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Fighting Food Insecurity in New York City: What Role for Street Trees?

Kristen Cooney
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ABSTRACT

Recent research suggests that urban forests have the potential to combat food insecurity via edible parts from trees. Many tree species commonly planted in urban spaces have edible parts that may also fulfill the nutritional needs of city residents that are food insecure, but no one has analyzed the value of city street trees to understand this potential. I analyzed New York City's street trees by each species' edibility to measure this potential. The Plants for a Future (PFAF) database was utilized to determine relevant tree species with edibility ratings on a scale of 1 to 5. Tree edibility in tandem with the NYC zoning initiative, Food Retail Expansion to Promote Health (FRESH) Program Zones, was used to locate food insecure communities and determine the potential of edible street trees to combat food insecurity where it occurs. The spatial analysis program, Geographic Information Systems (GIS) ArcMap Optimized Hotspot Analysis tool spatially quantified the usefulness and nutritional value of street trees in relation to food insecure residents. This analysis found that approximately 280,000 (40%) of New York City street trees are edible, and 12% of these trees occur in high densities in food insecure areas.

INTRODUCTION

In the face of food insecurity, there is a growing acceptance that trees in urban spaces may be able to serve food insecure residents through the harvest of their edible parts via activities such as foraging (Mclain et al. 2014). The issue of food insecurity is defined as the "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (USDA). In the fight against food insecurity, urban foraging is an activity that provides a mechanism of access to food, though it is not widely recognized as such, despite research suggesting that urban foraging is an active practice found around the globe and present in groups of people from many cultural and socioeconomic backgrounds (McLain et al. 2014, Shackleton et al. 2017). A growing practice that entails the intentional planning urban areas for food producing trees is called urban food forestry, and this concept is gaining traction in the conversation regarding food insecurity (Clark and Nicholas 2013). Even though urban food forestry is gaining more recognition, no one has analyzed the potential of preexisting city street trees to combat food insecurity. Particularly in New York City, the food insecure population has risen from an estimated 1.2 million to 1.5-2 million residents with the rise of the pandemic, suggesting that this issue is growing (City Harvest 2021).

In another study specifically regarding New York City and edible food parts from trees, researchers discovered that there is a great diversity of edible parts from trees available in the city (Hurley and Emery 2018). Identified edible trees and trees that foragers actively harvest may differ though, and that the range of species that are harvested by foragers is likely narrower (Hurley et al 2022). Despite the difference between alignment and actively foraged species, recent research suggests that prioritizing edible species in urban spaces can help build food resilient communities (Sardeshpande et al. 2021).

This led me to my research question, can New York City’s street trees combat the effects of food insecurity? In order to analyze the potential of street trees to provide edible parts for food insecure city residents, I began with the street tree data set publicly available through New York City Open Data (2015). To establish which trees are edible, the Plants for a Future (PFAF) database was used, and edible trees were selected from the data set. Then this data was added to ESRI’s GIS ArcMap, a geospatial software that visualizes, analyzes, and interprets data to understand spatial relationships (ArcGIS API). In order to understand how edible street trees may serve food insecure residents, the Food Retail Expansion to Support Health (FRESH) Zones was used as a proxy to identify where food insecure communities are located. Once edible street trees and food insecure communities were identified, A hot spot analysis was conducted to identify the highest densities of edible street trees and where or if they overlap with food insecure communities.

This analysis provides a model that can be used to identify areas of greatest potential for edible street trees to provide for food insecure residents by locating the highest densities of edible street trees and reveals if they occur in or near food insecure communities. Potential was determined through abundance of street trees and diversity of street tree species, and the greatest potential for residents was determined using the hot spot analysis and FRESH Zone overlaps. Lastly, seasonality was examined using hot spot and FRESH Zone overlaps to understand when food parts are available for residents, as this varies across the seasons in New York City.

LITERATURE REVIEW

Urban Forests, Provisioning Services, and Food Insecurity

Urban forests are socially ecologically diverse, multifunctional ecosystems (Mclain et al. 2012) that provide ecosystem services to cities and their residents (Fisher and Kowarik 2020). Urban forests include trees that are located within cities and towns (U.S. Forest Service) and are found across diverse urban greenspaces, such as parks. These spaces of the urban forest and the trees that call them home support wildlife habitats (so-called supporting services, Clark and Nicholas 2013), regulate air and water quality as sequester and store carbon (known as regulating services, Nowak 2006), and provide people with enriching recreational experiences (Lovell and Johnston 2009). Studies also indicate a city's trees in these diverse greenspaces have the potential to provide diverse provisioning services, or plant materials that people can consume for foods, use as medicines, or harvest for decorative materials and to make crafts (Hurley and Emery 2017, Hurley et al 2022).

At the same time, there is a growing awareness that urban forests have the potential to combat food insecurity, given that many tree and shrub species feature edible parts, namely fruits, berries, and nuts (Clark and Nicholas 2013). Food insecurity is defined by the USDA as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (USDA 2020). Urban food forestry (UFF) is one example of this growing awareness. UFF is a specific design intervention to reduce urban food insecurity through active plantings and is defined by Clark and Nicholas (2013) as "the intentional and strategic use of woody perennial food producing species in urban edible landscapes to improve the sustainability and resilience of urban communities". Urban food forestry builds on existing initiatives in urban spaces to provide resilience in the face of food insecurity via strategic species plantings in community gardens, urban food forests, and working to make other urban greenspaces and infrastructure edible (EGI) (Russo et al. 2017).

Urban food forestry highlights and elevates the importance of provisioning ecosystem services that provide raw materials, such as foods obtained from trees. UFF is a way to maintain the multifunctional benefits of plants and capitalize on their edible components. While recent research on urban food forestry includes efforts to map and identify existing species for harvest for their edible parts (Clark and Nicholas 2013), often through community-oriented efforts, the edibility of, or presence of edible plant materials within, the existing urban forests of cities has remained understudied.

Street trees represent a particularly pervasive feature of many city's urban forests and one type of urban greenspace that is widely accessible to residents. Street trees are defined as trees growing along public street right- of-way and managed by the city. Street trees also contribute to the physical and aesthetic value of urban life (McPherson et al. 2016). In an assessment of street trees in 320 U.S. cities, researchers found that there were 61.6 million street trees across the cities, and 63.4 trees planted per street, and .4 trees per person. Based on their model, McPherson and coauthors determined that there was room for an additional 66 million street trees to be planted. This study also estimated the multifunctional value of the nation's urban street trees to be $30 billion, at $500 USD per street tree (McPherson et al. 2016). Given their generally widespread distribution and accessibility, street trees represent a form of edible green infrastructure readily available to food insecure urban residents. Yet street trees are often overlooked in urban forest assessments when it comes to their ability to reduce food insecurity in cities.

Foraging in Urban Forests and Combating Food Insecurity

To some, the regular use and harvest of plant materials from the urban forest, whether from street trees or other areas, might seem improbable. Research on urban foraging, however, has found that various edible parts from trees in urban greenspaces may be a suitable option for supporting food sovereignty and resilience in urban communities (Fisher and Kowarik 2020). Urban foraging is an activity that provides a mechanism of access to food, though it is not widely recognized despite being an active practice found around the globe and present in groups of people from many cultural and socioeconomic backgrounds (McLain et al. 2014, Shackleton et al. 2017). Urban foragers partake in the activity for both economic and noneconomic reasons, (Hurley 2015, Sardeshpande and Shackleton 2020). Foraged items from some urban tree species subject to variable yields, suggesting limits for reducing food insecurity (Bunge et al. 2019) and thanks to seasonal access. Edible components foraged from trees have the potential to fill nutritional gaps via the diverse amount of part available, such as fruits, nuts, berries, which all provide different nutritional value (Frey 2017) though current urban policy often does not support it (Emery et al. 2012). Despite pushback from policy and lack of prioritization by urban managers, research suggests that foraged foods provide buffer against food insecurity, and if policy and managers were to support it, this potential could be increased (Garekae & Shackleton 2020, Sardeshpande et al. 2021).

