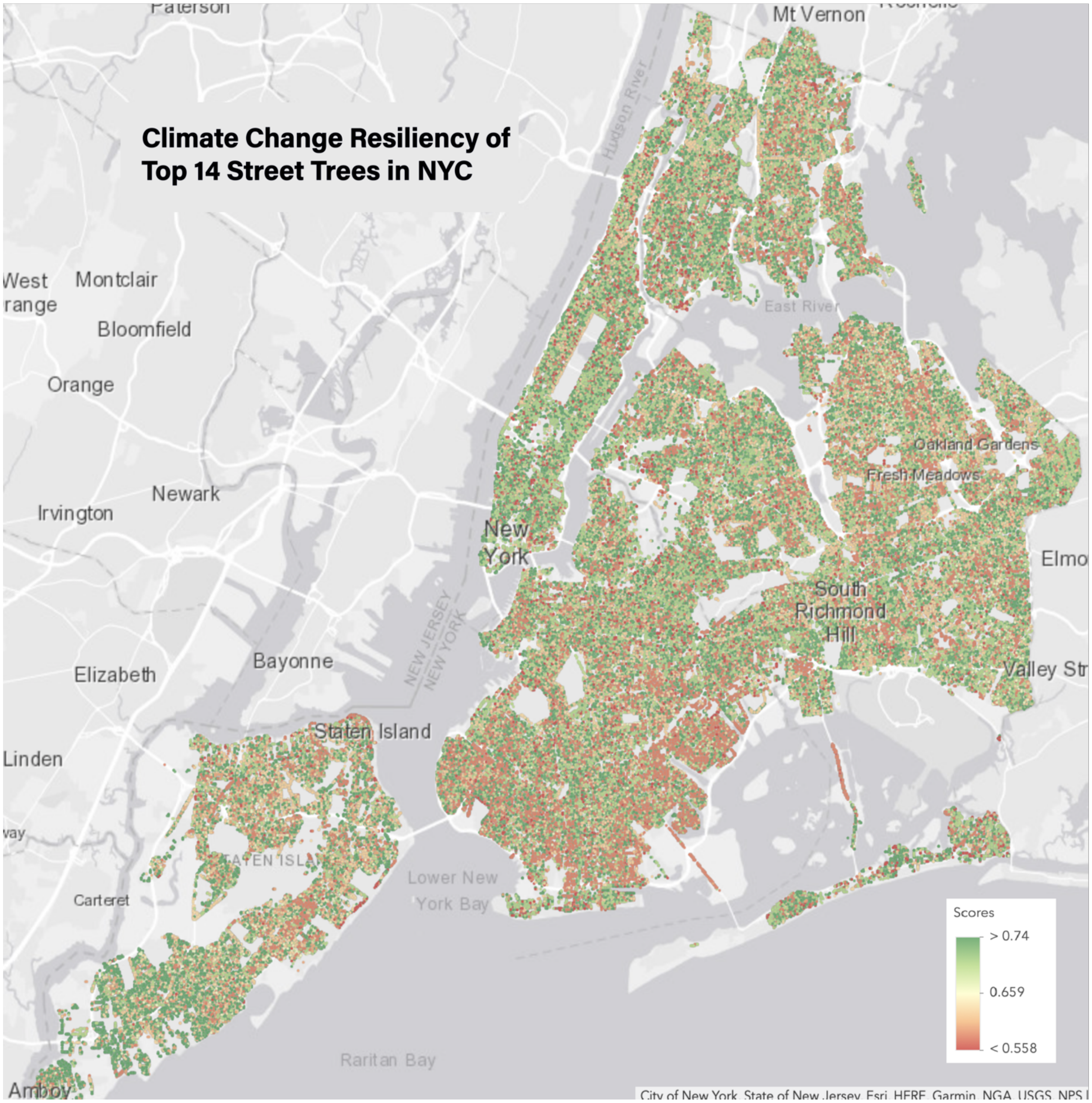
Table 2: Traits matrix for drought resiliency

