Cities and the Environment
2010 Volume 3, Issue 1 Article 4

Prioritizing Preferable Locations for Increasing Urban Tree Canopy in New York City

Dexter H. Locke, J. Morgan Grove, Jacqueline W.T. Lu, Austin Troy, Jarlath P.M. O'Neil-Dunne, and Brian D. Beck

Abstract

This paper presents a set of Geographic Information System (GIS) methods for identifying and prioritizing tree planting sites in urban environments. It uses an analytical approach created by a University of Vermont service-learning class called "GIS Analysis of New York City's Ecology" that was designed to provide research support to the MillionTreesNYC tree planting campaign. These methods prioritize tree planting sites based on need (whether or not trees can help address specific issues in the community) and suitability (biophysical constraints and planting partners' existing programmatic goals). Criteria for suitability and need were based on input from three New York City tree-planting organizations. Customized spatial analysis tools and maps were created to show where each organization may contribute to increasing urban tree canopy (UTC) while also achieving their own programmatic goals. These methods and associated custom tools can help decision-makers optimize urban forestry investments with respect to biophysical and socioeconomic outcomes in a clear and accountable manner. Additionally, the framework described here may be used in other cities, can track spatial characteristics of urban ecosystems over time, and may enable further tool development for collaborative decision-making in urban natural resource management.

Keywords

Urban Forestry; UTC; urban tree canopy; possible; preferable; geographic information systems; GIS; trees; green space; vegetation.

Locke, D.H., M.Grove, J.W.T. Lu, A. Troy, J.P.M. O'Neil-Dunne, and B. Beck. 2010. Prioritizing preferable locations for increasing urban tree canopy in New York City. Cities and the Environment 3(1):article 4. http://escholarship.bc.edu/cate/vol3/iss1/4. 18 pp.

INTRODUCTION

MillionTreesNYC is one of 127 initiatives of PlaNYC, a program launched in April 2007 to "create the first environmentally sustainable 21st century city" (www.nyc.gov/2030). MillionTreesNYC was created in recognition of the well-documented environmental, social, and economic benefits of urban trees. The MillionsTreesNYC initiative's goal-setting was largely based on an analysis of New York City's tree canopy by Grove et al. (2006). This analysis introduced the "Three Ps" framework (Possible UTC, and Preferable UTC, and Potential UTC). Possible UTC is non-road, non-building, and non-water land, essentially where it is biophysically feasible to plant trees. Preferable UTC considers where it is socially desirable to plant trees (both needed and suitable) as discussed below and is the focus of this paper. Finally, Potential UTC is focused on the economic feasibility of tree planting based on available incentives and cost-effectiveness. Methods for calculating Potential UTC is the subject of future research and policy development.

In general, public agencies can enhance their impacts by collaborating with other organizations that have an interest in tree planting. This type of cross-collaboration is becoming more popular and important as cities launch offices of sustainability and continue comprehensive urban environmental planning. Furthermore, urban environmental stewardship throughout the Northeastern U.S. is increasingly carried out by hybrid organizations – those that contain members from civil society, government and business sectors (Svendsen and Campbell, 2008). As Grove et al. (2006) have pointed out, 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.

This paper addresses Preferable UTC and offers decision support for three city stakeholder groups – New York City Department of Parks & Recreation's Natural Resources Group and Central Forestry & Horticulture division, and the not-for-profit organization New York Restoration Project. Here we outline a method for strategically identifying and prioritizing sites for tree-planting in urban environments using biophysical and socio-economic criteria chosen by leaders of stakeholder organizations working on the MillionTreesNYC campaign. This method optimizes urban forestry investments with respect to biophysical and socioeconomic benefits and constraints. Special attention is paid to the specific programmatic interests of stakeholder organizations and how each planting partner can contribute to increasing urban tree canopy (UTC) as a way to achieve their own particular goals.

The analytical framework explained and applied in this paper is relatively straightforward. It addresses the question: How can society achieve the most benefits per newly planted tree? To answer that larger question, two smaller questions are addressed. Where are the areas in need of tree planting, and where are areas that are most suitable for different organizations with different goals? The tools outlined in this paper can help advance New York City's goal of achieving 30% UTC by 2030.

APPROACH

GIS data relevant for tree planting were classified into a flexible framework used for matching variables to programmatic interests. Here the term "variables" refers to measurements of specific components for individual analysis (see Table 1 for chosen variables). Data are discussed and analyzed based on how they support variables that describe need-based (Tier 1) and suitability-based (Tier 2) criteria. Tier 1 criteria are calculated and synthesized at the neighborhood level, using the New York City Department of City Planning definitions and data. Tier 2 criteria are computed and synthesized at the parcel level—Tier 2 criteria are specific to each organization, e. g. Natural Resources Group, New York Restoration Project, and Central Forestry & Horticulture. Finally, Tiers 1 and 2 are combined to create a set of parcel rankings for each stakeholder group – which identify areas where both the benefits of trees are needed and planting sites suitable for each organization's programmatic goals. The resulting combined rankings are then displayed in maps.

Table 1. Tier 1 – Need-based Criteria used for Urban Tree Canopy (UTC) Preferability Analysis. Clusters were created to prevent inadvertent overweighting of variables in the combined analysis. Variables are measurements of specific components for individual analysis, whose rationale for inclusion and associated data are shown.

Cluster	Variable Chosen	Rationale	Datasets Used for Analysis	Literature Cited
Air Quality/Noise Pollution	Major Road Density	Planting trees in high traffic volume areas may mitigate some air pollution impacts. Major road density is used as a surrogate for traffic induced air and noise pollution.	Major Roads	(Akbari et al. 2001; Nowak, 2002; Nowak et al. 2006)
Biodiversity	Ecological Corridor Density	Planting trees along and near ecological corridors will increase connectivity (the degree to which the landscape permits movement from patch to patch).	Ecological Corridors	(Fernandez-Juricic, 2000; Rudd et al. 2002)
	Existing Habitat Density	Planting more trees in and near areas of existing habitat may improve the quality of the habitats and better integrate them into the surrounding landscape.	Natural Areas, Preserves, DEC Freshwater Wetlands	(Fernandez-Juricic, 2000; Rudd et al. 2002)
Public Health	Percent Sedentary Population	Public health may be improved by planting trees. This data identifies areas of poor health.	Census block group, Department of Health and Mental Hygiene Statistics	(Bell et al. 2008; Jackson, 2003; Lovasi et al. 2008; Mitchell and Popham, 2008; Takano et al. 2002)
	Percent Obese Population			
	Percent Diabetic Population			
	Percent Population Hospitalized from Asthma			

(Continued)

Table 1. *Continued.*

Cluster	Variable Chosen	Rationale	Datasets Used for Analysis	Literature Cited
Water	Flood Density	Planting trees may ease the burden on existing infrastructure. This data identifies flooding hotspots.	Service requests from flooding	(Beattie et al. 2000; Nowak et al. 2007)
	Percent Impervious Surface	Planting trees reduces impervious cover which may reduce flooding and summer heat.	High resolution land cover data	(Raciti et al. 2006, Nowak et al. 2007)
Urban Heat Island	Maximum Average Surface Temperature	Trees are known to lower surface air temperatures. This data will identify areas of high temperature that could benefit from tree planting.	Remotely sensed surface temperature derived from Landsat	(Rosenfeld et al. 1998; Akbari et al. 2001; Nowak, 2002; Streiling and Matzarakis 2003; Akbari and Konopacki, 2005; Nowak et al. 2007)
Socioeconomic	Income	Trees provide positive impacts such as community empowerment and neighborhood beautification. This data will identify neighborhoods of low income and/or high crime.	Census block group	
	Crime		Census block group, CrimeRisk	(Kuo and Sullivan, 2001; Lidman, 2008; Troy and Grove, 2008)

Tier 1 values are used to assess whether urban trees can help address a neighborhood's current needs. High Tier 1 values denote areas lacking many of the benefits that trees could provide. Areas that experience frequent flooding and high summer surface temperatures, for example, have a greater need for additional trees because trees play an important role in absorbing water during storm events (Beattie et al. 2000; Nowak et al. 2007), and reducing the urban heat island effect (Rosenfeld et al. 1998; Akbari et al. 2001; Nowak, 2002; Streiling and Matzarakis 2003; Akbari and Konopacki 2005; Nowak et al. 2007). High rankings in need-based criteria indicate Preferable areas to plant trees in the Three Ps framework developed by Grove et al. (2006).

