
A Report on Methods for Prioritizing Areas to Increase Urban Tree Canopy in New York City

Prepared by:

Dexter Locke, Kelly Goonan, Michele Romolini

The University of Vermont
Rubenstein School of Environment and Natural Resources
81 Carrigan Drive
Burlington, VT 05401

March 25, 2009



I. Introduction

During the fall semester of 2008 the University of Vermont (UVM), in collaboration with the New York City Department of Parks and Recreation (DRP) and the USDA Forest Service, offered a course entitled, “GIS Analysis of New York City's Ecology.” The purpose of this course was to build on the existing collaborative work conducted by these three organizations and assist NYC in targeting locations for tree plantings in support of the MillionTreesNYC initiative (www.milliontreesnyc.org). This report presents a method for finding places that need and/or are suitable for tree planting in urban environments. Special attention is paid to existing organizations and programmatic interests, and how they may contribute to increasing urban tree canopy as a way to achieve their particular goals. By outlining an approach to measuring need and suitability of tree planting sites, this document helps explain how decision-makers may optimize the urban forest with respect to socioeconomic and biophysical conditions.

MillionTreesNYC is part of PlaNYC, a program launched in April 2007 with the intent to “create the first environmentally sustainable 21st century city” (www.nyc.gov/2030). For its part, MillionTrees was created in recognition of the now well-documented environmental, social, and economic benefits of urban trees. Specifically, the program was largely based on a 2006 analysis and report to the New York City Department of Parks & Recreation from the instructors of this course (Grove et al. 2006). This report looks at the initial stage of a useful “Three Ps” sequence of urban tree canopy (UTC) assessment (Possible, Potential, and Preferable) and provides recommendations for the city to develop an implementation plan to realize its goal of 30% UTC by 2030.

Within the bounds of Possible UTC provided by the Grove et al. report, students used spatial analysis tools to determine locations that would be suitable and preferable for planting trees. Analyses were performed on two different scales. First, city- and borough-wide variables were examined to determine the specific neighborhoods considered to be a high priority for tree planting. This was followed by a parcel-level analysis within high priority neighborhoods to determine possible and preferable locations for tree planting. These analyses occurred at the block level, and depending on the detail and accuracy of the data, sometimes even a precise location could be identified. Variables used in the prioritization were chosen based on students’ understanding of urban tree benefits and the goals of the city.

While the applicability and level of analysis for any given city will largely depend on the human and technological resources available, the geospatial process and methods used by students in this course (as described in this paper) can be generally applied to other cities seeking to increase their urban tree canopy. City agencies and other organizations can use these methods to identify both suitable and preferable areas to plant trees, according to a set of chosen variables. This approach can help cities systematically reach their urban tree canopy goals along with achieving other social, economic, and ecological goals.

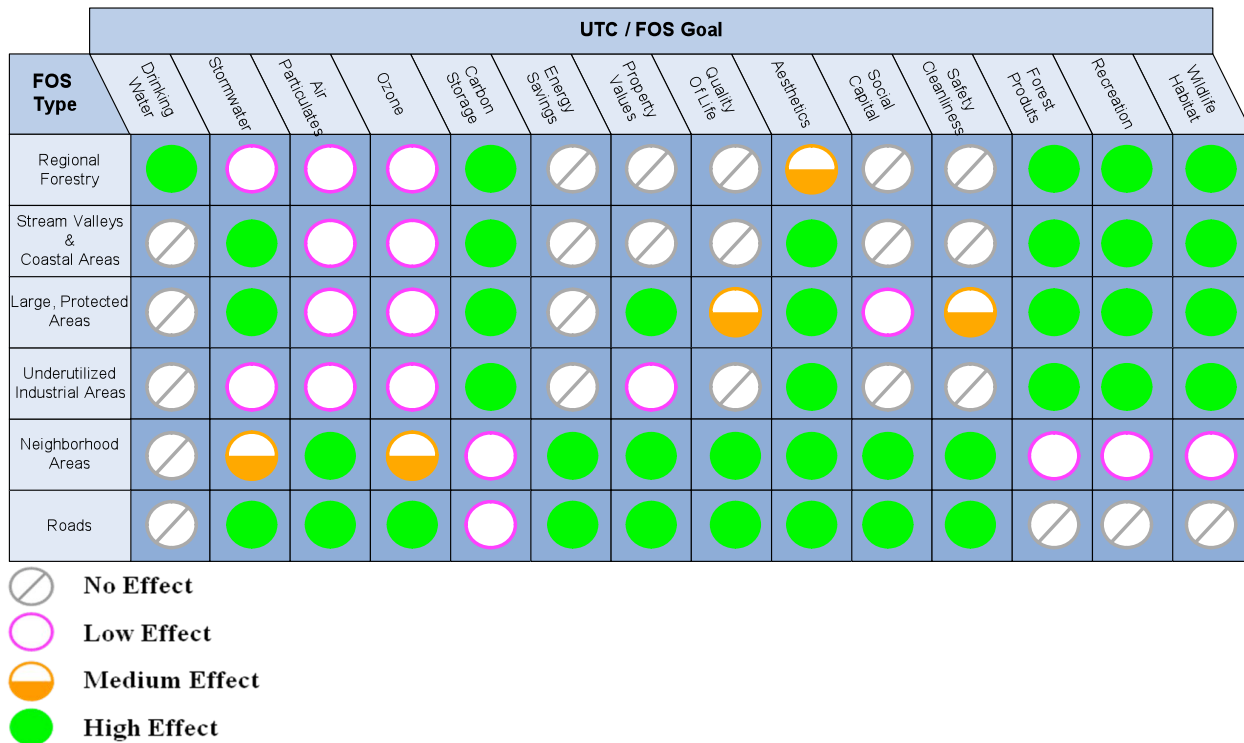


Figure 1. A Comparison of Forest Opportunity Types (Grove et al. 2005) and Urban Tree Canopy (UTC) Goals Highlights the Complementarity of UTC Goals (Raciti, 2006)

