Appendix D
Methods

Calculating Tree Benefits

Air Quality

The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for air quality. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports air pollutant removal rates and monetary values for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM) (Hirabayashi 2014).

Within the i-Tree Canopy application, the U.S. EPA's BenMAP Model estimates the incidence of adverse health effects and monetary values resulting from changes in air pollutants (Hirabayashi 2014; U.S. EPA 2012). Different pollutant removal values were used for urban and rural areas. In i-Tree Canopy, the air pollutant amount annually removed by trees and the associated monetary value can be calculated with tree cover in areas of interest using BenMAP multipliers for each county in the United States.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for each of the five listed air pollutants.

Carbon Sequestration

The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for carbon storage and sequestration. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports carbon storage and sequestration rates and monetary values. Methods on deriving storage and sequestration can be found in Nowak et al. 2013.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for carbon storage and sequestration.

Stormwater and Sewersheds

How tree benefits of stormwater are calculated. The i-Tree Hydro v5.0 (beta) Model was used to quantify the value of ecosystem services for stormwater runoff. i-Tree Hydro was designed for users interested in analysis of vegetation and impervious cover effects on urban hydrology. This most recent beta version (v5.0) allows users to report hydrologic data on the city level rather than just a watershed scale giving users more flexibility. For more information about the model, please consult the i-Tree Hydro v5.0 manual. (http://www.itreetools.org).

To calculate ecosystem services for the study area, land cover percentages derived for Cleveland were used as inputs into the model. Precipitation data from 2010 were selected within the model as that year closely represented the average rainfall (37 in.) for the City of Cleveland (NOAA 2015). Model simulations were run under a Base Case as well as an Alternate Case. The Alterative Case increased canopy by 1% and assumed that impervious and vegetation cover would decrease by 0.3% and 0.7%, respectively, as plantings would ultimately reduce these land cover types. This process was completed to assess the runoff reduction volume associated with a 1% increase in tree canopy since i-Tree Hydro does not directly report the volume of runoff reduced by tree canopy. The volume (in cubic meters) was converted to gallons and multiplied by the current canopy percentage (19%) in Cleveland to retrieve the overall volum*e reduced by the tree canopy*.

Through model simulation, it was determined that tree canopy decreases the runoff volume in Cleveland by 1.79 billion gallons during an average precipitation year. This equates to approximately 188,000 gallons per acre of tree canopy (1.79 billion/9,491.4 acres). To validate the model, the results were compared to the City of Indianapolis Municipal Forest Resource Analysis report (Peper et al. 2008) which detailed the ecosystem services of trees in the Lower Midwest STRATUM climate zone (U.S. Forest Service 2012). This report was consulted because the City of Cleveland is located in a similar climate zone and the two cities are less than 330 miles apart in distance making their climate and weather patterns similar in nature.

In order to assess runoff reduction volume on the neighborhood level, the 188,000 gallons per acre value was used since i-Tree Hydro does not directly utilize boundaries other than watershed and city limits. To place a monetary value on stormwater reduction, the City of Cleveland provided the price to treat a gallon of stormwater in 2015 ($45 per McF).

About Stormwater Priority Ranking. During the ranking process, data derived from the UTC analysis, data provided by MSD, and environmental data were used to prioritize neighborhoods (see Table 7). The datasets were classified based on the value of "risk" from 0–4, with 4 posing the highest "risk" of contributing to stormwater runoff. Variables were weighted to produce a results grid. The grid was summarized using zonal statistics by each feature layer and given an average risk score. These scores were divided up into five bins to produce the final maps. Higher priority areas received a larger risk score.

Table 7. Prioritization Factors and Weights

Dataset	Weight	Source
Impervious Distance	0.30	Urban Tree Canopy Assessment
Slope	0.25	National Elevation Dataset
Floodplain	0.20	City of Cleveland
Soils	0.15	Natural Resource Conservation Service
Canopy Distance	0.10	Urban Tree Canopy Assessment

Energy Savings

Trees have a profound effect on building energy and has been studies using various methods (Carver et al. 2004; McPherson and Simpson 2003). The process of estimating energy (electricity) savings starts with determining the number of one-unit structures by vintage (age) class within each census block group. Vintage refers to construction type for a building (i.e., average floor area, floor types, insulation (R-value), and number of stories) and was broken into three categories: pre-1950, 1950–80, and post–1980.