Tier 2 values are calculated to identify areas that are suitable for planting based on a particular organization's programmatic interests and the site types they focus on (i.e. street trees versus backyard trees). High Tier 2 values denote areas that are most suited for a particular organization because the site type fits their mission or mandate. Examples include areas in and around existing protected habitats and natural areas for Natural Resources Group and private land for New York Restoration Project. Again, working from the Three Ps framework developed by Grove et al. (2006), sites with high rankings in suitability-based criteria would be considered Preferable planting areas. Low suitability implies greater constraints to tree establishment or long-term survival, either in terms of site conditions or stewardship.

Tier 1 and 2 analyses were conducted with tools in a ModelBuilder environment within ArcMap (ESRI 2009). This allows analyses to be repeated quickly and easily. Criteria datasets such as the U.S. Census, land cover and public health measures are periodically updated over time; the tools can be rerun in the future with new data to produce updated rankings and cartographic products.

Variables Analyzed

Selection of variables for the analysis is closely tied to programmatic goals of city agencies and other organizations. Choosing appropriate variables helps promote effective, efficient, and equitable tree planting prioritization plans. Using variables that complement current government agency mandates or programs already underway helps prevent "reinventing the wheel." The variables chosen and analyzed here for Tier 1 (need-based criteria) are listed in Table 1.

We created columns for each variable in ArcMap (ESRI 2009) that enumerate each variable at the neighborhood level. Figures 1 and 2 are examples of individually mapped variables. Figure 1 shows how we use data on flood reports received at the 311 Call Center to identify priority neighborhoods for tree planting based on the need for trees to help minimize storm water floods. Figure 2 illustrates the process for prioritizing tree planting sites to reduce urban heat island effects, using Landsat-derived surface temperature data. Both of these variables are mapped at the neighborhood scale and were colored based on a ranking of the data values.

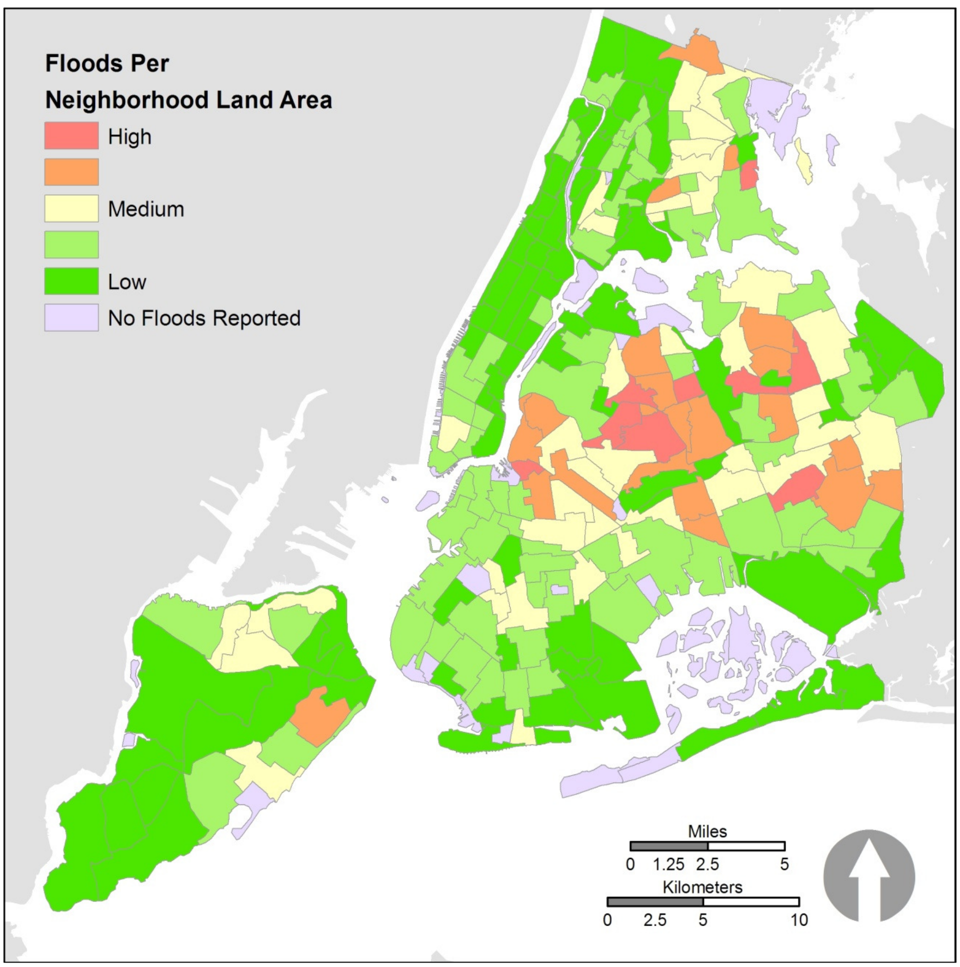

Figure 1. The number of calls to the 311 Call Center, New York City's non-emergency reporting hotline from September 8, 2004 to April 15, 2007 reporting floods, normalized by neighborhood area. Neighborhoods shown in red have higher flood reporting rates and a higher need for tree planting.