II. Variables

When prioritizing tree planting, organizations may wish to select certain criteria for systematizing their approach. This method allows for more comprehensive results while breaking up the otherwise large task into smaller, more manageable components. In this paper, we use the term “variables” to refer to measurements of specific components for individual analysis.

a. Selecting Variables

Choosing appropriate variables helps promote effective, efficient, and equitable tree planting prioritization plans. We believe that selecting variables that complement current government agency mandates or programs already underway helps prevent “reinventing the wheel.” Rather than launching new organizations focused around urban tree planting, it may prove easier and more practical to augment and enhance current programs in order to achieve existing programmatic goals. Another way agencies can further enhance their impact would involve collaborating with the wide variety of organizations that have an interest in tree planting. This type of cross-collaboration may become more popular and important as cities launch offices of sustainability. Thus, attention should also be paid to nonprofit organizations and other programmatic interests, as a mix of planting sites on private and publicly owned and managed lands will be necessary in order to achieve a diverse range of UTC goals.

An example of matching a current government mandate with a measurable benefit of urban forestry can be seen in planting trees along major transportation corridors in areas with low air quality. A well known and documented benefit of urban trees is their ability to absorb and

minimize the dispersal of air pollutants. The Environmental Protection Agency (EPA) has required that cities meet the National Ambient Air Quality Standards (NAAQS)—a level of air quality deemed acceptable. Therefore, trees could be planted strategically to improve air quality, and/or in places that contribute to poor air quality.

At a more localized level, block captains are charged with beautification of their neighborhood. Such community organizations may be interested in planting and taking care of trees not only for their aesthetic qualities, but also because urban trees have been shown to increase property values. Again, the point is to match programmatic interests with a specific benefit of urban forestry. This approach has the inherent benefit of amplifying the work already done by others. Additionally, this method can make “selling” the idea of urban forestry easier because trees are satisfying a need or want that has already been strategically targeted. For other examples of benefits of urban forestry, see Figure 1.

The above two examples expose the need for sufficient data for such program-oriented planting. The air quality example elicits the question, “Where are the areas that are in violation of their NAAQS?” Similarly, the second example leads us to ask, “Where are these block captains who are interested in improving the streetscape’s appearance?” These questions can be answered with proper data. Examples of urban forestry benefits and associated example datasets are presented in Table 1 and Figure 1. Figures 2 and 3 show high priority planting areas based on the need for trees to help mitigate hospitalizations from asthma at the city and borough level respectively.

Table 1. Examples of Urban Forestry benefits and potential associated datasets.

Benefits of Urban Forestry	Example Datasets
Air purification	<ul style="list-style-type: none"> • Points of known air pollution emission • Transportation corridors
Storm water management/purification	<ul style="list-style-type: none"> • National Hydrography Dataset (NHD) • National Wetlands Inventory (NWI) • Impervious surfaces
Urban heat island mitigation	<ul style="list-style-type: none"> • Surface temperature • Impervious surfaces • UTC
Building/increasing social capital and community connectedness	<ul style="list-style-type: none"> • Stewardship Networks and Mapping (STEWMAP)
Improving cityscape aesthetics	<ul style="list-style-type: none"> • Vacant lots
Wildlife habitat	<ul style="list-style-type: none"> • Parks • Existing UTC • Aerial imagery • ForeverWild sites • Ecological corridors
Carbon management	<ul style="list-style-type: none"> • UTC • Surface temperature
Increasing property values	<ul style="list-style-type: none"> • PLUTO • Census
Improved human health	<ul style="list-style-type: none"> • Asthma rates • Other detailed health data: obesity, mental health, etc.
Educational opportunities	<ul style="list-style-type: none"> • Schools • Community centers and gardens