Census data obtained from the 2010 American Community Survey (Table B25024 – UNITS IN STRUCTURE and Table B25034 - YEAR STRUCTURE BUILT) were used to determine the number of one-unit structures.

The data were based on five-year estimates. Since the number of one-unit structures differed at the block group level, the number of one-unit structures was determined by vintage and block group by multiplying the percentage of units in each vintage by the total number of one-unit structures in each block group (McPherson et al. 2013). For each block group, total energy savings were tallied for each block group using a function of percent UTC, vintage class, and energy saving coefficients (McPherson and Simpson 2003, McPherson et al. 2013).

To provide energy savings for neighborhoods, block groups were assigned based on their spatial positioning related to the block group data. While the boundaries do not overlay perfectly, it does provide a rough estimate for these boundaries. The kWh saved were summarized for each neighborhood by adding up the kWh from each assigned block group.

The monetary value for energy savings was valued by summing all estimated kWh saved for each vintage class and multiplied by the current 2015 electricity cost priced at $0.11 per kWh.

Table 8. Prices for Ecosystem Services in 2014

	Energy Savings	CO_2 Storage	CO_2 Sequestration	CO	NO_2	O_3	SO_2	PM_{10}	Rainfall Interception
	$/MWh	$/Ton	$/Ton	$/Ton	$/Ton	$/Ton	$/Ton	$/Ton	$/McF
Service Value	110	49.43	19.43	85.08	26.86	140.47	7.45	304.43	45

Property Values

Many benefits of tree canopy are difficult to quantify. When accounting for wildlife habitat, well-being, shading, and beautification, these services are challenging to translate into economic terms. In order to provide some estimation of these additional services, this report calculated a property value based on the value of home prices for the City of Cleveland. Limitations to this approach include determining actual value of individual trees on a property and extrapolation of residential trees to other land use categories (McPherson et al. 2013).

In a study completed in 1988, it was found that single-family residences in Athens, Georgia had a 0.88% increase in the average home sale price for every large front-yard tree on the property (Anderson and Cordell 1988). Using this study, the sales price increase was utilized as an indicator of additional tree benefits. While home sales vary widely, in 2014 the median home sales value in the City of Cleveland was $27,050 (Exner 2014). Using this median sales price and multiplying by 0.88%, the value of a large front-yard tree was $238. To convert this value into annual benefits, the total added value was divided by the leaf surface area of a 30-year-old shade tree which yields a base value of $0.33/ft^2$. Using methodology from McPherson et al. 2013 to convert into units of UTC, the base value of tree canopy was determined to be $0.03795 ft^{-2} UTC. Since this value was derived using residential land use designations, transfer functions were used to adapt and apply the base value to other land use categories.

To be conservative in the estimation of tree benefits, the land use reduction factors calculated property value at 50% impact for single-family residential parcels, 40% for multi-residential parcels, 20% for commercial parcels, and 10% for all other land uses.

The price per unit of UTC values were multiplied by the amount of square feet of tree canopy within each land use category and summarized for the city and neighborhoods.

Table 9. Land Use Reduction Transfer Function Values

Land Use Category	Impact	Price Per Unit of UTC
Single-Family Residential	50%	$0.0190
Multi-Family Residential	40%	$0.0152
Commercial	20%	$0.008
All Other	10%	$0.004

Mapping Surface Temperature and Hot Spots.

A metric to identify urban heat island within the City of Cleveland was to create a ratio of impervious surface to canopy cover by establishing a grid of 50 X 50 meter squares. For each square, the amount of impervious surface and tree canopy was calculated. The amount of impervious area was then divided by the canopy cover, yielding a ratio value for each grid cell. A larger ratio indicated areas of "hotter" surfaces, or the presence of urban heat islands. These areas were synonymous with impervious surfaces such as buildings and parking lots. Small ratio values (less than 1) had a much greater presence of tree canopy.

Vacant Land Analysis

As a focus to plant readily available land with the City of Cleveland, a prioritization of vacant parcels was essential. A prioritization framework was set up using the amount of current tree canopy cover, canopy type (i.e., fragmentation level), and the amount of available planting space. Each vacant parcel was analyzed based on these three factors. The current tree canopy percentage was calculated based on the UTC assessment that was previously complete. Canopy type was derived using a customized tool to assess forest/canopy fragmentation throughout the City. There were four levels of fragmentation: patch canopy, edge, perforated, and core. The amount of available planting space was estimated by combining the area of bare soil and grass/low-lying vegetation from the UTC assessment.