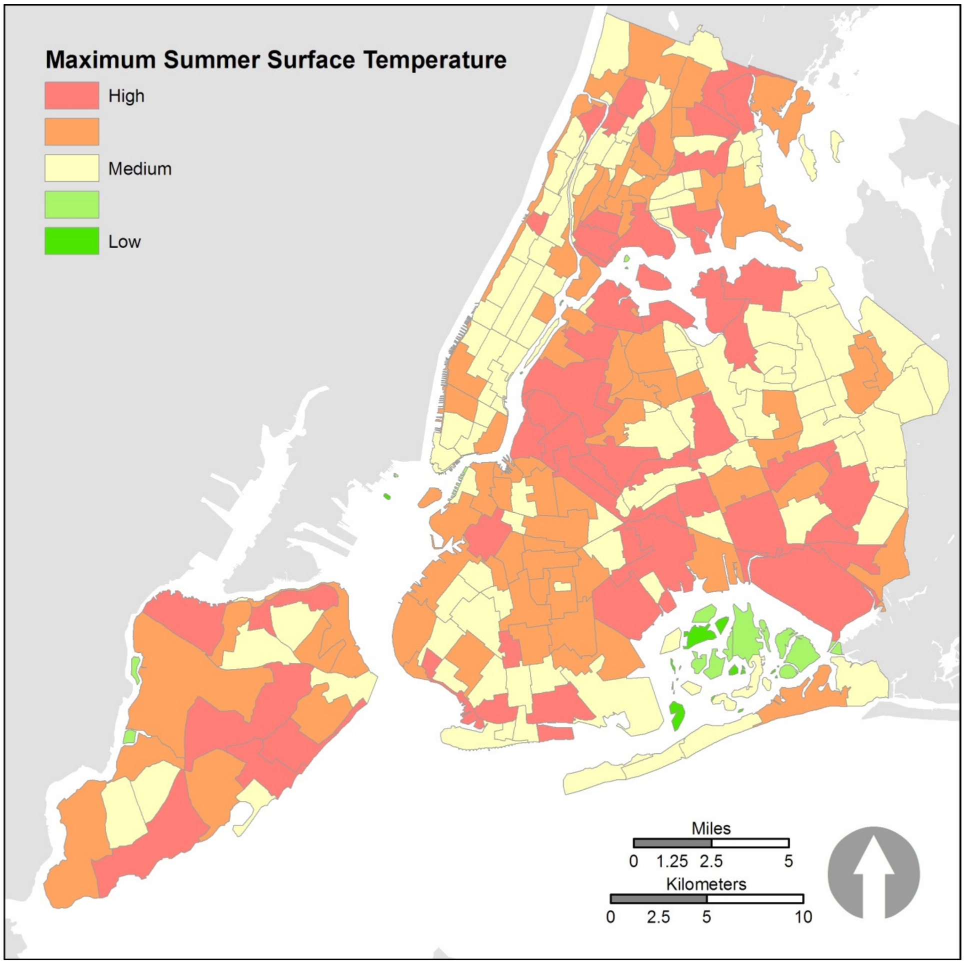

Figure 2. Maximum Average Summer Surface Temperature per Neighborhood, data acquired from Landsat (NASA, 2002). Neighborhoods shown in red are hotter in the summer and therefore have a higher need for tree planting.

Data Sources, Challenges and Opportunities

The data required to conduct a need-based or suitability-based analysis will almost never be available from a single organization or department. Individuals, private companies, and government agencies all collect pertinent data for tree planting prioritization and, as abundant as this data may be, accessing it remains a challenge. This analysis required access to the full spectrum of data ranging from political boundaries to volunteered geographic information (Goodchild 2007), like 311 service requests for flooding.

Some data may not exist in a usable format and data generation can be expensive and time-consuming. For example, it can take months for a highly trained geospatial analyst to perform an Urban Tree Canopy (UTC) assessment that maps the location of the current and potential urban forest – assuming that the input data sets are available at all. Finally, policies may exist that inhibit even the best-intentioned programs from acquiring data valuable to the analysis. Some data, like health statistics, are regulated to protect privacy. Patience and understanding can go a long way when trying to obtain needed datasets.

Another potential challenge is data quality. Limitations may include data errors, out-of-date datasets, missing or inadequate metadata, and overall lack of organization in the available data. For example, Figure 3 shows parcels that are misidentified as vacant in the NYC parcel database called “PLUTO” (primary land use tax lot output). Another problem may be the incongruent geographic boundaries among datasets or even within the same dataset. For example the Department of Health and Mental Hygiene (DOHMH), which provided data for calculating a public health index, collects their data in geographies that aggregate zip codes while minimum average household income and CrimeRisk data are organized by U.S. Census block groups. Zip code and U.S. Census block group polygons do not align. Issues related to the spatial resolution of the data are a major consideration for the dataset’s applicability for tree planting and prioritization.

Figure 3. Virtual validation using orthorectified photographs taken in 2006 reveals out-of-date or inaccurate data in Brooklyn: the use of aerial imagery revealed that many lots identified as “vacant” in a 2003 PLUTO parcel dataset are no longer vacant. Image adapted from a graphic created by Daniel Erickson, Michele Romolini, and Jiaxin Yu for the University of Vermont course “GIS Analysis of New York City's Ecology” class in the fall of 2008, which provided much of the foundations for this analysis.

METHODS: INTEGRATION OF VARIABLES AND ANALYTIC TOOLS

Tier 1 Criteria Explained

Air Quality/Noise Pollution - Trees improve air quality directly and indirectly by reducing ambient air temperatures, removing air pollutants and by reducing the energy demand from cooling buildings (Akbari et al. 2001; Nowak 2002; Nowak et al. 2006). A 1997 UFORE analysis estimated that the pollution removal from New York City’s urban forest removed 2,202 short tons/year of air pollution valued at $10.6 million/year (Nowak et al. 2007). Major road density is used as a surrogate measurement of vehicular air and noise pollution. The length of all major road segments per neighborhood are summed and divided by the area of the containing neighborhood. Neighborhoods without major roads are left null. Neighborhoods with more major transportation corridors have higher values, indicating greater Preferability for tree planting.

Ecological Corridor Density - Planting trees in, around, and in between ecological corridors helps increase landscape connectivity, improving the ability for urban wildlife like birds to move throughout the otherwise harsh urban matrix (Fernandez-Juricic 2000; Rudd et al. 2002). The sum of the ecological corridor areas (as defined by planning, design and environmental engineering firm EDAW) normalized by neighborhood land area are used to measure the need for planting. Areas with higher values are prioritized for tree planting because additional trees may improve the viability of the corridor for certain species, and help support patch to patch movements. Neighborhoods without ecological corridors are left null.

Existing Habitat Density - The rational for planting trees in and around existing protected wildlife habitats is similar the reasoning behind the Ecological Corridor variable. Planting trees in and adjacent to these protected open spaces may improve the quality of the habitat and better integrate them into the surrounding landscape for certain species (Fernandez-Juricic 2000; Rudd et al. 2002). NYC Parks' Natural Areas and Preserves, and New York State's Department of Environmental Conservation Freshwater Wetlands data were merged together and their combined area normalized by neighborhood land area. Again, higher values indicate greater potential for habitat enhancement and therefore greater Preferability for tree planting, and neighborhoods without existing habitats as defined above are left null.

Public Health variables - Several studies have shown a positive correlation between public health and access or proximity to trees and green space in urban areas (Takano et al. 2002; Jackson 2003; Bell et al. 2008; Lovasi et al. 2008; Mitchell and Popham 2008). Community health is measured with four related variables: the percent of the neighborhood population that is (1) sedentary, (2) obese, (3) diabetic and (4) hospitalized because of asthma in 2006. This set of measurements identifies areas of the city with higher proportions of residents in poor health. Because the health data were collected at different geographies (conglomerates of zip codes) than the summary neighborhoods (conglomerates of U.S. Census block groups), these estimates were created by disaggregating zip code data and reaggregating afflicted population percentages in the corresponding Neighborhood geography using an area weighted method. Higher values indicate greater Preferability for planting.

Flood Density - Planting trees and reducing impervious cover may ease the burden on existing infrastructure due to flooding (Beattie et al. 2000; Nowak et al. 2007). We represented this tree planting need using the number of geocoded 311 calls about floods in each neighborhood and normalized by area to quantify storm water events per neighborhood. These data identify areas where the infrastructure may be under stress and at risk of future flooding. Higher values indicate greater Preferability for tree planting.