Column1	Column2	Column3	Column4	Column5	Column6	Column7
Traits	**Leaf Thickness (LENGTH UNIT)**	**Height**	**Heat Tolerant**	**score**	**/total**	**Ratio**
Species						
Platanus x acerifolia	NA	1	3	4	6	0.66666667
Gleditsia triacanthos var. Inermis	1	2	3	6	9	0.66666667
Pyrus calleryana	NA	3	2	5	6	0.83333333
Quercus palustris	NA	2	2	4	6	0.66666667
Acer platanoides	2	1	2	5	9	0.55555556
Tilia cordata	2	1	2	5	9	0.55555556
Zelkova serrata	2	2	3	7	9	0.77777778
Ginkgo biloba	3	1	3	7	9	0.77777778
Styphnolobium japonicum	NA	2	NA	2	3	0.66666667
Acer rubrum	3	1	1	5	9	0.55555556
Fraxinus pennsylvanica	1	2	3	6	9	0.66666667
Tilia americana	2	1	2	5	9	0.55555556
Acer saccharinum	2	1	2	5	9	0.55555556
Liquidambar styraciflua	1	1	3	5	9	0.55555556

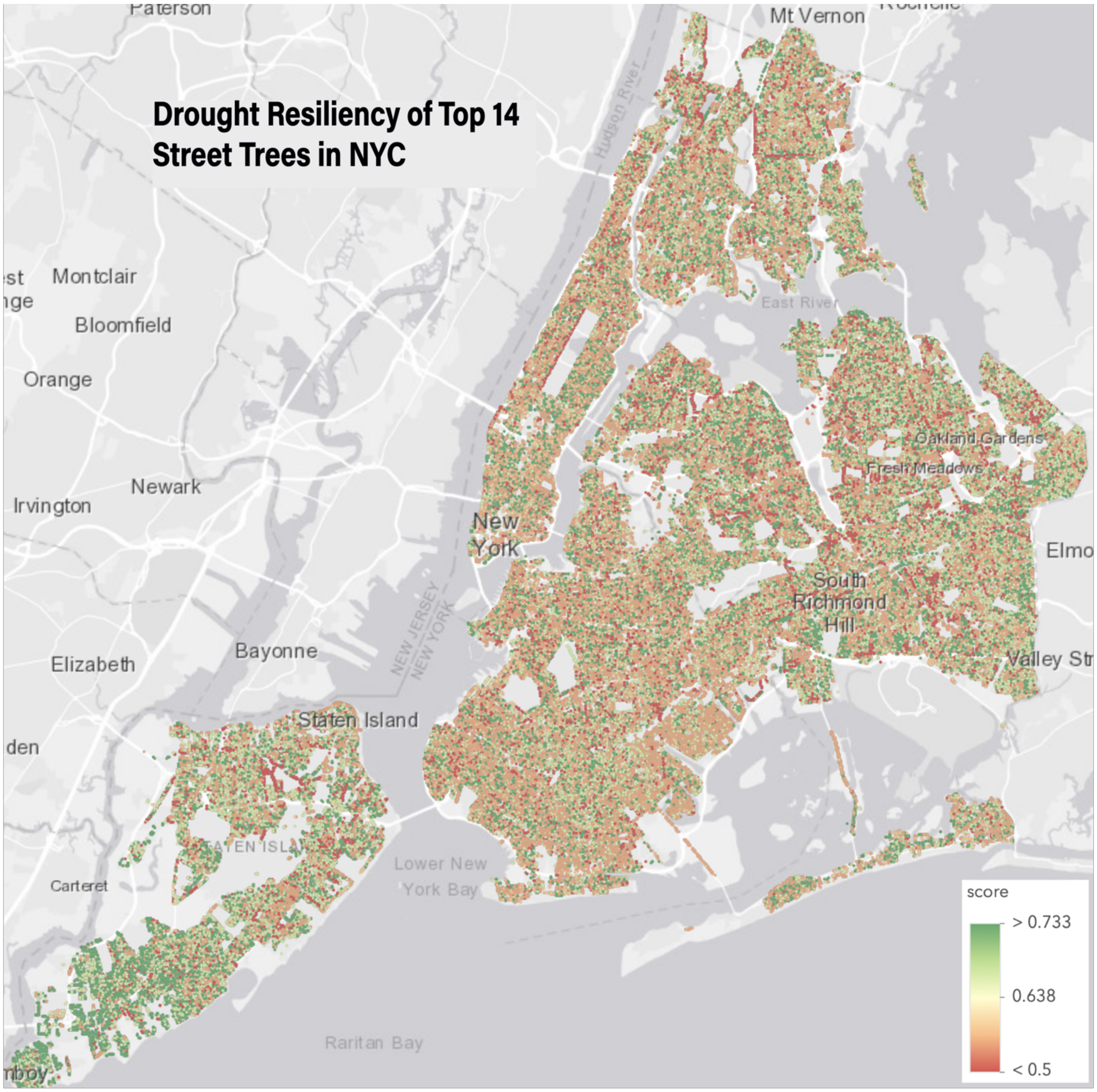
Table 3: Trait matrix for heat resiliency