Creating space for edible green infrastructure may be an important facet in creating food resilience specifically in light of disasters like a pandemic (Sardeshpande et al. 2021). The foraging of edible parts from urban trees and other organic organisms, like groundcover and fungi, is also present in urban spaces across the globe, and it is an ubiquitous practice (Shackleton et al. 2017). The foraging of fresh, edible food parts from urban trees is not without its limits though, as researchers suggest that edible green infrastructure alone likely cannot handle the capacity of nutritional gaps for all food insecure city residents (Clark and Nicholas 2013). This is not to say they cannot fulfil some of the needs, however, as the diversity of trees already present in urban forests have the capability to provide a buffer against some of the worst effects of food insecurity through the harvesting of their diverse edible parts.

Urban tree management does not consider planting trees for their edible parts a priority, overlooking urban foragers and failing to integrate urban food forestry into policies (Shackleton et al. 2017). If urban street trees are to combat food insecurity to their fullest potential, more efforts in the realms of urban policy and management is essential. In another northern U.S. city, Seattle, where policy is moving towards encouraging the use of urban space towards edible green infrastructure (EGI), and encouraging gathering, has connected urban residents with nature as stewards, promoting the many other ecosystem services that plants in these spaces provide (Mclain et al. 2012).

METHODS

This analysis suggests a model by which to understand the potential of urban street trees to help reduce food insecurity among city residents in New York City. As represented in Figure 1, I first utilized the street tree inventory (New York City Open Data, 2015) for the plotted locations of New York City’s street trees. This data was imported into ESRI’s GIS ArcMap to spatially plot the distribution of street trees. ArcMap is a software program that displays layers of geographic information and through which an analyst can investigate spatial patterns and generate statistics about a phenomenon of interest (ArcGIS API). Once I had plotted the city’s species, I analyzed the trees to determine species abundance, diversity, and specific distributions. Second, to identify and analyze trees with edible components, I used the *Plants for a Future Database* (PFAF). The

PFAF database provides information on ecological and sustainable horticulture, organizing species by edible, medicinal, and other uses. Using this information, I determined which species found in the city include an edible component, or material. Edible quality ratings (EQR) of 3, 4, or 5. PFAF determines edible trees using a scale of 0-5, 0 being inedible, to 5 which is highly edible and likely has multiple desirable edible parts. Trees in the PFAF database also had utility and medicinal ratings, but these ratings were not considered in this analysis. The steps of this analysis are depicted in Figure 3.

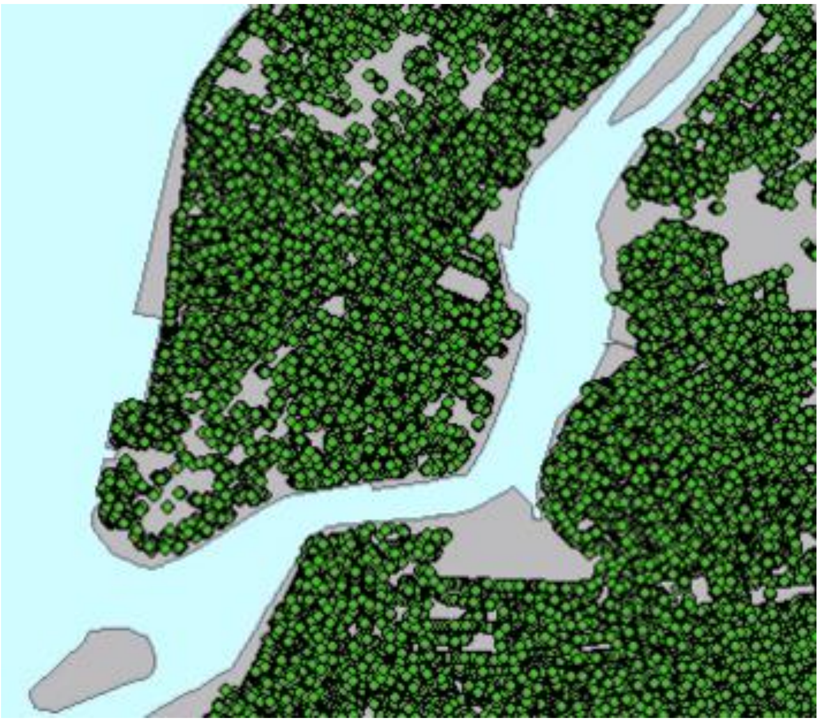

Figure 1. Detail image of street tree data points in GIS ArcMap.