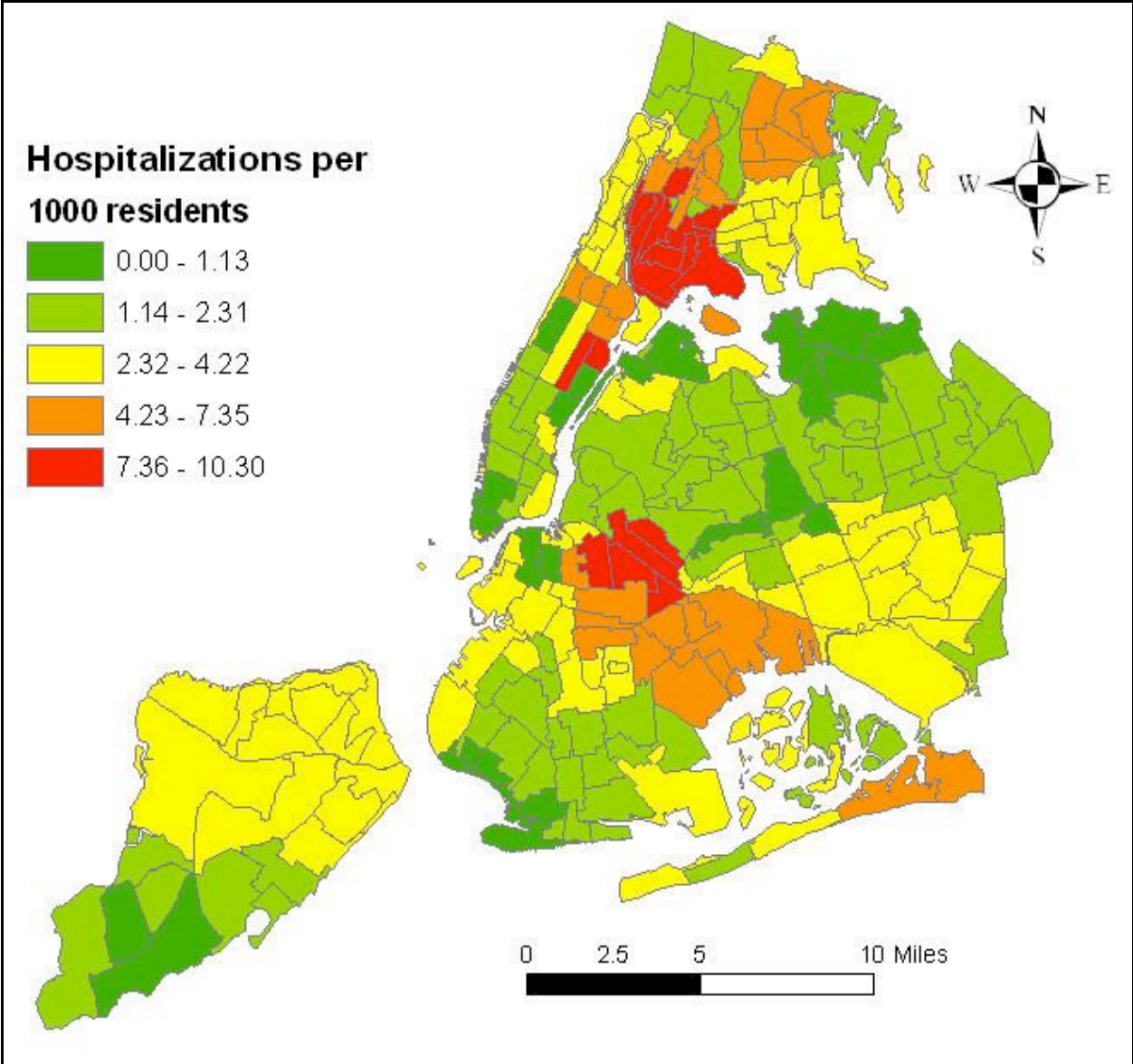


Figure 2. Citywide asthma rates measured in hospitalization rates per 1000 people.