Percent Impervious Surface - Reducing impervious surfaces and planting trees improves water quality and can reduce flooding by reducing runoff speeds, improving the infiltration of water, by absorbing nutrients and evapotranspirating water into the atmosphere (Raciti et al. 2006; Nowak et al. 2007). The percentage of neighborhood land area that is impervious is used to measure the need for tree planting, where higher values indicate greater Preferability.

Urban Heat Island - Trees are known to reduce the urban heat island effect (UHI) by intercepting incoming solar radiation, reducing impervious surfaces which often store and emit heat, and they evapotranspirate which cools the local air (Rosenfeld et al. 1998; Akbari et al. 2001; Nowak, 2002; Streiling and Matzarakis 2003; Akbari and Konopacki, 2005; Nowak et al. 2007). The urban heat island is measured using the average of Landsat-derived surface temperature from July 22nd, August, 14th, and September 8th 2002. Then the mean and maximum surface temperature in each neighborhood are calculated to measure the urban heat island effect. These data identify areas where trees can be planted to reduce summer surface temperature, and therefore help mitigate the urban heat island. Higher values indicate greater Preferability for tree planting.

Income - Trees are planted to improve the local urban environment and improve the quality of life for all urban dwellers. Interested in investigating environmental justice issues and targeting underserved communities, tree planting organizations asked that income be used to help prioritize plantings. Unlike the other variables used where greater values indicate higher priority, lower values of median household income indicate greater Preferability.

Crime - Trees impact criminal activity through structural, functional, and symbolic mechanisms. Kuo and Sullivan (2001) documented lower levels of fear, and aggressive and violent behaviors in areas with more vegetation. Furthermore they found that crime rates were lower in areas with more abundant vegetation, and lowest in open grassy areas with large canopy trees, where the trees do not provide hiding places for criminal activity. Lidman (2008) builds off of Kuo and Sullivan's work and found that certain types of vegetation structure and appearance play a role in the crime-vegetation relationship in Baltimore, Maryland. Specifically, well maintained vegetation that appeared to signify cared-for landscapes were associated with lower crime rates. Better maintained urban landscaping appears to signify higher levels of social organization and ownership. Troy and Grove (2008) showed how tree dominated landscapes like urban parks add value to nearby properties, but only when the criminal activity in these parks is below a particular threshold. In other words, the contribution of urban parks as an amenity (or disamenity) to property values is conditioned by the level of crime in that area, with higher crime rates diminishing adjacent values. The Total Crime Index from the national CrimeRisk database obtained from Applied Geographic Solutions (now Tetrad, Inc www.tetrad.com) is averaged per neighborhood to represent the need for more trees in our analysis. Higher values indicate greater Preferability for tree planting.

Standardization of Variables

Because the variables used to measure need- and suitability-based criteria rarely use the same scales, each variable needs to be standardized before a successful integration can occur. For example, floods per neighborhood range from 0 to 371, average maximum summer surface temperature ranges from 83 to 110, and measures of public health are expressed as percentages. To convert data to standard units, the *mean* and *standard deviation* for each variable were calculated. Next, those values were used to calculate the z-score using the following formula:

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

Where *n* is the observed value of variable n, $\bar{x}_n$ is the mean of variable n, and SD_n is 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 variable. This is done by simply adding up all of the z-scores and dividing by the number of variables being analyzed. If a particular variable was null, then n was reduced to reflect the non-applicability of that variable for that place.

$$\frac{Z_a + Z_b \ldots + Z_j + (-1 \times Z_k) + Z_l}{n}$$

Where Z = z-score of variables *a, b, c… l*, and n = number of z-scored variables
Some z-scores are multiplied by negative 1 when a high magnitude corresponds with a low priority. An example from this analysis is minimum median household income. In order to address environmental justice concerns, an area with low average minimum income represents higher priority for tree planting, while an area with a high income represents a lower priority for planting. Conversely, an area with high summer temperatures would reflect a high priority area for tree planting and an area with lower temperatures would reflect a lower priority site.

Weighting of Variables

The formula given above for calculating z-scores creates a final prioritization ranking in which each variable is ranked equally. However, some Tier 1 criteria variables measure similar characteristics or different components of the same thematic cluster. Therefore, some Tier 1 variables may become inadvertently double-counted, and potentially overweighted. Sub-weightings correct this problem. Two Tier 1 rankings were created for this analysis, one where each variable was weighted equally and a second where each variable cluster (Table 1) was weighted equally. For example, percent sedentary, obese, diabetic and hospitalized asthmatics collectively constitute a public health cluster. Each of the four public health variables was assigned a weight of ¼ to give the overall public health cluster an equal weight to other "need" variables. The difference between the, unclustered and clustered weighting methods can be seen in Figure 4. The formula used for clustered analysis is:

$$\frac{Z_a + \left(\frac{Z_b + Z_c}{n_\alpha}\right) + \left(\frac{Z_d + Z_e + Z_f + Z_g}{n_\beta}\right) + \left(\frac{Z_h + Z_i}{n_\gamma}\right) + Z_j + \left(\frac{(-1 * Z_k) + Z_l}{n_\delta}\right)}{q}$$

Where $a, b, c \ldots l$ = measure of need-based criteria, Z = z-score of variables a, b, c… l, n = number of variables in associated cluster $\alpha, \beta, \gamma, \delta$ (biodiversity, public health, water, socioeconomics, respectively), and q = number of variables

Final Output — Tier 1 Prioritization Map

After calculating a final z-score for each unit (e.g. neighborhood, parcel, etc.), a final prioritization ranking map was generated. Whether using the unclustered and clustered z-score fields, areas representing a high priority for tree planting become easily visible (Figure 4).

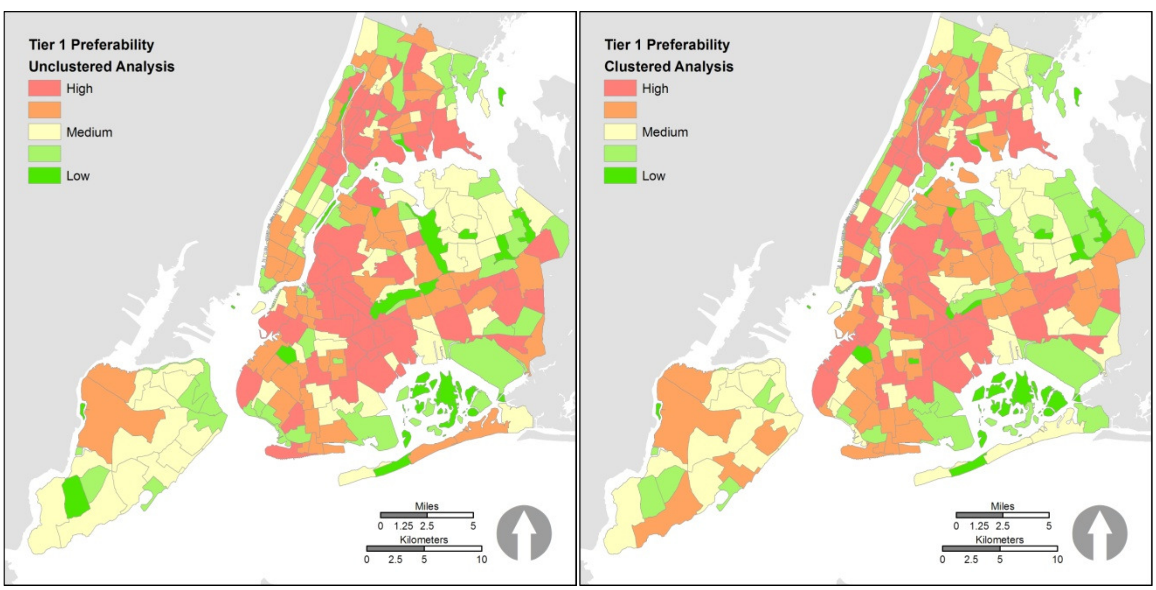

Figure 4. The panel on the left shows a version of Tier 1 where all variables found in Table 1 are weighted equally (unclustered). The panel on the right shows the same variables found in Table 1 where each thematic cluster is weighted equally. All variables are summarized at the neighborhood level.