Traits	Stem dry mass per stem fresh volume (stem specific density, SSD, wood density) (Wood density PROXY)	Plant Woodiness (PROXY)	Height	spread	Breakage	Pest resistance	Score	/Total	Ratio
Species									
Platanus x acerifolia	1	1	1	1	3	1	5	18	0.27777778
Gleditsia triacanthos var. Ir	1	1	2	2	3	3	12	18	0.66666667
Pyrus calleryana	NA	NA	3	3	3	2	11	12	0.91666667
Quercus palustris	1	1	2	2	2	3	11	18	0.61111111
Acer platanoides	2	2	1	2	3	3	13	18	0.72222222
Tilia cordata	3	2	1	2	3	3	14	18	0.77777778
Zelkova serrata	1	1	2	1	2	3	10	18	0.55555556
Ginkgo biloba	1	1	1	1	3	3	10	18	0.55555556
Styphnolobium japonicum	2	1	2	1	1	3	10	18	0.55555556
Acer rubrum	2	3	1	3	1	3	13	18	0.72222222
Fraxinus pennsylvanica	1	1	1	1	1	1	6	18	0.33333333
Tilia americana	1	2	1	2	2	3	11	18	0.61111111
Acer saccharinum	1	1	1	1	1	3	8	18	0.44444444
Liquidambar styraciflua	1	3	1	2	3	3	13	18	0.72222222

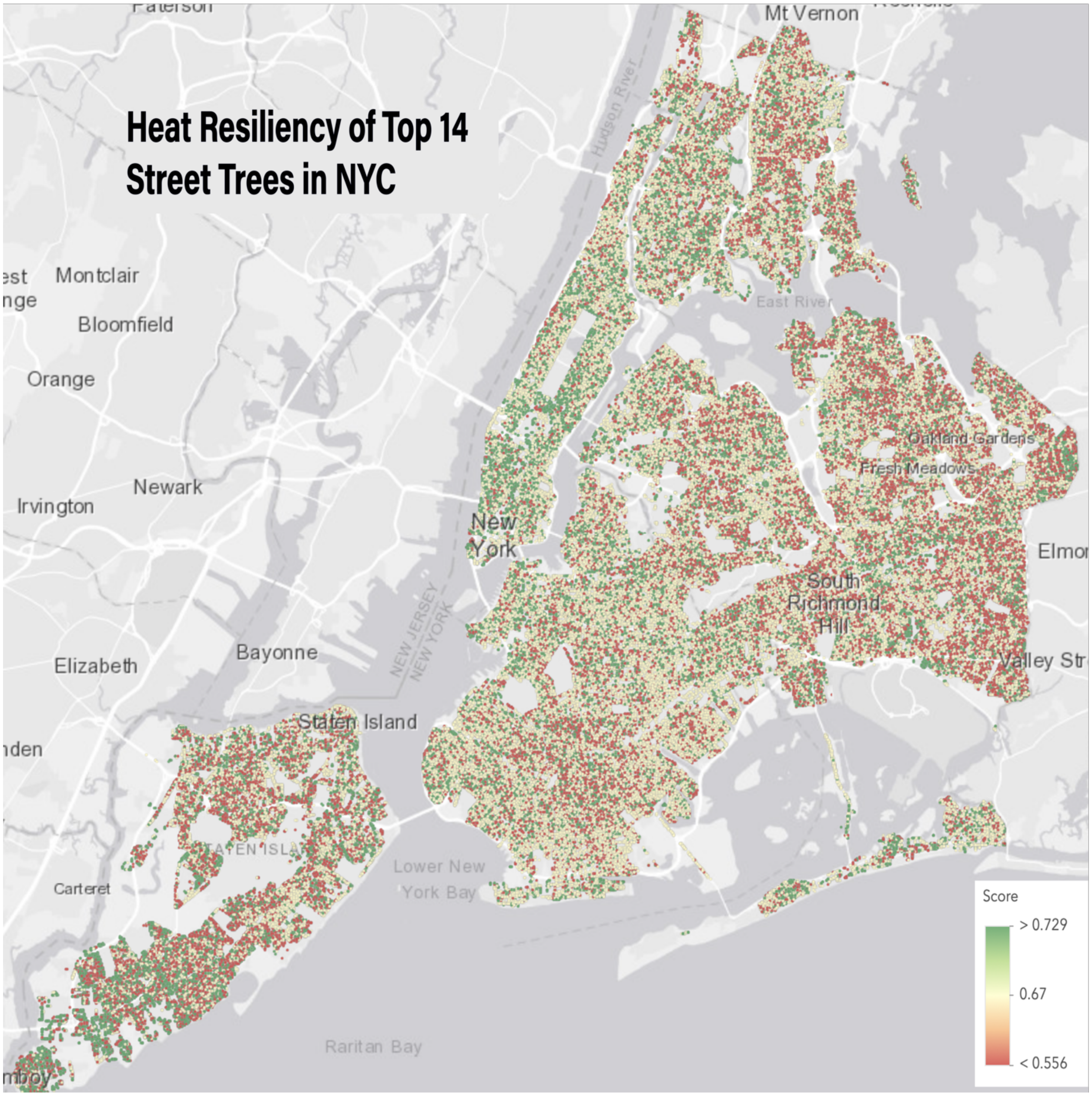
Table 4: Trait matrix for storm surge resiliency