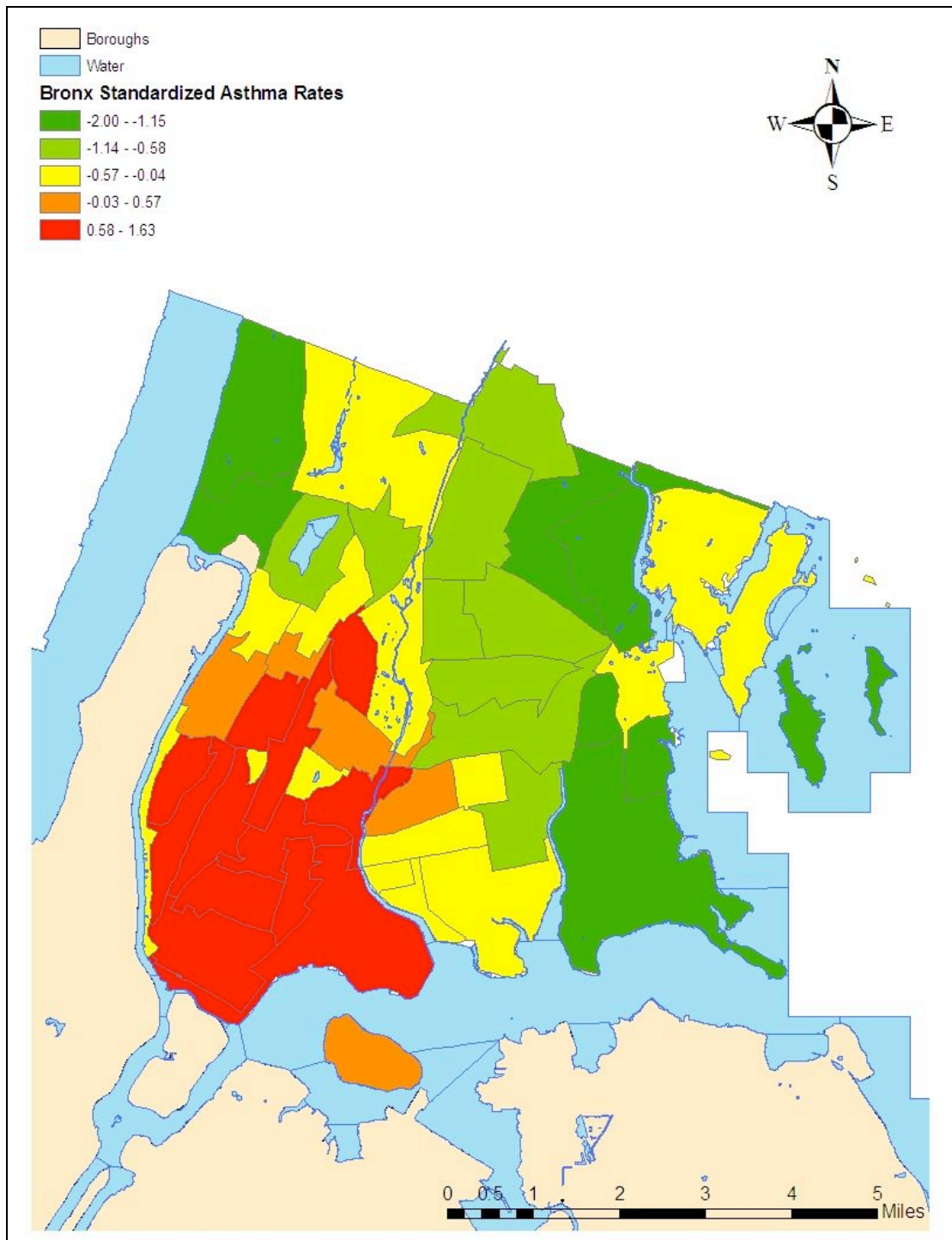


Figure 3. The Bronx and high priority planting neighborhoods based on asthma rates. Neighborhoods shown in red and orange reflect high rates of hospitalization and thus a high priority for tree planting. Map created by Kelly Goonan, David Seekell and Zac Nuse during the University of Vermont course “GIS Analysis of New York City's Ecology” class in the fall of 2008, using the average asthma hospitalization rates per 1000 people.

b. Types of Data

In the following section, relevant data for tree planting are classified into a flexible framework used for matching them to programmatic interests. Data are discussed and analyzed based on how they support variables that describe need-based and suitability-based criteria, and whether they refer to a primarily socioeconomic or biophysical characteristic.

Need-based criteria are used to identify whether the benefits of urban trees can address a current need. Examples include poor air quality, frequent or severe flooding, low access to green space, or high asthma rates. Working from the Three Ps framework developed by Grove et al. (2006), sites with high rankings in need-based criteria would be considered Preferable or desirable.

Suitability-based criteria are used to identify whether trees can be planted and are likely to survive. Examples include available planting space (like vacant lots), water availability (proximity/access to water), and the number of stewardship groups and their proximity to potential planting sites. Again, working from the Three Ps framework developed by Grove et al. (2006), sites with high rankings in suitability-based criteria would be considered Potential or likely.

Notice that air quality, flooding, planting space, and access are indicative of biophysical conditions; and access to green space, asthma rates, and the prevalence of stewardship groups pertain to social factors that influence tree planting. Data can therefore be described along these two dimensions simultaneously. The classification of need or suitability and biophysical or social data can help better match programmatic interests with tree planting when data are already collected and updated.

III. Data Sources

Rarely will all of the data required to conduct a needs-based or suitability-based criteria analysis come from one organization or department. A comprehensive analysis will require access to the full spectrum of data ranging from political boundaries to volunteered geographic information (Goodchild, 2007). Data can come from multiple sources. Individuals, private companies, and government agencies all collect pertinent data for tree prioritization. However, as abundant as this data may be, accessing it remains a challenge.

a. Data Challenges

Key issues: accessibility, accuracy, scalability, metadata, temporal issues, applicability, and maintenance.

As mentioned above, gaining access to specific necessary data can be a challenge. Some data, like health statistics, are regulated to protect privacy. This is, of course, if those data already exist. If not, data collection can be an expensive and time consuming task depending on the type of data sought. For example, an Urban Tree Canopy (UTC) assessment, which maps the location of the current and potential urban forest, can take months for a highly trained geospatial analyst to perform – and again that assumes that the input data sets are available. Finally, policies may exist that occasionally inhibit even the best intentioned programs from acquiring data valuable to the analysis. Patience and understanding can go a long way when trying to obtain needed datasets.

In addition to gaining access, another potential challenge is the quality of the data. The analysis for tree planting prioritization will only be as good as the quality of the data available.

Limitations may include data errors, out of date datasets, missing or inadequate metadata, and overall lack of organization of the data provided. Another limitation of data may be the scale at which it is collected. For example data collected at the citywide scale is significantly different from data that is sub-parcel. Issues surrounding the spatial scale of the data are a major consideration for the dataset's applicability for tree planting and prioritization. It is important for the analyst to consider the quality of the data provided, including the reliability of the source.

While this may sound discouraging, there is hope. Collectors of data, municipalities in particular, are increasingly investing in both the *quality* and the *quantity* of their spatial data. Additionally, the advances in GIS software and computer hardware have made analysis and data creation easier, faster, and more cost effective than ever before.

b. Derived Variables

While much data relevant for tree planting prioritization is collected, some is created using GIS. For example, public-right-of-way areas (PROW) were derived in the Grove et al. (2006) paper using an overlay process. This process used existing datasets, namely land cover, roads and buildings, to find the areas that are in the public domain and may be available for street tree planting. Once derived, these variables can be incorporated into the prioritization analysis.

Derived data can result from both spatial and temporal analysis and be based upon both socioeconomic and/or biophysical variables. Spatially derived variables include measures such as adjacent to ..., distance from ..., size, and shape. An example of a spatially derived variable would be the distance of residential parcels to public parks. This derived variable would help measure the relative success of the PlaNYC goal that every New Yorker lives within a 10-minute walk of a park by 2030 (The City of New York, 2009). Temporally derived variables could measure characteristics like rates of change or thresholds. An example would be the rate of change in home occupancy or property values, which could indicate a declining or gentrifying neighborhood.

IV. Integration of Variables and Analytic Tools

A major challenge of achieving a final prioritization scheme is integrating variables from different scales. For example, combining asthma rates – measured in hospitalizations per 1000 persons – and existing canopy cover – measured as the percent area with canopy cover – is problematic given the different scales and units of each variable. The following sections describe a method for converting data into values that can be directly integrated into the final tree planting prioritization scheme.

a. Standardization of variables

Converting data to *standard units* solves the problem described above. The resulting values, called *z-scores*, can be directly compared and integrated into a final prioritization map.