Tier 2 Methods and Integration

Once all neighborhoods were ranked based on their need based criteria, three separate selections were performed to find parcels suitable for each planting partner – Natural Resources Group, New York Restoration Project, and Central Forestry & Horticulture. Parcels were selected based on criteria that are aligned with each organization's reasons for planting, their mandate or mission, and constraints – or what is collectively referred to as their "focal type." Selected parcels were then analyzed using Forest Service's Forest Opportunity Spectrum Toolbox – specifically, the UTC toolbox created by Jarlath O'Neil-Dunne and Brian Beck of the University of Vermont's Spatial Analysis Lab. The UTC tools were used to compute Possible UTC – that is, area that is not a road, a building, water, or existing canopy using zonal function in ArcGIS (ESRI 2009). Then, parcels were ranked based on their Possible UTC. Finally, two new ranks were computed, one based on the unclustered neighborhood rank and one based on the clustered rank. Parcels were given a final rank which was the neighborhood rank followed by a decimal, followed by the parcel rank behind the decimal (Figure 5).

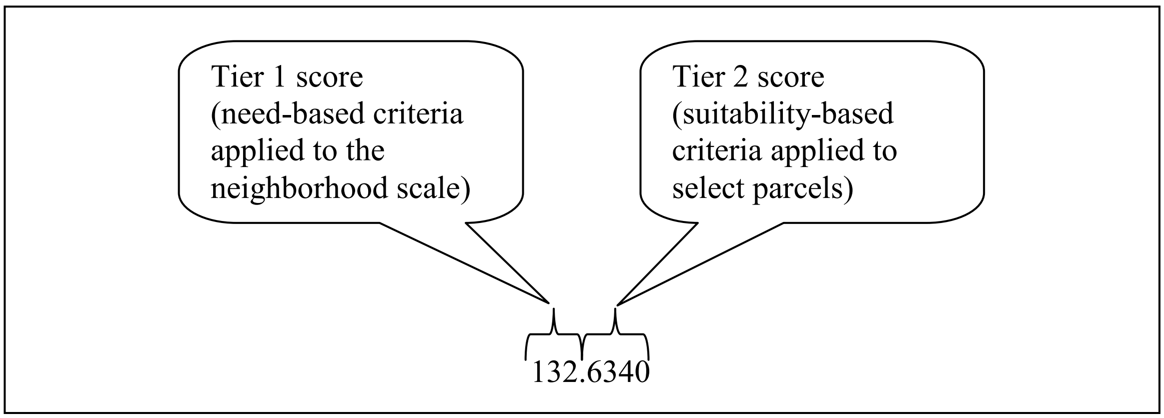

Figure 5. Showing how Tier 1 and 2 are integrated. An urban forester would interpret this as the 132nd neighborhood and the 6340th parcel in that particular neighborhood. A score of 1.1 would be the highest priority parcel in the highest priority neighborhood.

Natural Resource Group's focal type was defined as those parcels greater than 10 acres and publicly owned. The airports and Central and Prospect Parks were excluded. Some golf courses fill the entire parcel, in which case they were simply excluded, while other golf courses are only a part of the parcel. In these cases the golf courses were erased out, creating new polygons that contained other possible planting sites, but not the course. Each of the 14 courses was manually inspected using aerial imagery to determine which type it was. Once all 10 acre or greater parcels with the above mentioned exceptions were selected, a modified possible UTC analysis was run, where park features such as basketball courts, baseball fields, volleyball courts, and other active recreation resources were incorporated into the land cover dataset as buildings so that they would not be considered possible planting sites (Figure 6). Additionally, community gardens were identified as agriculture so they are considered not plantable when the UTC model is run. Parcels with higher modified possible UTC were given higher priority for planting. That resulting ranking was concatenated onto the Tier 1 unclustered ranking, as described above (Figure 7).

New York Restoration Project has varied planting site types corresponding to different planting programs. Therefore, two separate analyses were performed, each intended to address the needs of that particular program. One focal type was defined as publically owned land less than 10 acres. Once those parcels were selected, the UTC metrics were calculated. Parcels with higher possible UTC were given higher priority. The resulting ranking was concatenated onto the Tier 1 ranking (Figure 8), as described above. The other focal type was defined as privately owned and zoned as one and two family buildings. There are 18,878 parcels that meet these criteria.

Central Forestry & Horticulture, unlike Natural Resources Group and New York Restoration Project, does not operate at the parcel level. Instead, it plants street trees in the public-right-of-way (PROW). Therefore, Tier 2 was calculated by computing the Possible UTC for the PROW. That resulting ranking was concatenated onto the Tier 1 ranking (Figure 9).