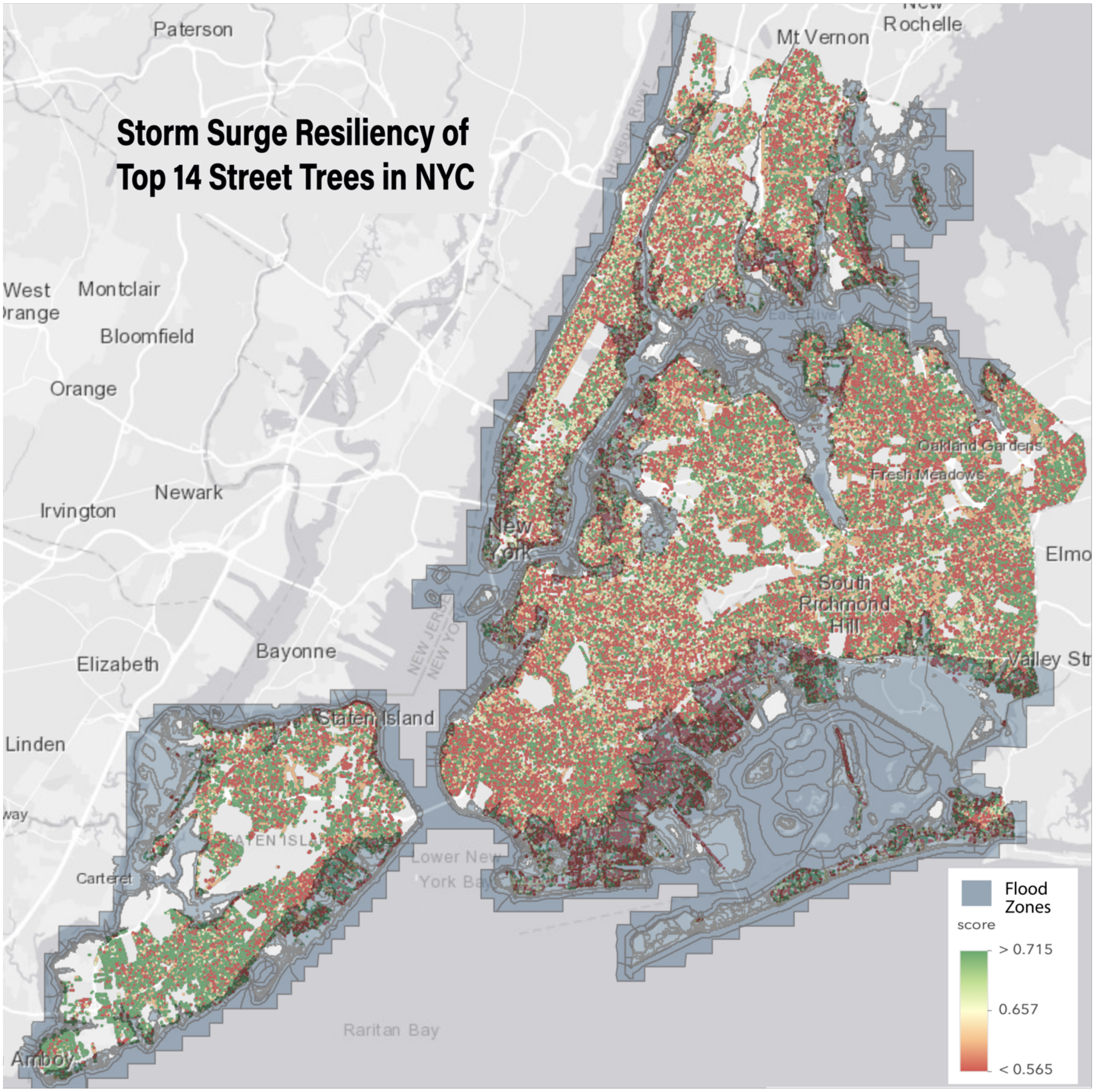
Map 1: Climate Change Resiliency of Top 14 Species in NYC