About the Ranking Determination: Rankings were split up into five bins or classes that ranged from Very Low to Very High priority. Each of the three factors was distributed into these bins.

- *Current Canopy Percentage.* To assign a rank to current canopy percentage, the data were divided into five 20% canopy level intervals (e.g., 0–20, 21–40, 41–60, etc.) with higher levels of canopy receiving a lower score rank because they were already well served with having robust tree canopy already present. As an example, canopy percentages within the 80–100% range were assigned a value of 1 while percentages in the 0–20% bracket were assigned a 5 to indicate that they would benefit from planting trees.
- *Canopy Type/Fragmentation.* A canopy fragmentation layer was created prior to analysis. Using this layer, the amount of area for each fragmentation type was weighted with core canopy forest receiving the greatest weighting for prioritization. This would identify what type of canopy structure was present within the parcel and at what priority level it should be assigned. The lower the overall result of the weighted values would indicate that the parcel was consisted of all or mostly all patch canopy and, therefore, not a higher priority when it came to planting since fragmentation was so great that additional tree planting would not increase canopy function. These values were also assigned into five classes with a 1–5 ranking.
- *Available Planting Space.* The final metric used for prioritization was determining the amount of actual planting space available within each parcel. If a parcel had smaller percentages of planting space, there would be little benefit to focus on that parcel since it would have small amounts of available space in which to plant trees. Similar to current canopy, the data were extracted from the UTC assessment and binned into five 20% class intervals. However, instead the rankings were flipped with higher percentages of space receiving a higher rank in efforts to put a greater focus on parcels with sufficient planting space to support numerous trees.
- *Composite Ranking.* The ranking from each variable was additively combined to form the final result dataset. Higher result values equaled a higher priority rank as those scores would indicate low amount of present tree canopy, with more core forest, and high amounts of planting space.

Demographics and Socioeconomic Data

Data acquired for the socioeconomic analysis were provided by the U.S. Census Bureau at the census tract and census block levels, specifically 2006–2010 American Community Survey 5-Year Estimates, as shown in Table 10.

Table 10. Socioeconomic Data Sources

Variable	Data Source	Table Number	Table Description
Age	ACS 2006-2010 5YR	B01001	Age of Population
Education Level	ACS 2006-2010 5YR	B15001	Educational Attainment Population 18+
Median Income	ACS 2006-2010 5YR	B19013	Median Income of Population
Building Value	ACS 2006-2010 5YR	B25075	Value of Buildings
Building Age	ACS 2006-2010 5YR	B25034	Year Structure Built
Single Family Homes	ACS 2006-2010 5YR	B25024	Units in Structure (1-Detached)

Equity Calculations

The Equity Index was created by ranking each of the 34 Cleveland neighborhoods in three socioeconomic categories: rates of child poverty, unemployment, and population density. Rankings were created on a scale of 1–34 with 34 representing the highest priority or need. The highest percentage of child poverty, highest unemployment rates, and the most densely populated neighborhoods given the highest scores in each category. After rankings were assigned, a composite score was tabulated by adding the scores from each category. Neighborhoods that received the highest composite scores are considered as having the greatest need in terms of equity. Note that this need ranking does not, however, take into account the canopy cover level for each neighborhood. Thus, focus should be on the neighborhoods with the highest equity need score and lowest canopy cover. Methodology for data collection and analysis in each of the three categories follows:

- **Child Poverty.** This category determines the dispersal of children (an individual under the age of 18) who are considered to be living below poverty within neighborhoods throughout the City of Cleveland. In order to complete this analysis, both the census tract data and the block group data were obtained for the City of Cleveland. Census tract data specifying populations age and block group data defined the poverty levels were joined together. Because neighborhood boundaries do not correlate to census tract and block group boundaries, data were estimated using the largest percent of the block group and tracts that were contained within a neighborhood boundary. The area of the neighborhood was then divided by the population that was under the age of 18 and below the poverty line.

Data sources used to obtain Child Poverty by Block Group and Census Tract: U.S. Census Bureau, Age by Census Tract: File Name: H17, http://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t&keepList=f and Minnesota Population Center. National Historical Geographic Information System: Version 2.0. Minneapolis, MN: University of Minnesota 2011. File Name: nhgis0005_ds201_20135_2013_blck_grp, https://www.nhgis.org/documentation.