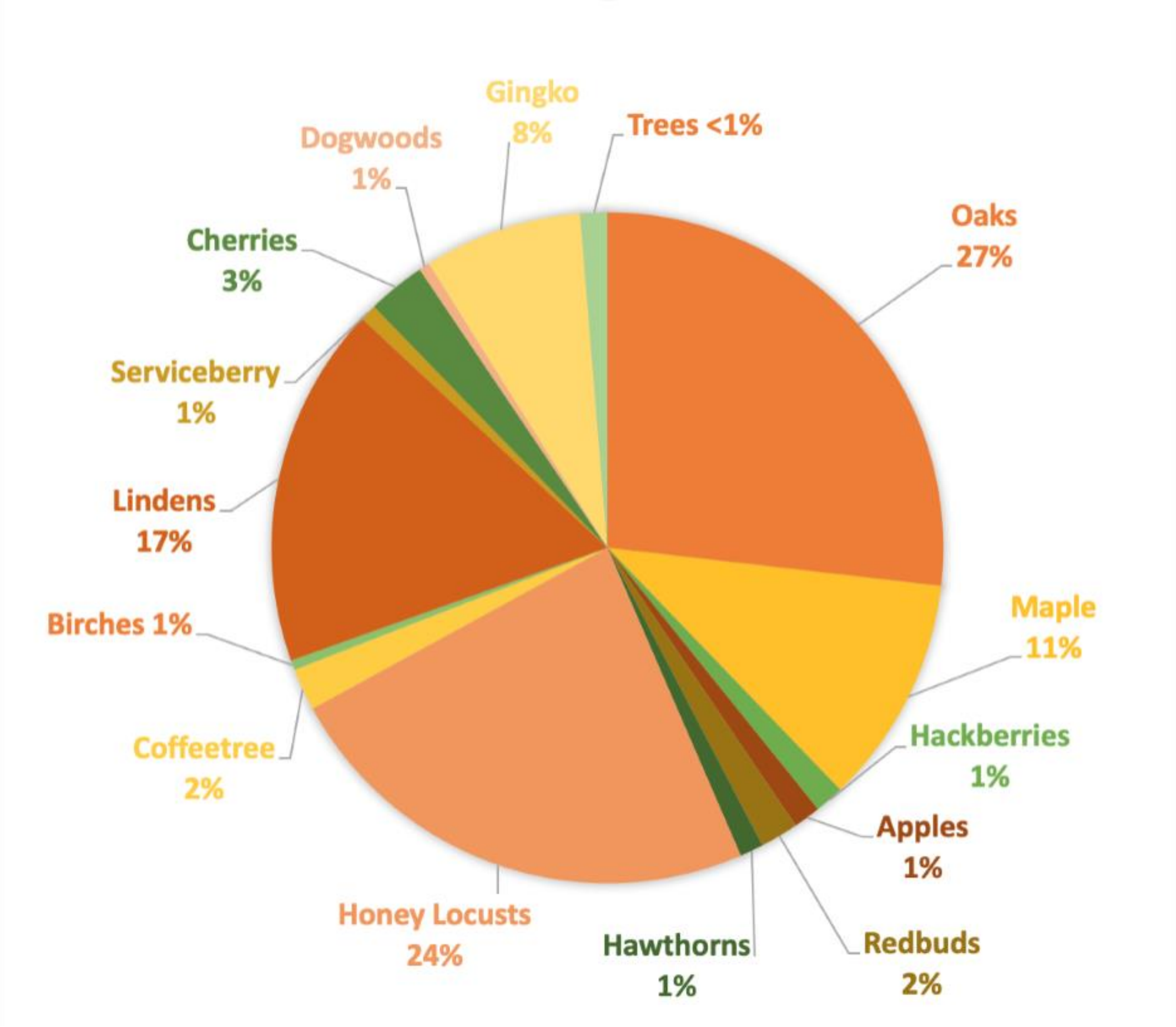

Figure 2. Edible Street trees of New York City organized by genera. Genera of trees <1% include Tea, Sassafras, Pines, Yellowhorn, Chestnuts, Hickory, Black Locusts, Walnuts, Horse Chestnuts, Buckeyes, Hazelnuts, and Beech. Total individual trees in >1% = 3640.

Next, I located food insecure communities and to later identify overlaps with edible street trees to understand potential. I imported data about the Food Retail Expansion to Support Health Initiative's FRESH Zones to ArcMap to explore this parameter, shown in Figure 4. The FRESH Zones are part of a citywide initiative to locate areas in which the proportion of grocery aisle space dedicated to fresh and healthful perishable produce to residents served is inadequate (NYC Industrial Development Agency 2008). This analysis did not consider income, access to transportation, or related means; instead, it only determined inadequate grocery aisle space dedicated to produce within the city's neighborhoods. FRESH Zones are part of an ongoing analysis of the city's grocery stores and were developed to create zoning and tax incentives to create more produce space in grocery stores and supermarkets across the city. This dataset represents the only known citywide analysis of food insecurity for the city, which was compatible with GIS analysis. As a proxy for food insecurity, consideration of the overlap of FRESH Zones, or areas where city residents are underserved by their stores, and street trees with edible components provides one measure of assessing the relationship of food insecurity and the role street trees might play in addressing this issue.

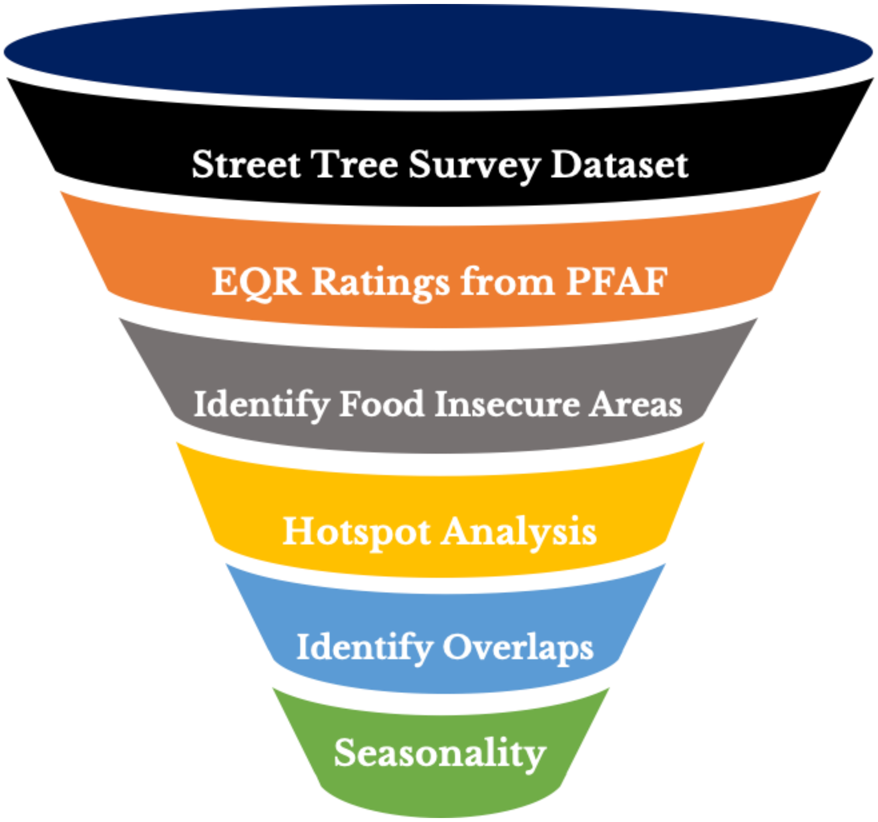

Figure 3. Methods graphic depicting the steps of the analysis.

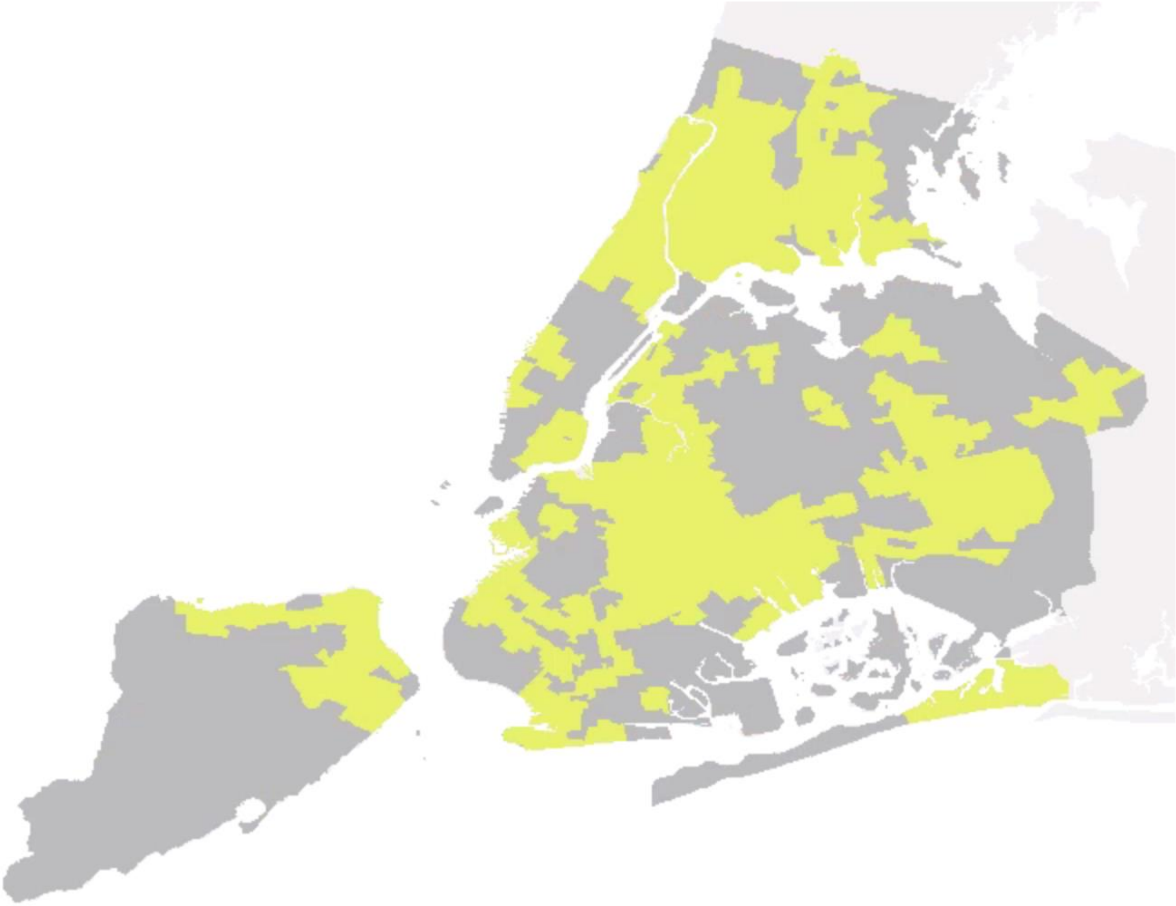

Figure 4. FRESH Zones (highlighted in yellow) of New York City map.