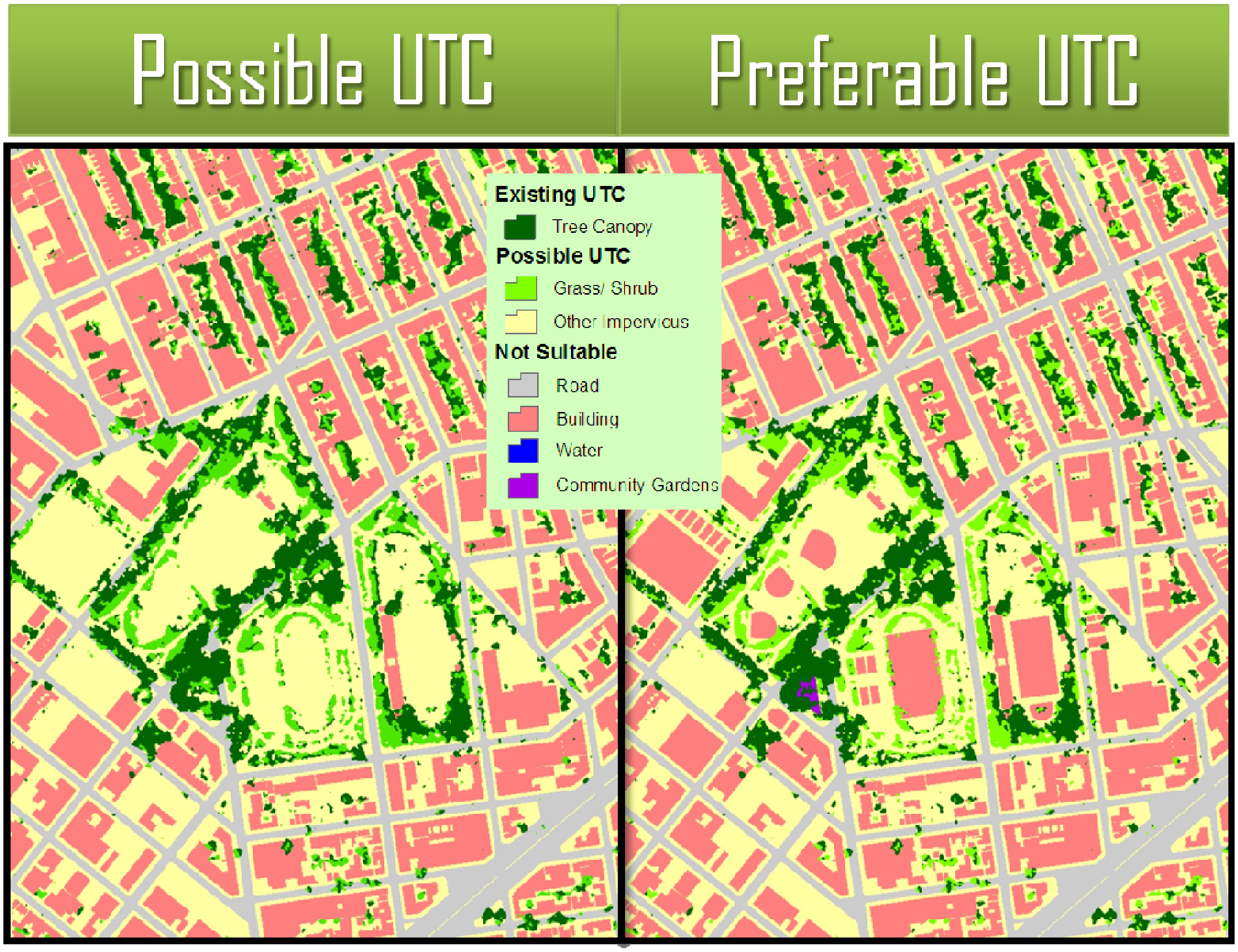

Figure 6. McCarren Park showing both Possible UTC and Preferable UTC. The right pane shows active recreation sites such as tennis courts and baseball fields classified for analytic purposes as not possible planting sites (buildings), along with community gardens.

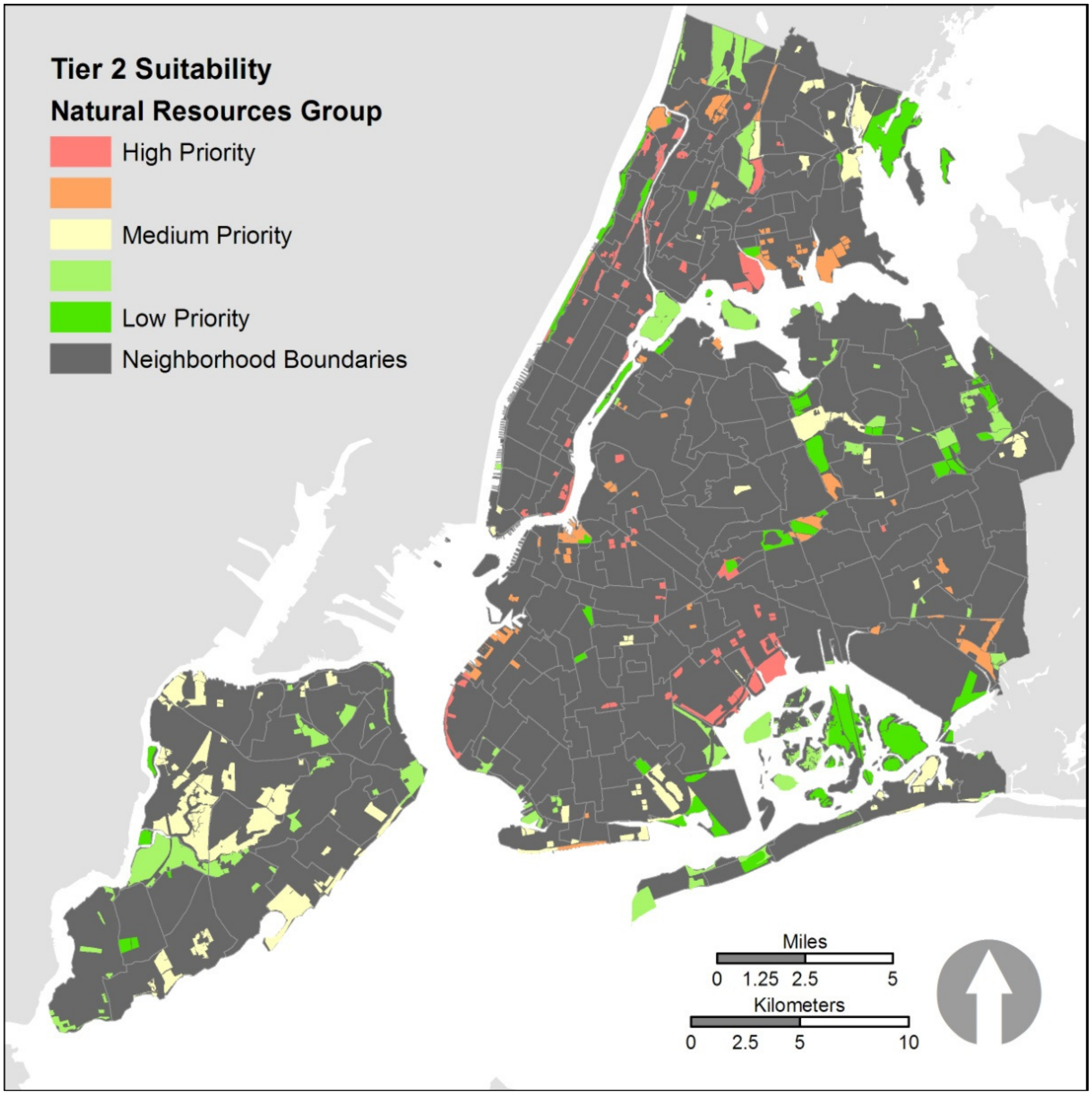

Figure 7. Tier 2 map created for Natural Resources Group. Parcels greater than 10 acres and publically owned excluding Central and Prospect Parks, airports and golf courses were selected. Selected parcels containing the most non-road, non-building, non-water, non-agricultural land, not an active recreation site (i.e. basketball court), and not-existing UTC area (modified possible UTC) were given higher priority.