- **Unemployment.** This category depicts the total participation in the labor force to understand the unemployment rate. The labor force includes those individuals who are currently employed and/or those who have the ability to work. In order to complete this analysis, 2013 census block group data were aggregated for each Cleveland neighborhood. Because neighborhood boundaries do not correlate to census tract and block group boundaries, data were estimated. In instances where more of the block group area was incorporated in the neighborhood it was included in that neighborhood's unemployment value. The total population within the neighborhood was then divided by the individuals currently seeking work or employed within each neighborhood.

Data source used to obtain Unemployment by Block Group: Minnesota Population Center. National Historical Geographic Information System: Version 2.0. Minneapolis, MN: University of Minnesota 2011. File Name: nhgis0005_ds201_20135_2013_blck_grp, https://www.nhgis.org/documentation.

- **Population Density.** This category determines how population is dispersed throughout Cleveland's neighborhoods. Neighborhoods with a higher population density will require more tree canopy to benefit more people. A correlation exists between canopy coverage and social-economic issues. In order to complete this analysis, 2013 census block group data were aggregated for each Cleveland neighborhood. Again, because neighborhood boundaries do not correlate to census tract and block group boundaries, data were estimated. If more of the block group area was incorporated in the neighborhood it was included in the population value. The amount of people within the neighborhood was then divided by the area of the neighborhood to provide the population density for each neighborhood.

Data source used to obtain Population Density by Block Group: Minnesota Population Center. National Historical Geographic Information System: Version 2.0. Minneapolis, MN: University of Minnesota 2011., File Name: nhgis0005_ds201_20135_2013_blck_grp, https://www.nhgis.org/documentation.

Environmental Benefits Mapping and Analysis Program (BenMAP)

BenMAP is a software application developed by the U.S. EPA that uses community-level ambient pollution exposure data to estimate the health impacts and economic benefits occurring when populations experience changes in air quality. Benefit values derived from the BenMAP model focus only on adverse human health effects of air pollution and related patient treatment costs. The U.S. Forest Service incorporated an adaptation of the BenMAP model within their own i-Tree Eco model which allowed for estimation of reductions in air pollution and the resulting positive public health impact attributable to tree canopy.

Canopy Projections: Development and Applications

This plan references past, current, and projected tree canopy cover levels in Cleveland. The following describes the methodology used to obtain this canopy data.

The current urban tree canopy (UTC) cover rate of 19% was obtained from the 2013 Cuyahoga County Urban Tree Canopy Assessment.

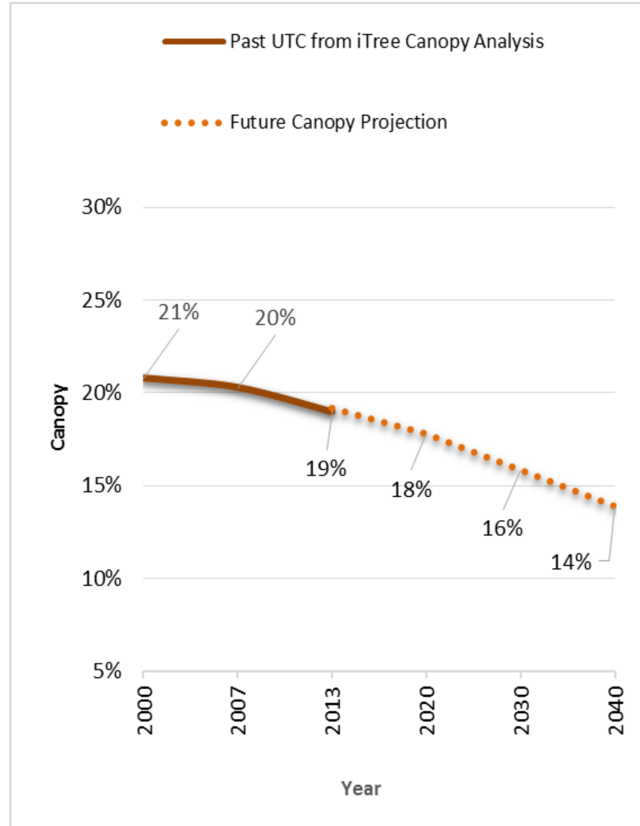
Past canopy cover was obtained using the i-Tree Canopy application, which utilized Google aerial imagery from 2000 and 2007. In i-Tree Canopy, 500 sample data points from each year were used to provide an estimated canopy and assess the change. Results showed a 2.24% drop in canopy from 2000 to 2007 and a 6.11% drop in canopy from 2007 to 2013. By applying these rates of change to today's 19% canopy coverage, past canopy levels could be estimated, as shown in Table 11.