After I identified food insecure communities, species diversity, abundance, and edibility, I used optimized hotspot analysis to identify statistically significant clusters of edible street trees. The hotspot analysis uses the Getis-Ord-Gi Statistic to generate fishnet grids from clusters of data points and determines hotspots based on the proximity between data points (Lopez and Scheffran 2017).

The resulting fishnet grids create a gradient of dark blue to white to dark red that signifies statistically insignificant, normal distributions, and statistically significant data via fishnet grids. Even though the hotspots are the focus of the analysis, they are not the only locations or trees through which city residents have access to forage from. The hot spots were used in identifying areas of greatest potential for edible street trees to provide for food insecure residents. Overlap percentages were then identified between hot spots and FRESH Zones and are estimates.

Lastly, seasonality was examined to understand the distribution of edible parts available from street trees throughout the year. To analyze this component, trees that produced edible parts in each season were selected and a hot spot analysis was conducted for edible trees that produce in each season. Overlaps were visualized in GIS ArcMap to view the seasonal distribution of edible parts and overlaps with FRESH Zones.

RESULTS

Across New York City, there are 689,227 mapped street trees encompassing 234 identified species. 77 of the identified street tree species are edible based on their designation of an EQR rating of 3-5. This number is likely an underestimate due to the status of some street trees in the dataset only being identified to genus and not species. Trees varied widely in the parts they provide that are edible, including but not limited to leaves, flowers, buds, fruits, berries, nuts, twigs, and more. For the purposes of this analysis, parts such as inner bark were not included as harvesting this part of a tree can often cause detrimental damage eventually causing death (Burns 1990).

Table 1. Select trees representing the majority of New York City’s edible street trees.

GENUS (LATIN)	GENUS (COMMON)	TOTAL INDIVIDUAL TREES	AVERAGE EQR	NUMBER OF TAXA
QUERCUS	Oaks	75,059	3.2	12
GLEDITSIA	Honey Locust	65,905	3	1
TILIA	Lindens	48,770	4.2	5
ACER	Maples	30,788	3.4	5
GINKGO	Ginkgoes	21,330	5	1
PRUNUS	Cherries	7,826	3.5	4
CERCIS	Redbuds	5,148	3	2
CELTIS	Hackberries	3,920	3	2
MALUS	Apples	3,674	3	≥3
CRATAEGUS	Hawthorns	3,168	3	≥1
AMELANCHIER	Serviceberries	2,237	4	≥4
CORNUS	Dogwoods	1,447	4.3	3
FABACEAE	Black Locust	1,280	3	1
BETULA	Birches	1,310	3	5

The EQR 3 category had the most individual trees, at 196,253, across 50 taxa. EQR 4 was the second most abundant category in terms of overall individual trees, with 62,164 individual trees across 18 taxa. Last is the EQR 5 category which consists of 21,491 trees across 9 species. This comes to a total of 279,908 individual street trees across New York City in the EQR 3-5 categories, and 77 identified species. In some cases, only the genus of the tree was specified, so this is potentially an underestimate for the edible street tree species in the city. Only a few species make up a majority of the edible street trees in the city, as shown in Table 1.

Table 2. Select identified edible street tree species, their EQR rating, abundance, and suggested edible parts and uses via PFAF.

Latin Name	Species Common Name	EQR	# Present in NYC Street Trees	Edible Parts	Edible Uses
Prunus virginiana	"Schubert" Chokecherry	3	3,867	fruit, seed	tea
Tilia americana	American Linden	3	10,337	flowers, leaves, sap	chocolate, sweetener, tea
Prunus Serotina	Black Cherry	4	493	Fruit, seed	condiment, drink
Robinia pseudoacacia	Black Locust	3	1,280	flowers, oil, seed, seedpod	condiment, drink, oil
Acer Nigrum	Black Maple	4	98	sap, seed	sweetener
Juglans nigra	Black Walnut	3	254	Oil, sap, seed	oil, sweetener
Acer negundo	Box Elder	3	49	leaves, sap, seed	sweetener
Cornus mas	Cornelian Cherry	4	956	Fruit, oil	coffee, oil
Malus sylvestris	Crab Apple	3	2,790	fruit, oil	oil, pectin, tea
Cercis canadensis	Eastern Redbud	3	3,315	flowers, leaves, seedpod	condiment
Quercus robur	English Oak	4	1,241	Seed	coffee, gum
Fagus sylvatica	European Beech	4	106	leaves, oil, seed	coffee, oil
Ginkgo Biloba	Ginkgo	5	21.330	oil, seed	oil
Crataegus monogyna	Hawthorn	3	2,407	flowers, fruit, tea	coffee, tea
Gleditsia triacanthos	Honey Locust	3	46,022	seed, seedpod	coffee, drink, gum, sweetener

Aesculus hippocastanum	Horse Chesnut	3	919	seed	coffee
Gymnocladus dioica	Kentucky Coffee Tree	3	2,490	seed, seedpod	coffee
Cornus kousa	Kousa Dogwood	5	224	fruit, leaves	N/A
Tilia cordata	Littleleaf Linden	5	22,814	leaves, sap	chocolate, tea
Quercus rubra	Northern Red Oak	3	6,189	seed	coffee
Morus	Mulberry	4	896	fruit, leaves, manna	tea
Betula papyrifera	Paper Birch	3	470	flowers, leaves, sap	sweetener, tea
Carya glabra	Pignut Hickory	3	83	sap, seed	N/A
Quercus palustris	Pin Oak	3	41,063	seed	coffee
Acer rubrum	Red Maple	3	14,353	leaves, sap, seed	sweetener
Betula nigra	River Birch	3	414	sap	sweetener
Amelanchier	Serviceberry	4	1,881	fruit	N/A
Betula pendula	Silver Birch	3	300	flowers, leaves, sap	tea
Tilia tomentosa	Silver Linden	3	5,888	leaves	condiment, tea

Acer saccharinum	Silver Maple	3	10,524	leaves, sap, seed	sweetener
Acer saccharum	Sugar Maple	4	2,277	leaves, sap, seed	sweetener
Quercus bicolor	Swamp White Oak	4	4,902	seed	coffee
Corylus colurna	Turkish Hazelnut	3	240	oil, seed	oil
Quercus alba	White Oak	3	1,248	seed	coffee

Hotspots are generally inconsistent in location across each EQR category, and coverage was estimated based on the resulting maps in Figure 5 and 6. The EQR 3 category has over 20 distinct hot spots, distributed throughout all 5 boroughs of the city. The 5 boroughs all have cold spots in the EQR 3 category as well. EQR 4 hot spots existed in each borough of the city, though they were smaller and occurred less, including some overlap with FRESH Zones, but less so than EQR 3 (Figure 5). Cold spots are generally larger in the EQR 4 category, and the largest ones exist in the Bronx, Queens, Brooklyn, and Staten Island. Manhattan had several small cold spot in this category, but hot spots far outweigh cold spots in the EQR 4 map for the borough. The EQR 5 category map has several large hot spots, but they are dispersed disproportionately across the city's boroughs. Manhattan has the most hot spot coverage in this category, with no cold spots. The Bronx, Brooklyn, and Queens have some hot spots and some cold spots dispersed through each borough. Staten Island has no hot spots in the EQR 5 category, and most grid space consists of cold spot coverage. In the EQR 5 map (Figure 5, bottom right corner), around half of the hot spots are within or overlapping with FRESH Zones in each borough except Staten Island.