To convert data to standard units, calculate the *mean* and *standard deviation* for each variable. Once these values have been obtained, calculate the z-score by using the following formula:

$$\frac{n - \bar{x}_n}{SD_n}$$

where:

- n = the observed value of variable n
- \bar{x}_n = the mean of variable n
- SD_n = the standard deviation of variable n

Once all of the variables have been converted to standard units, they can be combined into a final z-score for each unit (e.g. neighborhood, parcel, etc.) being included in the final prioritization. This is done by simply adding up all of the z-scores and dividing by the number of variables being analyzed:

$$\frac{z_{asthma} + z_{canopy} + \dots + z_n}{n}$$

It is important to remember that not all variables reflect *increased* need or suitability. An example of this would be existing canopy cover. An area that already has a high percentage of canopy cover represents a low priority for tree planting, while an area with a lower percentage of canopy cover represents a high priority for planting. Conversely, an area with a high incidence of hospitalization due to asthma would reflect a high priority area for tree planting, whereas an area with lower hospitalization rates due to asthma would reflect a lower priority site.

When a high value of a variable represents a low priority for tree planting (such as existing canopy cover in the example given above), take the *inverse* value before calculating the z-score for that variable. The inverse of a value is n^{-1} .

b. Weighting of variables

The formula given above for calculating a z-score result in a final prioritization in which each variable is ranked equally. However, an agency or group may consider a specific variable, such as asthma rates, to be relatively more important than another variable, such as existing canopy cover. If this is the case, variables can be weighted according to their relative importance in meeting the overall canopy/tree planting goals. Simply multiply the z-score by a value reflecting the variable's relative importance. Make sure that the weighting values used add up to equal 1. An example is given below in Box 1.

It is important to keep in mind that some variables measure similar characteristics, like asthma rates and proximity to known point-sources of air pollution – they each capture an aspect of general air quality. Therefore, some needs-based criteria may become inadvertently double counted, and therefore potentially over weighted. Sub-weightings could subvert this problem. Another way to handle this issue would be to focus on just one surrogate measure.

Box 1. Example of weighting variables to reflect their relative importance in final prioritization.

ABC City has adopted a goal to increase its urban tree canopy cover to 45% by 2015. In order to achieve this goal, they must identify tree planting sites. For effective, efficient, and equitable planting, they have taken on the task of prioritizing city neighborhoods based on the following criteria: asthma rates, vacant land, nearby environmental stewardship groups, and possible canopy cover. ABC City has chosen to limit the number of variables to a concise, manageable list to prevent “double weighting” of related and correlated variables. The groups involved have decided that these criteria fall into the following order of relative importance:

1. Asthma rates
2. Possible canopy cover
3. Stewardship groups
4. Vacant land

To reflect their relative importance, the groups will weight each variable in the following manner:

- Asthma rates: 0.4
- Possible canopy: 0.3
- Stewardship groups: 0.2
- Vacant land: 0.1

The resulting formula for deriving the final prioritization (z-) scores is thus:

$$\frac{[(z_{asthma} \times 0.4) + (z_{canopy} \times 0.3) + (z_{stewardship} \times 0.2) + (z_{vacant} \times 0.1)]}{4}$$

One approach to collaborative decision making for prioritizing UTC areas would be to ask individual groups to develop their own citywide prioritization to identify areas that would greatly benefit from more trees. This could be done by selecting variables they think are important. Next, the resulting prioritization maps from each group could be weighted together based upon what each group thinks about its own relative importance. Then, the spatial results from each group’s prioritization, or maps, can be compared.

This whole process could then be repeated within high priority areas in a way that specifically addresses individual stakeholders’ reasons for planting, their planting needs, and constraints.

This approach is important for several reasons. First, it allows each group to share their goals and analytical process in a transparent and quantifiable way, which promotes learning among groups. Second, it enables groups to identify areas of common agreement. We suspect that, in most cases, the areas of common agreement will probably exceed the local capacity to enhance urban tree canopy. Thus, one course of action may be to plant those areas of common agreement first and reprioritize the remainder after the initial common sites are planted.

c. Final output — prioritization map

After calculating a final z-score for each unit (e.g. neighborhood, parcel, etc.), a final prioritization map can be generated. Using the z-score field and the map symbology feature, areas representing a high priority for tree planting become easily visible. These maps are very useful as they easily convey the combinations of variables under analysis in an easy to interpret, visual manner, and are an important first step in guiding the siting of tree planting projects and other means for increasing urban tree canopy cover.