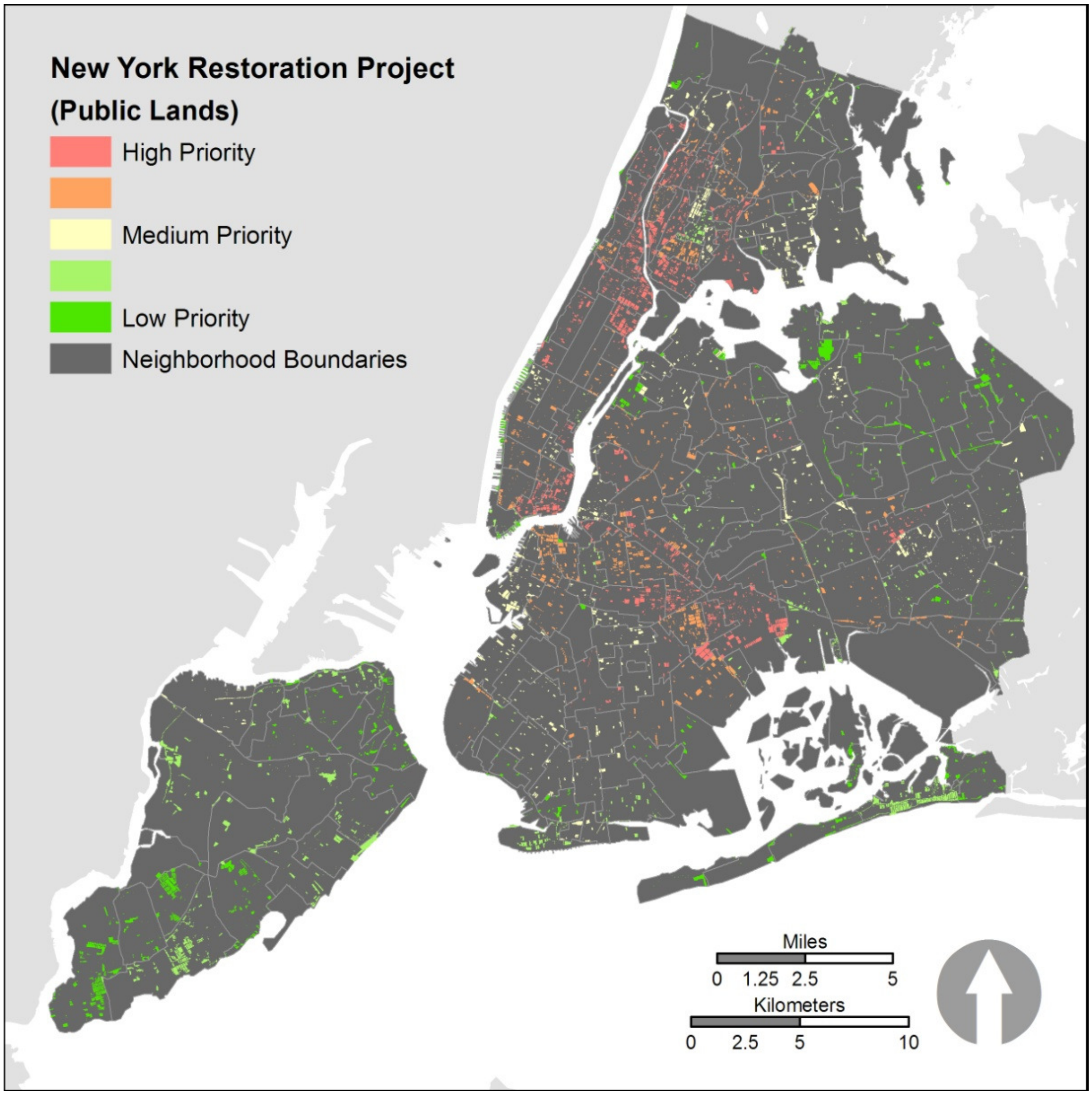

Figure 8. Tier 2 map created for New York Restoration Project. The left panel shows parcels shown are publicly owned land less than 10 acres, and the right panel shows a more in depth view where parcels are extruded relative to final rank for ease of visualization. Selected parcels containing the most non-road, non-building, non-water, non-agricultural land, and not an active recreation site (i.e. basketball court) and not-existing UTC area (Possible UTC) were given higher priority.

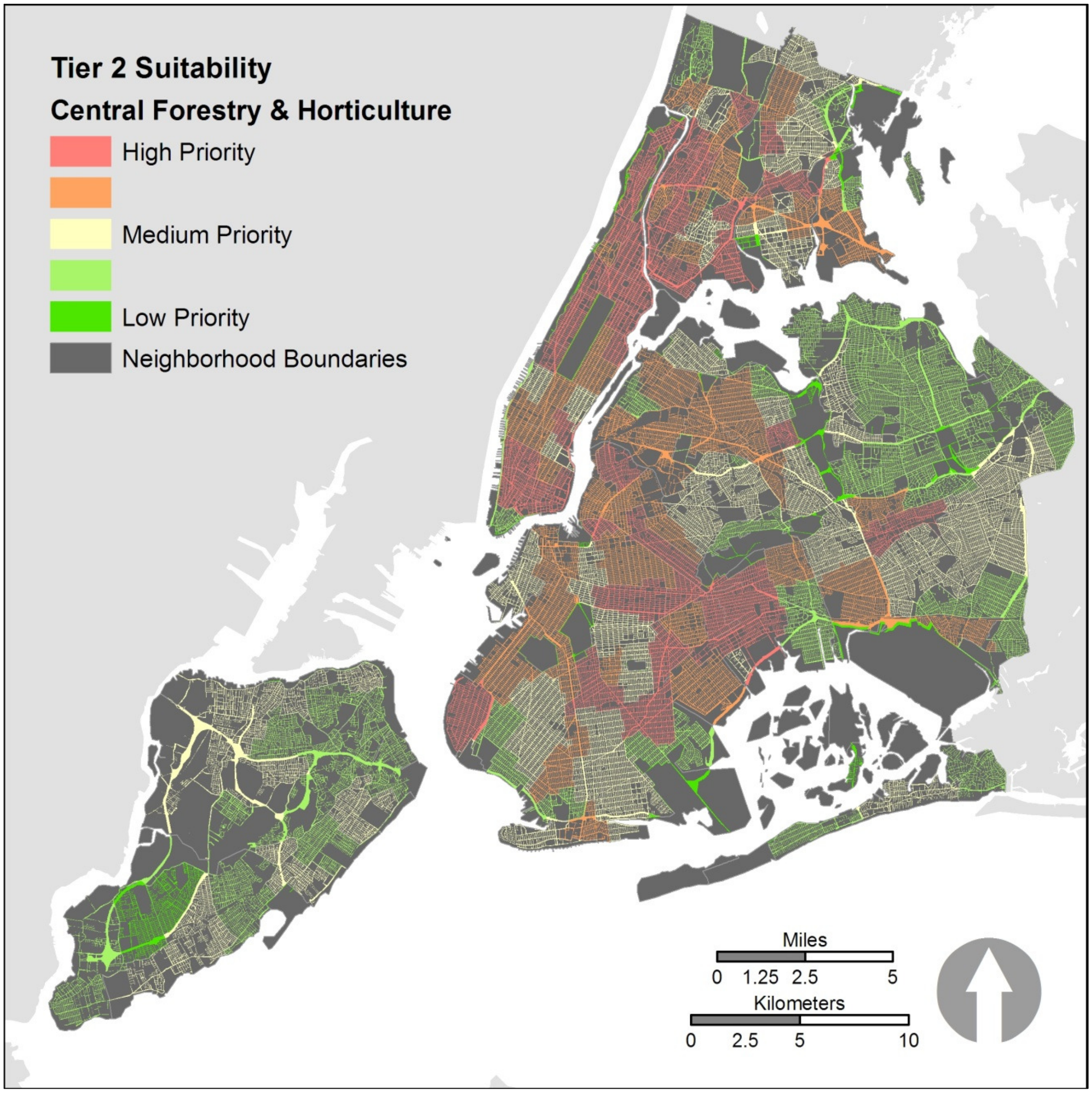

Figure 9. Tier 2 map created for Central Forestry and Horticulture. The Public Right of Way was assessed and ranked for Possible UTC. That ranking was concatenated behind the neighborhood ranking.

FUTURE OPPORTUNITIES AND CONCLUSIONS

There are at least two directions for further exploration based on the analysis presented here. The same tools and approach can be reused as new, more current data sets become available. For example, using 2010 U.S. Census data in place of the 2000 data or using an updated land cover data layer would likely change the results, and those changes can be tracked over time.