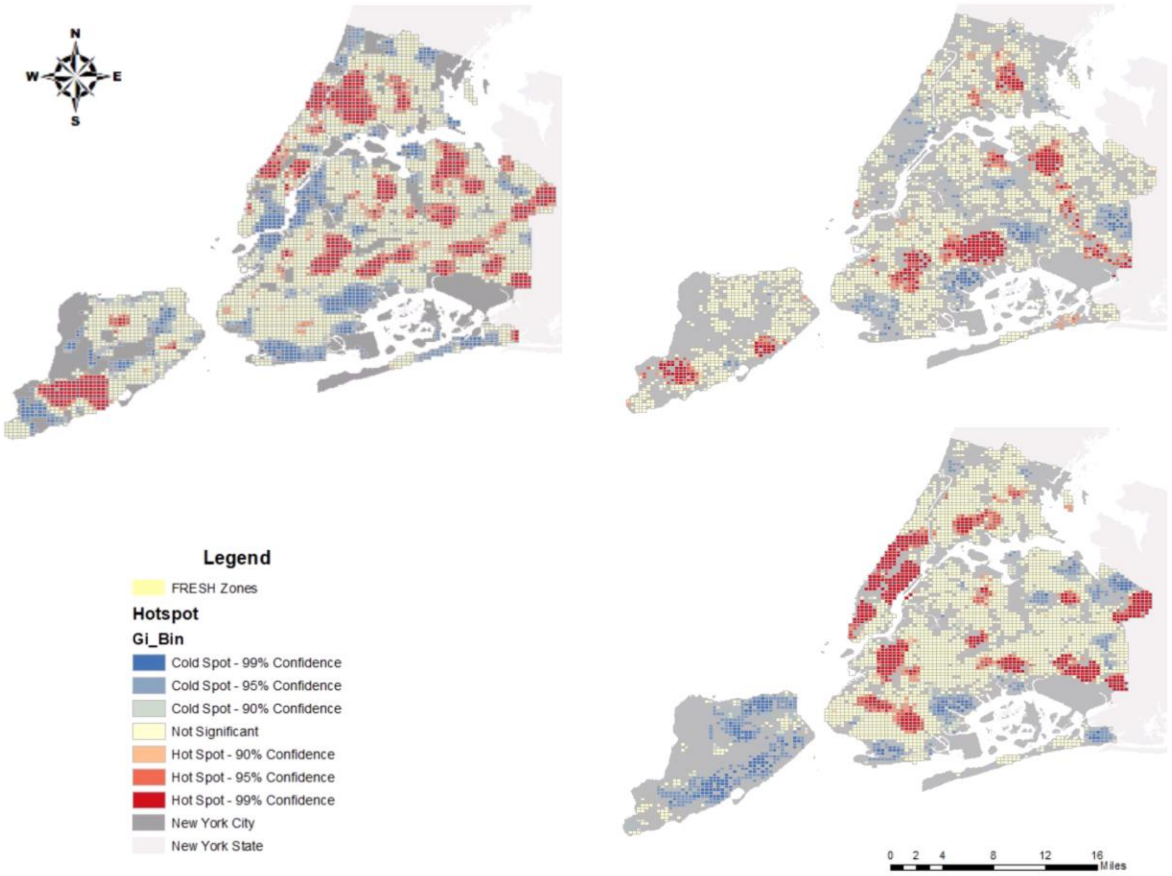

Figure 5. EQR 3, 4, and 5 separate edible street tree hot spot maps. (clockwise).

In Figure 6, the combined EQR 3, 4, and 5 hot spot map, all edible street trees data points were used to create the map. There are hot spots present in all boroughs here, and in all boroughs except Staten Island, there is between 10-30% overlap with the FRESH Zones. Overlap percentages were based on estimates. Figure 6 was used for determining overlap coverage for identifying areas of greatest potential in this analysis.

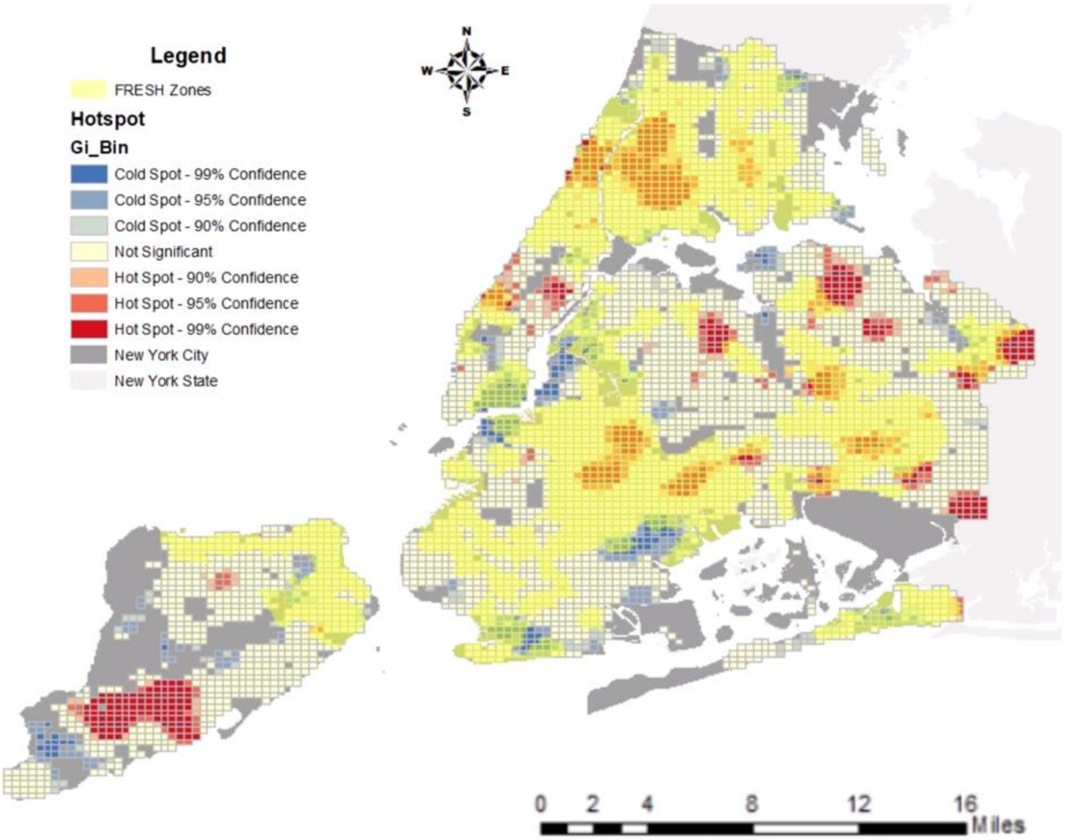

Figure 6. All edible street trees (EQR 3, 4, and 5 combined) hotspot and FRESH Zone overlap map.