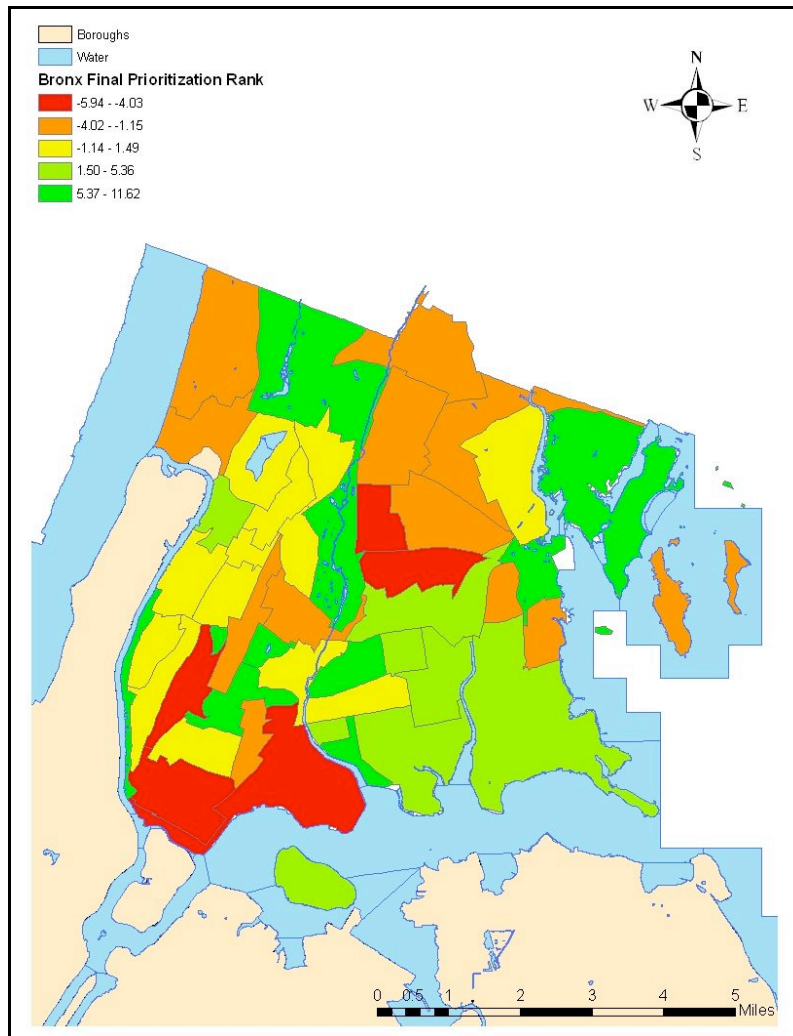


Figure 4. Final prioritization of Bronx neighborhoods based on an unweighted average of standardized asthma, vacant land, stewardship, vegetation cover, impervious surface, and possible UTC variables. Map created by Kelly Goonan, David Seekell and Zac Nuse during the University of Vermont course “GIS Analysis of New York City's Ecology” class in the fall of 2008.

d. Field validation of outputs

While the final prioritization map is an important product of analysis and tool for guiding next steps, field validation of the results is necessary – especially when the analysis and prioritization is done at the parcel/street level. Outdated or inaccurate data may cause an area on the map to appear highly attractive to tree planting when in fact it is not. Virtual validation can be done using recent aerial images or similar systems, such as Google™ Earth. This can provide a quick evaluation of a given site’s potential suitability for tree planting. Ultimately field validation in the form of a visit and inspection of the site is necessary before tree planting projects can be finalized. See Figure 5 for an example of an out-of-date vacant lots data and virtual validation.

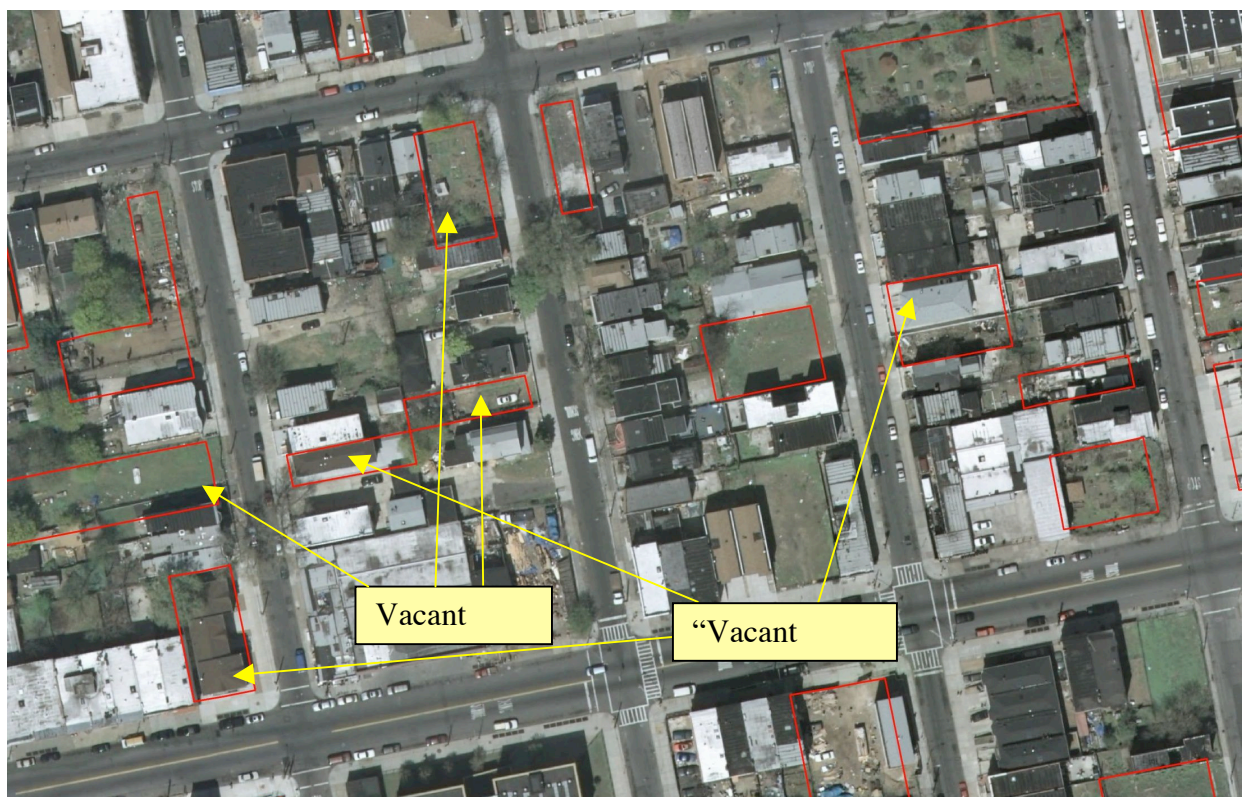


Figure 5. Virtual validation applied to outdated data in Brooklyn borough: the use of aerial imagery revealed that many lots identified as “vacant” in a 2003 PLUTO parcel dataset are no longer vacant. Created by Daniel Erickson, Michele Romolini, and Jiaxin Yu during the University of Vermont course “GIS Analysis of New York City’s Ecology” class in the fall of 2008.