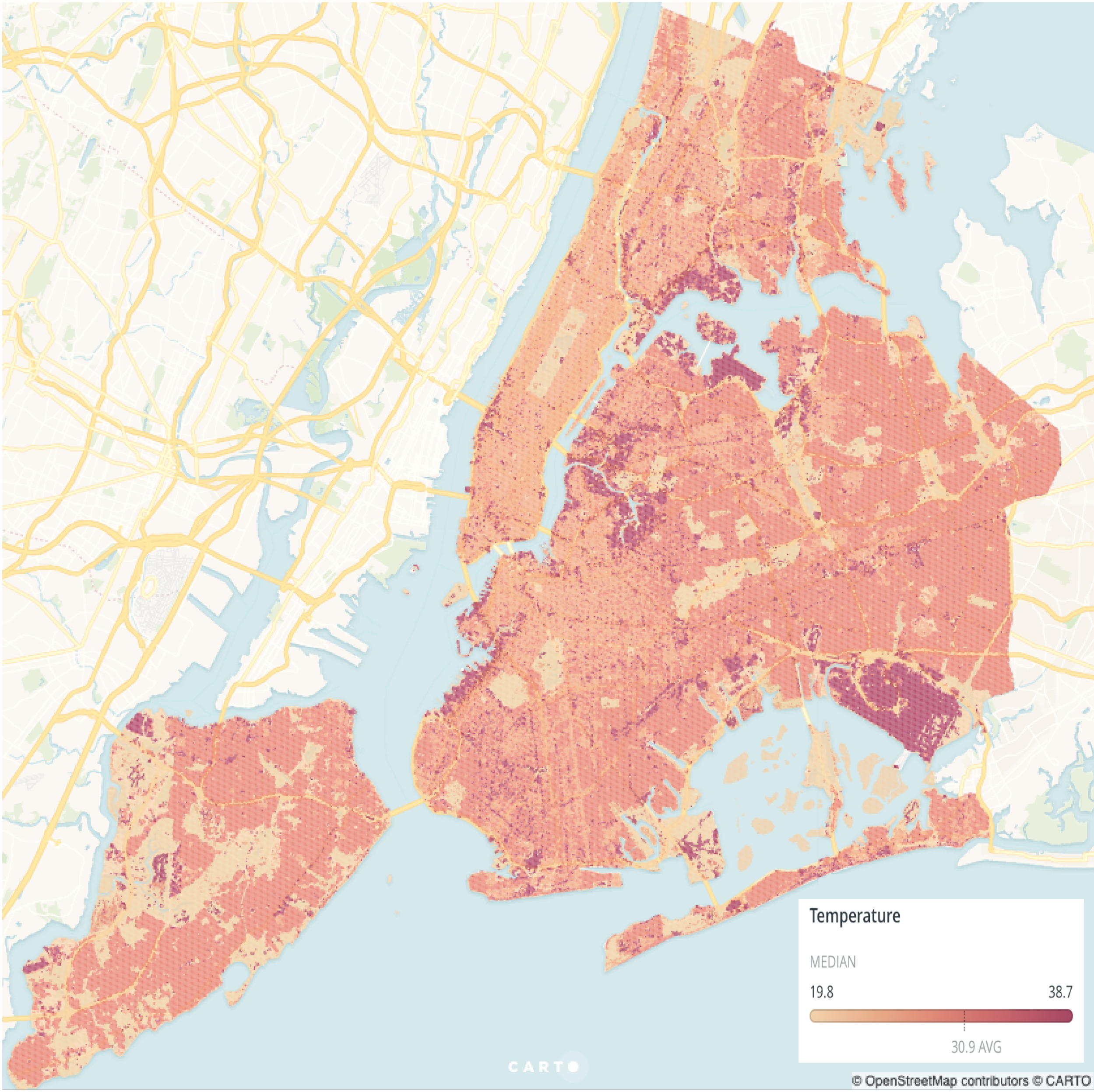
Map 2: Drought Resiliency of Top 14 Species in NYC



Map 3: Heat Resiliency of Top 14 Species in NYC



Map 4: Storm Surge Resiliency of Top 14 Species in NYC



Map 5: Heat Map

Traits

Wood density

This trait is the wood density of the tree. Studies suggests that drought will select for denser wood tree species because this trait provides increased physical support and that facilitates water movement.[18] Studies demonstrate that in forest ecosystems, denser wood trees do adapt better to drought for this reason.[19][20]

Woodiness

This trait is how much wood to stem does the tree have. The more wood to stem more resilient, for the same reason as the above.