There are 16 FRESH Zones throughout the city, and each was categorized in terms of estimated percentage overlap between the FRESH Zone and any hotspots. In some cases, no hotspots were identified within a FRESH Zone, placing them in the 0%-25% category, and so corresponding tree numbers were also 0. Individual FRESH Zone size varies widely, and so do the numbers of trees that may exist within the hotspot and FRESH Zone overlap. These numbers indicate that only 12% of edible trees exist within FRESH Zone and hotspot overlaps, suggesting that there is some potential for edible street trees to provide for residents, though these numbers imply that they cannot make up a significant portion of food insecure city residents' diets. The hot spots for Table 3 were drawn from the EQR 3, 4, and 5 map only, as hot spots varied in the individual EQR category maps and seasonality maps.

Table 3. Edible Street Trees in FRESH Zones, hotspots, and overlap of both FRESH Zones and hotspots.

% Overlap	FRESH Zone ID #	FRESH Zone Total Trees	EQR 3	EQR 4	EQR 5	Edible Trees in Overlaps
50%-100%	5	2,823	963 (73.8%)	0 (0%)	342 (26.2%)	1,305 (46%)
	13	9,932	1,240 (75.1%)	0 (0%)	411 (24.9%)	1,651 (17%)
26%-50%	8	25,479	2,868 (76.9%)	6 (.2%)	857 (22.9%)	3,731 (15%)
	15	72,618	9,323 (84.1%)	486 (4.4%)	1,279 (11.5%)	11,088 (15%)
0%-25%	1	22,613	194 (91.1%)	19 (8.9%)	0 (0%)	213 (.1%)
	3	3,145	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	4	1,258	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	6	2,473	0 (0%)	0 (0%)	117 (100%)	117 (5%)
	7	5,948	0 (0%)	0 (0%)	43 (100%)	43 (.1%)
	10	4,979	339 (100%)	0 (0%)	0 (0%)	339 (7%)
	14	8,171	396 (84.8%)	71 (15.2%)	0 (0%)	467 (6%)
	2	114,001	8,574 (7.5%)	224 (2.3%)	997 (10.1%)	9,795 (9%)
	9	3,117	102 (81.6%)	6 (4.8%)	17 (13.6%)	125 (4%)
	16	24,362	4752 (83.1%)	158 (2.8%)	807 (14.1%)	5,717 (23%)
	11	5,187	679 (82%)	149 (18%)	0 (0%)	828 (16%)
	12	15,385	1,902 (94.2%)	114 (5.6%)	4 (.1%)	2,020 (13%)
Totals	16	321,491	31,332 (83.9%)	1,233 (3.3%)	4,874 (13%)	37,349 (12%)

Table 4. Seasonality chart depicting what season trees are producing edible parts. Trees with an asterisk may not produce every year, and/or experience mast years, or sharp fluctuations in yield over a multi-year cycle. Note: If only a genus is specified, all edible species of that genus present within the city have the same edible parts during the same months/seasons. Harvestable parts not included are bark, inner cambium, sap, and roots because large harvests of these parts can be detrimental to the tree.

Season	Early Winter	Mid-Winter	Later Winter	Early Spring	Mid- Spring	Late Spring	Early Summer	Mid-Summer	Late Summer	Early Fall	Mid-Fall	Late Fall
Month	December	January	February	March	April	May	June	July	August	September	October	November
Species and Edible Part(s)	Crabapple (fruit)* Hackberry* (berry)	Crabapple (fruit)* Hackberry* (berry)	Kentucky Coffee Tree (seedpod, seed)	Linden (inner bark) Maples* (young seeds) Redbud (flowers, leaves) Kentucky Coffee Tree (seedpod, seed) European Beech* (young leaves)	Linden (inner bark) Linden (young leaves) Maples* (seeds) European Beech* (young leaves) Redbud (flowers, leaves)	Linden (inner bark) Linden (flowers) Linden (young leaves) Maples* (seeds) Hawthorn (leaves, flowers) Service berry* (berries) Mulberry* (berries) European Beech* (young leaves)	Linden (flowers) Black Cherry* (fruit) Service berry* (berries) Mulberry* (berries) Sassafras (leaves)	Black Cherry* (fruit) Mulberry* (berries) Sassafras (leaves)	Linden (nutlets) Black Cherry (fruit)* Cornelian Cherry* (fruit) Hawthorn* (berries) Hickory* (nuts) Turkish Hazelnut* (nuts) Kousa Dogwood* (fruit) Choke Cherry* (fruit) European Beech* (seeds)	Linden (nutlets) Black Cherry* (fruit) Black Walnut* (nut) Cornelian Cherry* (fruit) Hawthorn* (berries) Hickory* (nuts) Turkish Hazelnut* (nuts) Kousa Dogwood* (fruit) Chesnuts* (nut) Choke Cherry* (fruit) Hackberry* (berry) European Beech* (seeds) Oaks* (acorns)	Black Cherry (fruit)* Black Walnut (nut)* Hickory* (nuts) Crabapple (fruit)* Ginkgo* (berry, nut) Locust (seed, seedpod) Kousa Dogwood* (fruit) Chesnuts* (nut) Hackberry* (berry) Oaks* (acorns)	Crabapple (fruit)* Ginkgo* (berry, nut) Chesnuts* (nut) Hackberry* (berry) Oaks* (acorns)

Seasonality is a critical consideration in understanding the potential of the urban forests' street trees to provide for food insecure residents. Trees will not produce year-round, and production of desirable edible parts varies by species. Thus, creating an inconsistent harvest that will vary in abundance and diversity over the course of the year. As shown in Figure 7, trees producing edible parts in the season of fall were the most abundant and diverse, evident in the amount of grid space and the most hot spots present in this figure. Edible parts include nutlets from several linden species, cherries from black cherry and dogwood trees, nuts from black walnut, oak, hickory, chestnut, and hazelnut trees. Berries are accessible in the fall from hawthorn and hackberry trees. Lastly, crabapples are available, which are in the apple (*Malus* spp.) family, also considered a fruit. This high diversity and abundance of species available to harvest from in the fall reveals that this season provides the greatest potential to serve food insecure residents, while other times of the year have less abundance and diversity.

The second most abundant season is spring, with flowering species producing, including redbud and linden trees. Hot spots are present in Staten Island and Queens only, and though they cover 10% of Queens and almost 50% of Staten Island, there is little to no overlap with FRESH Zones, suggesting that food insecure residents will have to travel more to access harvestable goods from street trees during this season. Brooklyn, Manhattan, and the Bronx each have cold spots only, with substantial overlap of 10-25% with FRESH Zones in those counties. Select abundant trees that have edible parts in the spring include maples and lindens. Plants for a Future recommends harvesting leaves from species with edible leaves to pick them while they are young, in the spring, with linden (*Tilia* spp.) and beech (*Fagus* spp.) trees are among them. Maple (*Acer* spp.) and coffee (*Gymnocladus* spp.) trees have mature seeds available for harvest in the spring. Lastly, berries available in the spring include serviceberries (*Amelanchier* spp.) and mulberries

(*Morus* spp.). Spring has less abundant food parts and species, but still offers a variety of parts that may fill different nutritional gaps for food insecure residents as compared to fall. Street trees that have edible flowers that often produce in the spring include redbud (*Cercis* spp.) trees. Summer was the third most abundant season with noticeably less grid space than fall and spring. Areas with no grid space have no present producing edible street trees. Figure 7 shows summer only has 3 hot spots dispersed throughout the city, isolated to areas of southeastern Bronx, southern Queens, and Northern Staten Island with a small overlap of this hot spot into western Brooklyn. Each hot spot has substantial overlap with food insecure FRESH zone areas of the city, with at least 50% overlap for each hot spot. Summer produces fruit from black cherry, dogwood, and chokecherry trees. Berries are available in the summer from hawthorn and mulberry trees. Seeds are available for harvest from beech trees. Lastly, the first hazelnuts and hickory nuts are available for harvest in late summer. Available food parts in the summer are spotty across the city, but specific food insecure residents in the FRESH Zones of southeastern Bronx, southern Queens, and Northern Staten Island have the greatest access with close proximity to the highest densities of producing trees in the summer.