IV. Lessons Learned & Conclusion

This report outlines potential methods and analysis for creating an urban tree planting prioritization plan. As with any citywide plan, this process has inherent complexities. Throughout the paper, the various challenges that arose during the development of this process were highlighted. By addressing these challenges at the outset, it is the intent that the future application of such an approach can become more streamlined and be improved.

First, it is important to recognize that this is a top-down approach. Numerous data are gathered from many different sources and distilled down to meet the needs of stakeholders working at a local level. It is recognized that this method may work best when informed by local knowledge of the landscape and more extensive field validation. In order to be successful, urban tree planting prioritization must be a collaborative effort.

Perhaps the greatest challenge foreseen is access to high quality, up-to-date data. For a truly comprehensive analysis, this will require developing, acquiring, and integrating data from multiple sources. It is also important to consider the timeliness of the analysis. An analysis of this type requires a strict timeline, as selecting specific sites for tree planting is time sensitive. Sites that are available for tree planting at any given time may not be available if the window between analysis and implementation is too long.

In conclusion, this approach can be a powerful and dynamic tool to assist cities in reaching their tree canopy goals. The flexibility in choosing and weighting variables lends itself to collaboration among diverse stakeholders, as certain variables can meet multiple social, ecological, and economic goals simultaneously. This allows governmental and non-governmental organizations to work together to meet individual needs as well as larger citywide mandates.

References

- Goodchild, M. F. (2007). Citizens as Sensors: The World of Volunteered Geography. *GeoJournal*, 69(4), 211-221.
- Grove, J.M., W. R. Burch and S.T.A. Pickett. 2005. "Social Mosaics and Urban Forestry in Baltimore, Maryland." Pp. 248-273 in *Communities and Forests: Where People Meet the Land*, edited by R. G. Lee and D. R. Field. Corvallis: Oregon State University Press.
- Grove, J. M., J. P. M. O'Neil-Dunne, K. Pelletier, D. J. Nowak and J. Walton (2006). A Report on New York City's Present and Possible Urban Tree Canopy. Prepared for Fiona Watt, Chief of the Division of Forestry & Horticulture. New York City's Department of Parks and Recreation, Northern Research Station, USDA Forest Service.
- Raciti, S., M. F. Galvin, J. M. Grove, J. P. M. O'Neil-Dunne, A. Todd and S. Claggett (2006). Urban Tree Canopy Goal Setting: A Guide for Chesapeake Bay Communities, United States Department of Agriculture, Forest Service, Northeastern State & Private Forestry, Chesapeake Bay Program Office, Annapolis, Md.
- The City of New York (2009). *PlaNYC 2030 – Open Space*. Retrieved from http://www.nyc.gov/html/planyc2030/html/plan/land_space.shtml

Acknowledgments

The methods presented in this report were developed as a collaborative effort between the three authors and the other students, the course instructors, and the representatives from New York City, as follows. Thanks to all!

A special thanks to our wise guides, Jarlath O'Neil Dunne and Morgan Grove, who provided us with encouragement, direction, and multiple edits.

University of Vermont students participating in the Fall 2008 "GIS Analysis of New York City's Ecology" course:

Loona Brogan
Michael Brown
Helen Carr
Katharine Duskin
Daniel Erickson
Zachary Nuse
Burton Putrah
David Seekell
Jiaxin Yu

Course Instructors:

Jarlath O'Neil Dunne, UVM Spatial Analysis Laboratory
J. Morgan Grove, USDA Forest Service
Austin Troy, UVM Spatial Analysis Laboratory

Collaborators from NYC:

Jessie Braden, New York City Department of Parks and Recreation
Lindsay Campbell, USDA Forest Service
Jackie Lu, New York City Department of Parks and Recreation
Erika Svendson, USDA Forest Service
Fiona Watt, New York City Department of Parks and Recreation

Appendix.

Methods for Calculating the Number of Trees in One Acre of Urban Tree Canopy

Prepared by:
Michael Brown

Introduction

Cities across the country are doing urban tree canopy assessments to determine what percentage of their city is tree canopy, as well as to set UTC goals to create healthier, more environmentally friendly, and aesthetically pleasing cities. After determining existing and future UTC goals, areas to plant trees need to be determined, as well as the number of trees to be planted to reach desired UTC goals.

There are three methods that will be presented in this paper to calculate the number of trees per acre of UTC. The three methodologies will help to determine an acceptable range of trees per acre for UTC. The amount of trees per acre of UTC will range depending on site specifics and tree species.

Method 1

Using tree canopy diameters to determine surface area of canopy, and calculate the number of plantable trees.

After current UTC and a target UTC are set, areas need to be chosen that are suitable to plant trees, on. These can include vacant lots, parkland, and private land. Once potential plantable land is determined, the total area should be determined. This figure can be taken and divided by the total area of the neighborhood, giving the percent UTC increase if those selected areas were planted. Figure 1 shows the amount of potential UTC increase in the Brownsville neighborhood in Brooklyn, New York.