Height and Spread

These traits are tree height and crown spread. Tall trees are more likely to suffer wind damage and be uprooted, especially if the crown spread is wide. Storm surges will select for shorter trees with deeper roots and a less top heavy crown.[21] However, studies demonstrate that taller trees have a better capacity to tolerate warmer climates.[22]

Leaf area to dry mass (SLA)

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[18] O'Brien, M. J., et al. (2017). A synthesis of tree functional traits related to drought-induced mortality in forests across climatic-zones. *J. Appl. Ecol.*: 1–18

[19] Hacke, U. G., et al. (2001). Trends in wood density and structure are linked to prevention of xylem implosion by negative pressure. *Oecologia* 126 (4): 457–461;

[20] Greenwood, S.,et al. (2017). Tree mortality across biomes is promoted by drought intensity, lower wood density and higher specific leaf area. *Ecol. Letters* 20 (4), 539–553;

[21]Paz, H., Vega-Ramos, F., & Arreola-Villa, F. (2018). Understanding hurricane resistance and resilience in tropical dry forest trees: A functional traits approach doi://doi-org.libproxy.newschool.edu/10.1016/j.foreco.2018.03.052

[22] Guittar, J., et al. (2016). Can trait patterns along gradients predict plant community responses to climate change? *Ecology* 97 (10): 2791– 2801

This trait is the ratio of a leaf's area to its dry mass. Lower SLA means thicker leaves with higher carbon investment. Drought selects for lower SLA because it increases water loss resistance.[23]

Pest resistance

This trait refers to the trees susceptibility to infection and pests. Trees with healthier and less porous wood are less susceptible to breakage. Pests increase the liklihood of a trunk to decay and wood to be feeble and weak.

Breakage resistance

This trait refers to how easily the tree branches break. The more easily the tree breaks, the less resistant to wind throw and storm surges.

Leaf thickness

This trait refers to the thickness of the leaf. Just as the rational for lower SLA, thicker leaves are more resilient to water loss. Additionally, studies demonstrate that thicker leaves are also better equipped to handle increases in temperature.[24]

Tree Species

Platanus Acerifolia

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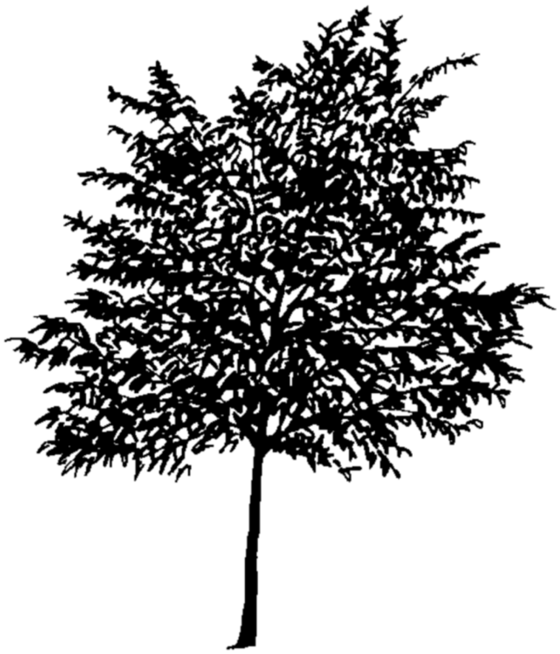
[23] Ribeiro, P. C., et al. (2016). Climatic drivers of leaf traits and genetic divergence in the tree *Annona crassiflora*: a broad spatial survey in the Brazilian savannas. *Glob. Chang. Biol.* 22 (11): 3789–3803;

[24] Soudzilovskaia, N. A., et al. (2013). Functional traits predict relationship between plant abundance dynamic and long-term climate warming. *Proc. Natl. Acad. Sci.* 110 (45): 18180–18184;

Common name London planetree, it is a large tree that is a cross between *Platanus orientalis* and *Platanus occidentalis*. The tree has an average height of 82 feet and a spread of 60 feet. It starts off with a pyramidal shape, but as it grows it develops a rounded crown. The plants best feauture is its bark, creamy-white to olive-green coloring. It has large leaves with a light undersides. It prefers full sunlight to shade, and moist soil.