Secondly, these tools and approach can be deployed in other cities. Many of the tools are ready to use on other dataset as they stand now. The remainder can be adjusted to accommodate other cities' land managers' unique datasets, goals and constraints. Current work with key urban forestry decision makers in both Baltimore, Maryland and Washington D.C. addresses their unique set of funding opportunities, available data, and the desire to achieve multiple ecological, social and urban planning goals simultaneously through increased UTC. The framework presented here can act as a tool for collaborative decision making, as site types and management objectives are clearly defined and organizations work toward the common goal of increasing UTC.

While this paper specifically addresses New York City and the MillionTreesNYC campaign, the methods and tools used can be applied to other cities seeking to increase their UTC, using their own planting need and suitability criteria. The applicability and level of analysis for any given city will largely depend on the human and technological resources available. Beyond simple tree canopy targets, this approach can also help cities systematically reach other social, economic, and ecological goals.

ACKNOWLEDGEMENTS

Special thanks are due to Jessie Braden, Fiona Watt, Jennifer Greenfeld, Erika Svendsen, Lindsay Campbell, Michele Romolini, Kelly Goonan, Brian Voigt, Loona Brogan, Michael Brown, Helen Carr, Katharine Duskin, Daniel Erickson, Zachary Nuse, Burton Putrah, David Seekell, Jiaxin Yu, Cherie Fisher, three anonymous reviewers who provided valuable feedback and the CATE team for providing us with the space to share our work.

LITERATURE CITED

Akbari, H., M. Pomerantz, and H. Taha. 2001. Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Solar Energy 70(3):295-310.

Akbari, H. and S. Konopacki. 2005. Calculating energy-saving potentials of heat-island reduction strategies. Energy Policy 33(6):721-756.

Beattie, J., C. Kollin, and G. Moll. 2000. Trees tackle clean water regs. American Forests 106(2):18.

Bell, J. F., J.S. Wilson, and G.C. Liu. 2008. Neighborhood greenness and 2-Year changes in body mass index of children and youth. American Journal of Preventive Medicine 35(6):547-553.

ESRI. 2009. ArcMap 9.3.1. Redlands, California: ESRI.

Fernandez-Juricic, E. 2000. Avifaunal use of wooded streets in an urban landscape. Conservation Biology 14(2): 513-521.

Goodchild, M.F. 2007. Citizens as sensors: The world of volunteered geography. GeoJournal 69(4):211-221.

Grove, J.M., J. O'Neil-Dunne, K. Pelletier, D. 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 and Horticulture. New York Department of Parks and Recreation, USDA Forest Service, Northern Research Station. 28 pp. http://nrs.fs.fed.us/nyc/local-resources/downloads/Grove_UTC_NYC_FINAL.pdf (accessed 01/26/2011).

Jackson, L.E. 2003. The relationship of urban design to human health and condition. Landscape and Urban Planning, 64(4): 191-200.

Kuo, F.E. and W.C. Sullivan. 2001. Environment and crime in the inner city - Does vegetation reduce crime? Environment and Behavior 33(3): 343-367.

Lidman, A.A. 2008. Vegetation, neighborhood satisfaction, and crime: Case studies in Baltimore, MD. M.S. Thesis. University of Vermont. Burlington, Vermont. http://voyager.uvm.edu/vwebv/search?searchType=7&searchId=2190&maxResultsPerPage=50&recCount=50&recPointer=0&resultPointer=0& (accessed 01/26/2011).

Lovasi, G.S., J.W. Quinn, K.M. Neckerman, M.S. Perzanowski, and A. Rundle. 2008. Children living in areas with more street trees have lower asthma prevalence. Journal of Epidemiology and Community Health 62, 647-649.

Mitchell, R. and F. Popham. 2008. Effect of exposure to natural environment on health inequalities: An observational population study. Lancet 372:1655-60.

NASA. Landsat Program. 2002. Surface Temperature: USGS.

Nowak, D.J. 2002. The effects of urban trees on air quality. Syracuse, NY: USDA Forest Service. 5 pp. http://nrs.fs.fed.us/units/urban/local-resources/downloads/Tree_Air_Qual.pdf (accessed 01/26/2011).

Nowak, D.J., D.E. Crane, and J.C. Stevens. 2006. Air pollution removal by urban trees and shrubs in the United States. Urban Forestry and Urban Greening 4(3-4): 115-123.

Nowak, D.J., R.E. Hoehn, D.E. Crane, J.C. Stevens, and J.T. Walton. 2007. Assessing urban forest effects and values: New York City's urban forest. Resour. Bull. NRS-9. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 22 pp. http://www.nrs.fs.fed.us/pubs/rb/rb_nrs009.pdf (accessed 01/26/2011).

Raciti, S., M.F. Galvin, J.M. Grove, J.P.M. O'Neil-Dunne, A. Todd, and S. Clagett. 2006. Urban tree canopy goal setting: A guide for Chesapeake Bay communities. Annapolis, MD. United States Department of Agriculture, Forest Service, Northeastern State and Private Forestry, Chesapeake Bay Program Office. 59 pp. http://www.jmorgangrove.net/Morgan/UTC-FOS_files/UTC_Guide_Final_DRAFT.pdf (accessed 01/25/2011).

Rosenfeld, A.H., H. Akbari, J.J. Romm, and M. Pomerantz. 1998. Cool communities: Strategies for heat island mitigation and smog reduction. Energy and Buildings 28(1): 51-62.

Rudd, H., J. Vala, and V. Schaefer. 2002. Importance of backyard habitat in a comprehensive biodiversity conservation strategy: A connectivity analysis of urban green spaces. Restoration Ecology 10(2): 368-375.

Streiling, S., and A. Matzarakis. 2003. Influence of single and small clusters of trees on the bioclimate of a city: A case study. Journal of Arboriculture 29(6): 309-316.

Takano, T., K. Nakamura, and M. Watanabe. 2002. Urban residential environments and senior citizens' longevity in megacity areas: The importance of walkable green spaces. Journal of Epidemiology and Community Health 56(12): 913-918.

Troy, A. and J.M Grove. 2008. Property values, parks, and crime: A hedonic analysis in Baltimore, MD. Landscape and Urban Planning 87 233-245.

Svendsen, E.S. and L.K. Campbell. 2008. Urban ecological stewardship: Understanding the structure, function and network of community-based urban land management. Cities and the Environment 1(1): 31.

Dexter H. Locke, New York City Urban Field Station, Northern Research Station, USDA Forest Service, and NYC Department of Parks and Recreation, 290 Broadway, 26th Floor, New York, NY 10007 Dexter.Locke@gmail.com

J. Morgan Grove, Northern Research Station, USDA Forest Service, University of Maryland, Baltimore County, 5200 Westland Blvd., TRC 171, Baltimore, MD 21227 MGrove@fs.fed.us

Jacqueline W.T. Lu, Forestry, Horticulture, and Natural Resources, City of New York Department of Parks and Recreation, Olmsted Center, Flushing Meadows Corona Park, Flushing, NY, 11368, jacqueline.lu@parks.nyc.gov

Austin Troy, Rubenstein School of Environment and Natural Resources, University of Vermont, 81 Carrigan Dr. Burlington, VT 05405 atroy@uvm.edu

Jarlath P.M. O'Neil-Dunne, Rubenstein School of Environment and Natural Resources, University of Vermont, 81 Carrigan Dr., Burlington, VT 05405 Jarlath.ONeil-Dunne@uvm.edu

Brian D. Beck, Rubenstein School of Environment and Natural Resources, University of Vermont, 81 Carrigan Dr., Burlington, VT 05405 bdbeck@uvm.edu