	Acres	Percent
Existing UTC	115	15%
Possible UTC Increase on Vacant Land	18	3%
Existing UTC + Possible UTC on Vacant Land	133	18%

Figure 1. Shows the potential percent increase of UTC if all of the available vacant land in the neighborhood was planted with trees.

To calculate the total number of trees that can be planted on a specific area, specific tree species need to be chosen. This depends on a number of variables, a good resource is Northern Trees¹, outlining heartiness zones, longevity, pests, and the shapes, heights and crown spreads of individual species. Tree species can be chosen on Northern Trees by common or scientific name,

¹ <http://orb.at.ufl.edu/TREES/index.html>

as well as by specific site characteristics. Another good resource for tree selection and information is the USDA Forest Service’s *Silvics Manual of North America*².

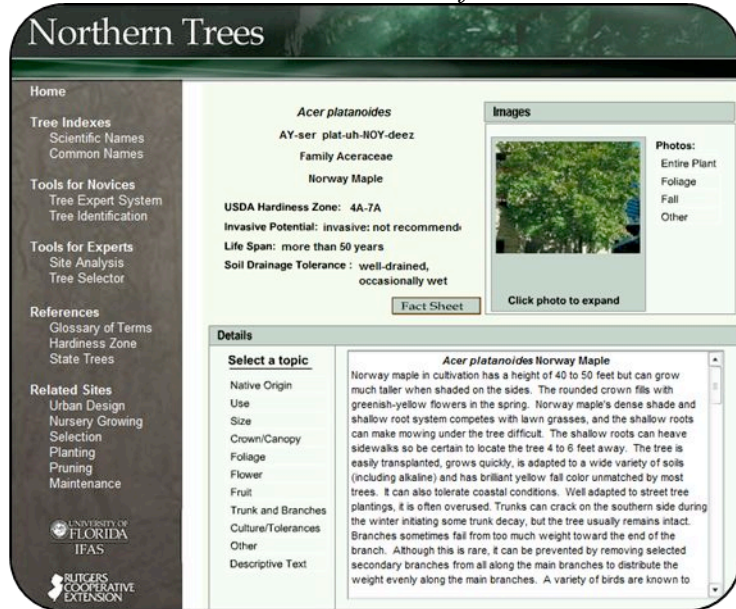


Figure 2. A screen grab of Northern Trees



Figure 3. Screen grab from the USDA Forest Service’s *Silvics Manual of North America*.

By taking the average diameter of a certain tree species, the surface area that the mature canopy covers can be calculated by using $A = \pi r^2$. The area of potential plantable land can be divided by the surface area of individual trees, giving the total number of trees that can be planted in a specific area. Make sure the area of the tree canopy and plantable land are both in the same units. See figure 4.

² http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm

$$(\pi)(20^2)=1256 \text{ feet}^2$$

Figure 4a. Using $A = \pi r^2$, area of a circle, yields the surface area covered by a mature tree canopy.

$$784,080 \text{ feet}^2 \div 1256 \text{ feet} = 624 \text{ trees}$$

Figure 4b. Dividing the total amount of land available, 18 acres (Converted to feet²) divided by the surface area of the tree canopy yields the number of trees that can be planted.

Calculating the number of trees that can be planted on a certain piece of property can be helpful for project logistics and budgeting, and when trying to achieve a certain amount of trees planted, or reach a UTC goal.

Tree Species	Diameter of Crown(feet)	Surface area of Canopy(feet ²)	Total Plantable Trees
Norway Maple	40	1256	624
Pin Oak	40	1256	624
Honey Locust	50	1962	400

Figure 5. Showing the conversion of tree canopy size to plantable trees per acre.

This ends up giving us approximately 35 trees per acre for Norway Maple and Pin Oak, and 22 trees per acre for Honey Locust.

Method 2

Developed and used by the Maryland DNR and Mike Galvin of Casey Trees, uses existing reforestation standards from the Mid-Atlantic, giving all trees the same average size canopy to simplify planning.

This method uses 24 feet as the average tree canopy diameter, yielding 100 trees per acre. This formula has been used by the Maryland DNR for years, and fits into regulations across the region. The numbers are also easy to translate into acres, since if someone plants 50 trees, that could be considered 0.5 acres of UTC.

Diameter of Crown(feet)	Surface area of Canopy(feet ²)	# Trees Per Acre
24	452	100

Figure 6. The ratio of # of trees per acre when using an average diameter of 24 feet as used by the Maryland DNR.

A 6 percent mortality rate is incorporated into the model, that Dave Nowak came up with, so to achieve 100 percent of a UTC goal, 106 percent should be what is aimed for. So for one acre of UTC, 106 trees should be planted, planning on 100 surviving.

Method 3

Field data collected in New York City was used to determine the average canopy diameter and surface area of street trees collected in August of 2005 by the Davey Resource Group.

The data was collected by using coring data and crown diameters on trees that were approximately 30 years old. The trees used in the inventory ranged from a minimum DBH of 15 inches to 21 inches and greater. The city wide crown diameter was 37.67 feet, averaged from 1,229 trees.

Diameter of Crown(feet)	Surface area of Canopy(feet²)	# Trees Per Acre
37.37	1096	39

Figure 7. The surface area and trees per acre of the average street tree in New York City. These numbers do not take into account for mortality or variation among species, but it does give real world field data that gives a nice average that could be worked with.

Conclusion

These calculations can help to give definitive answers to how many trees can be planted and what the expense will be to increase UTC by a certain percent in an area. The three methods were shown as there is no single method being used by cities, as the numbers are still being experimented with to come up with the most accurate and easy to replicate model.