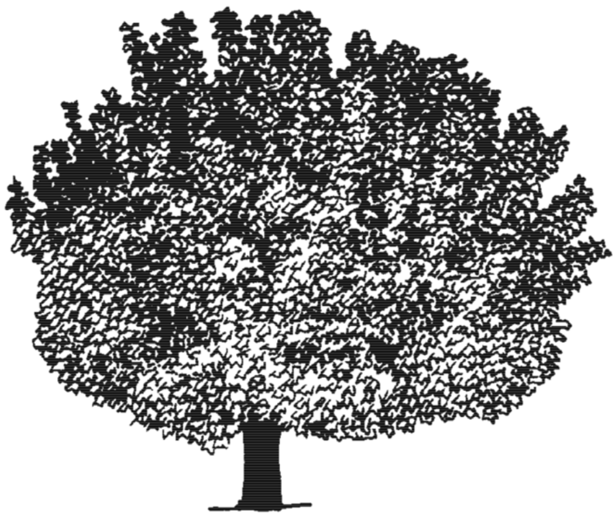
Gleditsia triacanthos var. inermis
Honeylocust, its common name, has an average height of 70 feet and an average spreed of 40 feet. It has an oval or rounded canopy. The leaves are either bipinnately compounded or pinnately compounded. It has thorns on the trunk and main branches. It is strong wooded. It has a yellow, yellow-green, or golden fall color at the top. It has fragrant spring flowers. It prefers full sunlight, but not picky with soil.



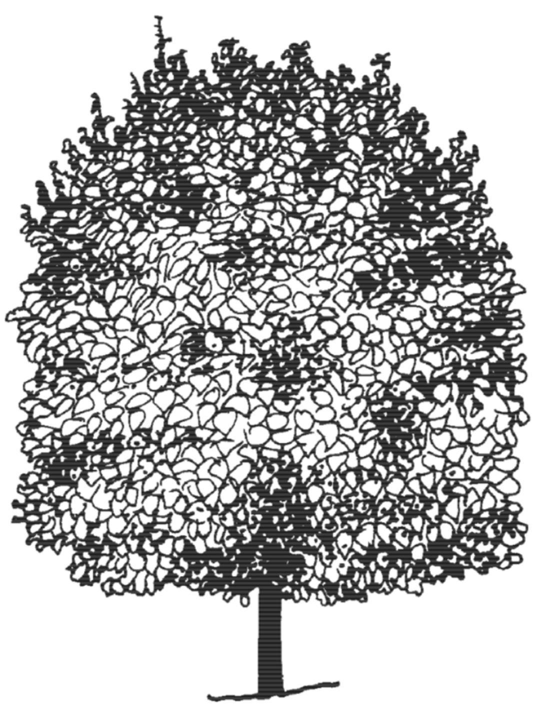
Pyrus Calleryana
Callery pear tree grows fast with an average height of 32 and spread of 30 feet. It is relatively small. It has brilliant white flowers that are have an unpleasant fragrance but later produce bitter fruit. The leaves are purple-red at the beginning. They become green and 1.5 to 3 inches long and turn red again in the fall right before falling.

Quercus Palustris
Pin Oak is one of the most commonly planted Oaks in the Midwest and eastern United States. It has an average height of 65.6 feet and a spread of 37.5 feet It starts off in a pyramidal shape and then matures into an oval crown. It has a dominant trunk and relatively small diameter branches. It has green leaves that turn into red/bronze before falling in the fall. This plant is attractive for landscapes.

Acer Platanoides
Norway maple is native to Europe but now it is widely planted in urban areas in the US. It has an average height of 82 feet and 37.5 feet. It has a rounded crown filled with greenish-yellow flowers in the spring. It is adapted to a wide variety of soils and has a very vibrant yellow fall color that is known to be extremely attractive. It also produces small yellow flowers.



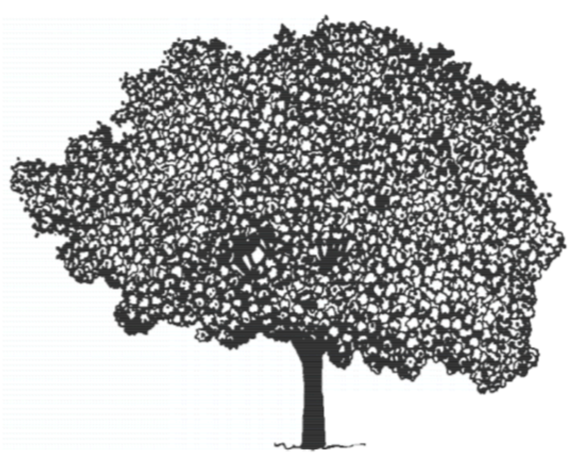
Tilia Cordata
Littleleaf Linden is native to Europe and Southwest Asia but is now planted in urban areas in the US, just like Norway maple. It has an average height of 88.5 and an average spread of 37.5. It has fragrant small flowers to show in late June. It prefers moist soil but has a wide range of adaptation. It has a dense, low-branched, pyramidal to ovate form and is used as an ornamental shade tree.