The least abundant season for edible street tree production is winter, as was expected, since most street trees in New York City are deciduous and are dormant in the winter. Present grid space in Figure 7 shows that winter has very little grid space overall, suggesting low levels of access is the normal distribution during the winter in New York City. There is a single hot spot grid located in southern Queens, which does overlap completely with a FRESH zone. Street trees with edible parts available in winter include coffee trees (*Gymnocladus* spp.), which have seedpods and seeds that are edible, crabapple (*Malus* spp.) trees with fruit, and hackberry (*Celtis* spp.) trees that have berries for harvest throughout the winter. Though this is a variety of edible parts, these are some of the less abundant trees in the city, collectively accounting for 4% of the edible street trees. The parts available in the winter still offer a few ways for residents to supplement their diets, but not to substantially improve food insecurity.

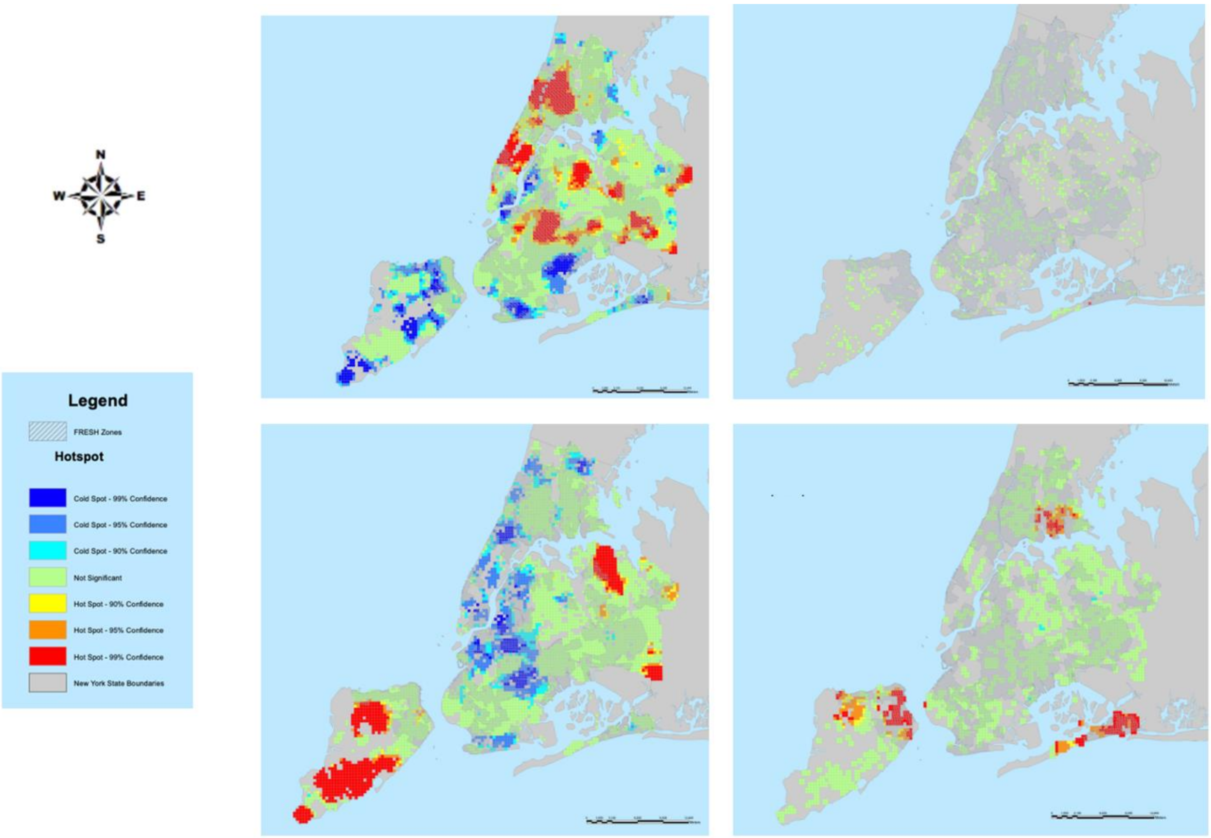

Figure 7. Seasonally producing street tree hot spot and FRESH Zone maps, fall, winter, spring, and summer (clockwise).

DISCUSSION

12% of the city’s street trees occur in hot spots and FRESH Zone overlaps, revealing areas of greatest potential for edible street trees to provide for food insecure residents in New York City. This study analyzed the potential of street trees to combat the effects of food insecurity, despite the abundance of other plants, namely groundcover, vines, shrubs, and other organisms such as fungi, that are part of forested urban greenspaces and also have potential to provide food for residents. In considering street trees, I assessed trees with an EQR 3 ranking of higher, revealing that approximately 280,000 (40.6%) street trees in New York City are edible street trees (with an EQR of 3+). There are 77 (32%) identified species of edible street trees in New York City. Oak trees are the most abundant and diverse edible street trees in the city, with about 75,000 (27.4%) individual trees across 12 species with an average EQR of 3.2. Other abundant street trees include 24% honey locusts (*Gleditsia* spp.), 17.8% lindens (*Tilia* spp.), 11.2% maples (*Acer* spp.), and 7.8% ginkgoes (*Ginkgo* spp.). By excluding trees with EQR 0, 1, and 2 rankings, it’s worth noting that many of these lower ranking trees still have edible parts, though they are considered less desirable or what some scholars describe as famine foods (Pierce and Emery 2005).

Street trees only of an EQR 3 or above in overlap and FRESH Zone areas were determined, to locate areas of the greatest potential for combatting food insecurity. These overlap areas occurred in all boroughs, but just barely in Staten Island with minimal grid space overlap at only 2 statistically significant fishnet grid rectangles total. In Brooklyn and Queens, there are hot spots within and outside of FRESH Zones, but only about 25% overlap coverage in both boroughs. In Manhattan, the only overlap occurred at the Northern tip of the borough. Lastly, in the Bronx, the largest hot spot occurred within the FRESH Zone of the western Bronx.

The numbers resulting from this analysis should be conservative, suggesting that the potential of the city's street trees is greater than the numbers show. As with famine trees above, this analysis excludes consideration of the many other edible street trees of an EQR of 3 or above across the city. For example, I did not analyze adjacency or proximity of trees, only edible tree hot spots directly within FRESH Zones (or the area of overlap) were identified and counted. In some cases, food insecure residents may be closer to a tree with highly edible materials just outside of a hotspot/FRESH Zone overlap than those within that area. Likewise, there are also trees in areas besides hot spots, including the white grid space and cold spots. Finally, areas with no fishnet grids did not have any identified street trees, but they may have other trees, such as those found in parks, urban gardens, and other greenspaces. This study only analyzed street tree potential in combatting food insecurity, but in the city, there are an estimated 5.2 million trees (Million Trees NYC 2020), and street trees only make up around 690,000 or 13.2% of them. Taken together, these points suggests that the overall potential of trees in the city to combat food insecurity is likely greater than shown here, suggesting the need for future research to explore these dynamics.