Future canopy projections applied the average acres of canopy lost per year from 2007 and 2013 (97 acres) to future years. Based on this projection, canopy will drop to 14% by the year 2040 as shown in Figure 15.

Table 11. Canopy Projection Data Table

Year	% Change Determined by i-Tree Canopy	Change Translated to UTC	Change Translated to Actual Canopy Acres	Canopy Acres Lost	Avg. Lost/ Yr
2000	n/a	21%	10,296	n/a	n/a
2007	-2.24%	20%	10,071	226	32
2013	-6.11%	19%	9,491	580	97
Total canopy acreage lost since 2000:			805		
Average acres lost over 14 years:			58		
Average acres lost per year (using recent 6 years)			97		
Projected acres loss 2013 to 2040			2,619		

Figure 15. Canopy Projections at Current Rate of Loss



Using the resulting canopy levels from the above processes, we see that 805 acres of canopy were lost between 2000 and 2013. This is a net loss, combining all canopy loss with all canopy growth (new plantings or growth of existing trees).

Over the most recent six years (2007 to 2013), Cleveland lost an average of 97 acres of canopy per year. If this rate of loss holds, Cleveland is expected to lose another 2,619 acres of canopy between 2013 and 2040 (27-year time span), as shown in Figure 15.

Estimate of Quantity of Trees Lost. The number of individual trees lost can be estimated using an average tree canopy diameter of 29 feet, allotting for an estimated 66 trees per acre. Based on the acres of canopy Cleveland is projected to lose between now and 2040, this equates to an estimated 172,854 trees lost total, or 6,402 trees lost per year.

Urban Forestry Budget Calculations

Without current and comprehensive data on the quantity and condition of all public trees, estimating appropriate funding levels is difficult. There is no standard table or formula to use, and need is always in flux. When inventory data are not reliable, current funding can be compared to national statistics provided by the American Public Works Association's series on urban forestry management.

National urban forestry statistics are provided by the National Arbor Day Foundation (NADF) and the U.S. Forest Service, calculated per capita and per tree. Using Cleveland's current population and spending levels, these statistics are compared in Table 12.

Based on these national statistics, Cleveland's current urban forestry budget is higher than the minimum spend required to be a NADF Tree City USA, and 20% lower than the NADF's average of $5.83 per capita budget finding for a city of Cleveland's size. Because of the large backlog of maintenance, the current urban forestry budget is inadequate for today's maintenance needs. However, it is *possible* that once caught up with the backlog of maintenance, the current budget levels may not be far off from an adequate level. A comprehensive inventory would be required to recommend a firm budget range.

About the APWA Series. On the recommendation of the National Urban and Community Forestry Advisory Council (NUFAC), and with the support of the U.S. Forest Service Urban & Community Forestry Council, the American Public Works Association researched and developed four reports in centered on best management practices in urban forestry management: Budget & Funding, Staffing, Ordinances, Regulations & Public Policies, and Urban Forest Management Plans. All four studies can be downloaded here: https://www2.apwa.net/about/coopagreements/urbanforestry.

Table 12. Urban Forestry Budget Calculations Table

	Cleveland TODAY	NADF Minimum ($2/capita)	NADF's Finding ($5.83/capita)	Pittsburgh, PA	Charlotte, NC	Charleston, SC	Minneapolis, MN
Population (approx.)	390,000	390,000	390,000	300,000	800,000	120,000	380,000
City Budget	$541,700,000						
Urban Forestry Budget	$1,800,000	$780,000	$2,273,700	$788,140	$1,819,460	$531,200	$9,209,040
Quantity of Street Trees (approx.)	120,000	120,000	120,000	30,538	85,141	15,242	198,642
Urban Forestry Spend Per Capita	$4.62	**$2.00**	**$5.83**	$2.44	$3.05	$5.06	$24.07
Urban Forestry Spend Per Tree	$15.00	$6.50	$18.95	$26.59	$21.37	$34.85	$46.36
		$2/capita Minimum Spend Required for Tree City USA Designation	*2006 Survey Findings (3,130 communities) result: Average $5.83 per capita spend for a city Cleveland's size.*	*Source: USFS's i-Tree Cost-Benefit Analyses Data, APWA*			