Zelkova Serrata
Japanese Zelkova is native to Japan, Taiwan, and eastern China. It has an average height of 65.6 feet and a spread of 60 feet. It prefers full sun. Its leaves turn a brilliant yellow-orange in the fall. It has been used as a substitute to the American Ulm because it is resistance to the Dutch elm disease.

Gingko Biloba
Ginkgo Biloba is known to be storm damage resistant and pest free (great for storm surge resilience!). They start off with an open canopy that becomes denser as they age. It is tolerant of most soil types and prefers full sun. It has an average height of 100.5 feet and spread of 55 feet. It does not make significant fruits.

Sophora Japonica (Styphnolobium japonicum)
Known as the Japanese padoga tree, this tree is native to China and Korea, but not Japan. It is a medium deciduous tree with an average height of 55.7 feet and a spread of 50 feet. They produce greenish-white to yellow showy flowers in mid to late summer but it must be at least 10 years old to bloom. It prefers full sunny and light soil.



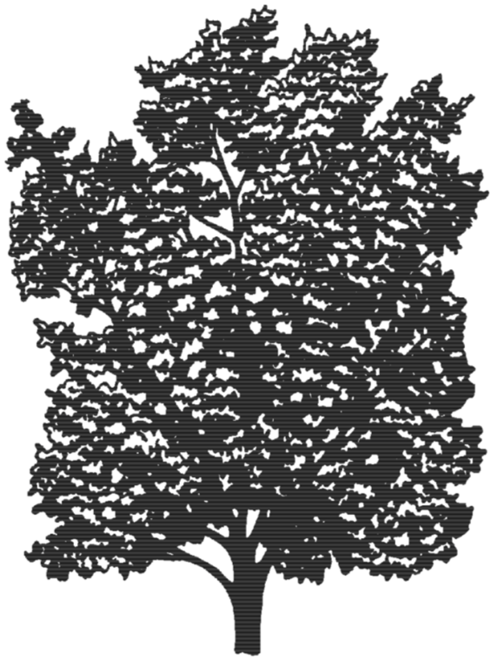
Acer Rubrum
Red maple has an average height of 98.4 feet and spread of 30 feet. It is used as a shade tree as well as a street tree. Prefers to grow in moist acidic conditions. It is very tolerant of the cold. The emerging leaves, twigs, flowers, and fruits have a red tint to them. The Red maple is preferred over the Silver maple or the Boxelder because it grows faster.

Fraxinus Pennsylvanica
Green ash has an average height of 59.0 feet and a spread of 50 feet. It is used as a shade tree and a street tree. This tree starts off as a pyramidal shape and matures into an irregular round crown. Green ash wood is used for commercial purposed like tool handles, oars, garden furniture, and sports equipment.

Tilia Americana
American Liden has an average height of 88.6 feet and a spread of 42.5 feet. It starts off in a pyramidal shape and develops into an oval canopy. In June, it develops green or yellow fragrant blooms that attract insects. Their leaves are heart-shaped and dark green and only fade to yellow before falling in the fall.

Acer Saccharinum

Silver maple is an average height 98.4 feet and a spread of 50 feet. It is fast growing with relatively weak wood. It is tolerant to wet areas and recommend to plant in flood prone zones. The roots are dense and often grow on the surface of soil making mowing grass difficult.



Liquidambar Styraciflua
Sweetgum has an average height of 70 feet and spread of 42.5 feet. It is used as a shade tree as well as a street tree. It has an oval or round canopy when mature. It has a wide range of fall colors from yellow, orange, purple, and red. Usually, it has glossy, deep green leaves. It gets its name from the gum that it produces that is used for commercial purposes like chewing gum, incense, perfumes, and folk medicine.

All tree data was compiled from:

- Arbor Day Foundation: https://www.arborday.org/trees/treeguide/TreeList.cfm
- Missouri Botanical Garden: http://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?kempercode=a917
- University of Florida, Environmental Horticulture: **http://hort.ufl.edu/database/trees/trees_scientific.shtml#G**

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