While analyzing urban street trees to provide for food insecure residents, one must consider what specific nutritional gaps the trees are capable of filling. Though nutrition was not analyzed in this research specifically, literature suggests that a diversity of edible items from plants offers a variety of different nutrients. Fruits are often high in vitamins E, C, and A, as well as potassium, calcium, magnesium, phosphorus, iron, and zinc (Frey 2017). Fruits also contain phytonutrients, such as carotenoids, bioflavonoids, and many others, which are suggested to support health even though they haven't been heavily researched, as many are still being discovered. Proper intake of these nutrients combats the risk of cancer, diabetes, and obesity, all of which are perpetuated in food insecure urban areas like New York City. The diversity of parts available from trees will also vary throughout the seasons, and this will cause the ability of street trees to fill nutritional gaps to be inconsistent throughout the year. The degree to which the composition of the urban forest will be able to fulfill specific nutrient gaps in urban residents' diet will vary based on city, as the species composition, and the edible components from trees, varies widely across American cities, even within similar climate zones (Hurley et al. 2022).

In addition to considering nutrient composition, edible parts from street trees have a limited shelf life on their own. There are options to store many parts from trees, through canning and other types of processing, such as suspension in vinegar, which is a popular choice that also preserves the bioavailable nutrients from the edible tree components (Frey 2017). This may be an avenue by which to combat the inconsistent yield across seasons and years. Whether or not food insecure residents have access to the necessary materials and information to preserve these perishable goods was not analyzed in this research but should be considered moving forward.

The accessibility of edible components from trees will be inconsistent over the course of the year in New York City due to the seasonal cycle of trees found there and their life cycles. The most abundant and diverse seasons include spring and fall, where many edible trees produce their primary, edible, and desirable components such as fruits, nuts, and leaves. During these seasons, the diversity of available edible parts makes it more likely for residents to have access to goods that can fulfill nutritional needs. Summer does not offer an abundance of edible parts, but it has a greater diversity of harvestable goods as compared to winter. This is likely due to the majority of the trees having produced their most desirable edible parts in the spring, or they are growing them during the summer for peak production in the fall. This suggests that access to food parts from street trees provide some potential to fulfill nutritional gaps of food insecure residents, but the access will be inconsistent throughout the four seasons.

Unlike in southern cities in the U.S. that may have plants with leaves and greens year-round, New York City's street trees are primarily deciduous and non-evergreen so many edible components will not be accessible during the winter months while the trees are dormant. For trees such as linden trees (*Tilia* spp.), the leaves are edible, but they are only available in the warmer months of the year, and harvest of the leaves is recommended while they are young, just after leafing out in the spring. Linden trees make up 17.8% of the street trees in the city, and thus seasonality affects a noticeable portion of the harvests available.

Winter was the least abundant season for harvests, with only a single red hot spot fishnet grid rectangle present in southern Queens. Although harvestable materials from street tree species in the winter include crabapple, seedpods from coffee trees (*Gymnocladus* spp.), and berries such as the Common Hackberry (*C. occidentalis*), though these trees are not widespread. This result suggests that winter is not a season that can adequately provide access to fresh foods that will meet the nutritional needs of food insecure residents.

Another consideration for determining availability to food is whether species are dioecious, that is they have male and female trees, and this sex difference is important to determining whether a desirable edible part is present. This data was not available in our dataset, so all trees of a given species were included in the analysis, including for known dioicous species, such as the Ginkgo (*G. biloba*), which are abundant in the city's street tree population (7.8%) but for which only female trees produce the desirable edible part (e.g., ginkgo nut). Though the study was conservative in estimates of edible trees overall, the numbers regarding edibility for diecious trees is likely overstated due to inability to distinguish the female from male trees in the data.

Several other factors may affect the availability of foods from street trees, such as the ability of the city's street trees adequately pollinate and produce edible parts, and how pollutants might affect the health and safety of consuming those edible parts.

Third, consumption in moderation is another key consideration for utilizing edible components from trees to fulfill gaps in the diets of food insecure residents, as suggested in the *Plants for a Future* database. Often, species that are noted for having edible parts in the PFAF database also feature a warning about the need to consume these materials in moderation; otherwise, the person can experience adverse side effects. This is the case for ginkgo nuts (*G. biloba*). This despite the fact the tree is rated as an EQR 5 for the nuts that the female Ginkgo tree produces. As PFAF notes, excessive consumption of nuts can cause food poisoning, but does not provide details regarding how much is excessive. Ginkgo trees are among the most abundant species of edible trees in the city as well and make up 7.8% of New York City's street trees. So, it is critical that residents are aware of information like this when foraging and consuming parts from trees.

In determining street trees' potential to reduce food insecurity one must consider yield. Determining whether a particular species differs in the amount of an edible produced from year to year or site to site will affect how much food is available. Different species have different cycles of product, or masting, that may play a role here. For example, oaks typically feature this type of productive life cycle, with approximately 75,000 oaks with an EQR of 3 or higher, understanding this affect on yield will be important to consider.

CONCLUSION

Urban street trees offer some potential to combat food insecurity, but this potential is limited to the diversity of edible parts available from the 77 identified edible street trees in the city, and the roughly 280,000 (40%) individual street trees available to harvest from. Oak (*Quercus* spp.) trees are the most abundant edible street trees in the city, with roughly 75,000 (27.4%) individual street trees, 12 identified species, and an average EQR of 3.2. 12 percent of the city's street trees occur in hot spots and FRESH Zone overlaps, but there are far more edible street trees that occur in regions outside of these overlap areas. Seasonal variation will dictate what food parts are available to residents when, with the greatest access to a diversity and abundance of food parts in the fall followed by the spring which are the most abundant seasons due to the diversity and abundance of edible street trees in the overlap areas.

In New York City, areas with the greatest potential for harvest were at their most abundant and diverse during the seasons of fall and spring, followed by the least abundant seasons of summer and winter. In Figure 6, the overall EQR 3, 4, and 5 map, the boroughs of the Bronx, followed by northern Manhattan, central Queens, and Brooklyn, have overlap of FRESH Zones and hotspots where the greatest densities of edible trees are present, with the greatest potential to serve food insecure residents.

This research demonstrates that existing urban forests have the potential to fight food insecurity, but likely cannot alleviate it fully on their own. Seasonality impacts what edible parts are available and when, and there is a lot of fluctuation in the yield of edible tree parts throughout the year. Natural fluctuations in harvest such as oak tree masting, sex of trees, and food production, and related factors will impact production of desirable edible parts. Despite these considerations, there are species with parts to harvest from year-round, even though the diversity and abundance of available food parts fluctuates across the seasons. The numbers for this study are conservative overall, as the analysis focuses on trees in small overlap areas and does not consider edible street trees in adjacent areas, like parks.

Whether or not food insecure residents have access to materials and information to properly preserve food parts was not analyzed in this research but should be examined in the future. Ultimately, this research provides a model by which to identify the areas of a city that have the greatest potential to provide for food insecure residents with fresh foods from existing street trees of the urban forest that are in immediate proximity. This analysis does not suggest that the edible components from street trees should serve in place of organizations already working to promote food security, but to provide an option in addition to those efforts for food insecure residents to supplement their diets. Future analysis should focus on what species residents are likely to harvest from and action should include a move towards policy that welcomes the multifunctional management practices of urban forestry. Urban tree managers would benefit from prioritizing edible trees in urban spaces, such as along streets, to maximize the ability of the trees to provide for residents, and to do so in a way that limits exposure to pollutants, having positive impacts on overall city health, including combatting some of the adverse effects of food insecurity in New York City.

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