Assessing Cleveland Metroparks Tree Cover
Part 1: Urban Tree Canopy Assessment
Part 2: i-Tree Ecosystem Analysis

Completed February 2011

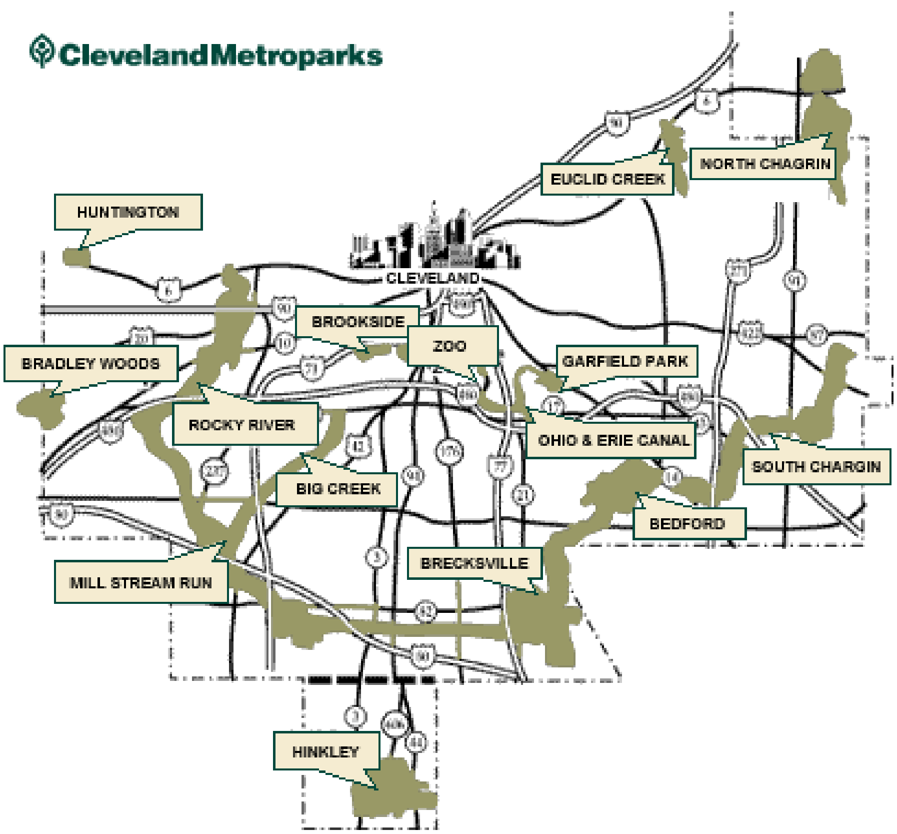

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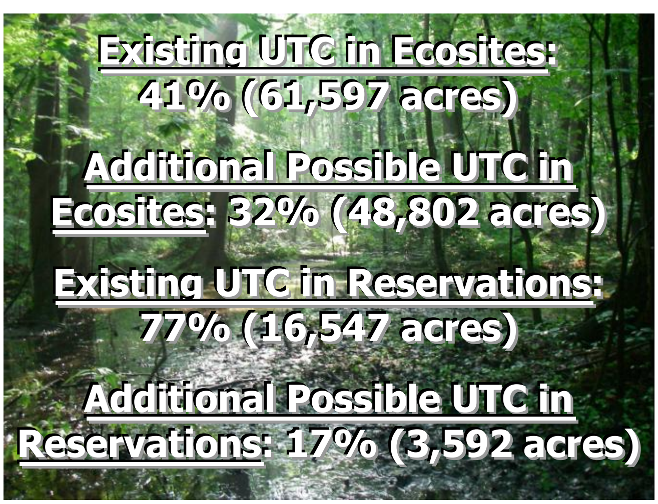
Figure 1. Total Project Area

Introduction

This assessment was part of an effort between Cleveland Metroparks (CMP), the Ohio Department of Natural Resources (ODNR), and AMEC Earth and Environmental, Inc. (AMEC), with funding assistance from the U.S. Forest Service (USFS). The objective was to map and assess the Existing and Possible Urban Tree Canopy (UTC) and other land cover classes in Cleveland Metroparks Reservations (Parks) and Ecosites (watersheds surrounding Parks) to gain a better understanding of tree cover, impervious surface area, and available space for tree planting in and around Reservations. The project also included a USFS i-Tree Eco Analysis (previously UFORE) that involved a Plot Inventory and Ecosystem Services Quantification. The Eco process entailed collecting forestry field measurements and data entry performed by CMP staff with subsequent analysis by the USFS to quantify the structure and functional value of forests in CMP's Reservations. This information will serve as a benchmark from which to measure the success of planning, restoration, development and natural resource policies and programs. The UTC project spanned approximately 235 square miles primarily in Cuyahoga County, Ohio while the i-Tree Eco project focused on CMP ownership totaling over 21,500 acres (see Figure 1 above and Figure 2 below).

UTC deliverables included 1-meter NAIP aerial imagery, a GIS-based five-class land cover layer (tree canopy, grass/open space, impervious surfaces, bare soil, and water), UTC and impervious metrics by Ecosite and Reservation in GIS format and in a UTC spreadsheet, and this report. Eco deliverables included the plot-based forestry measurements and the analysis of structural and functional values of the trees and forests that makeup CMP's Reservations, also included in this report.

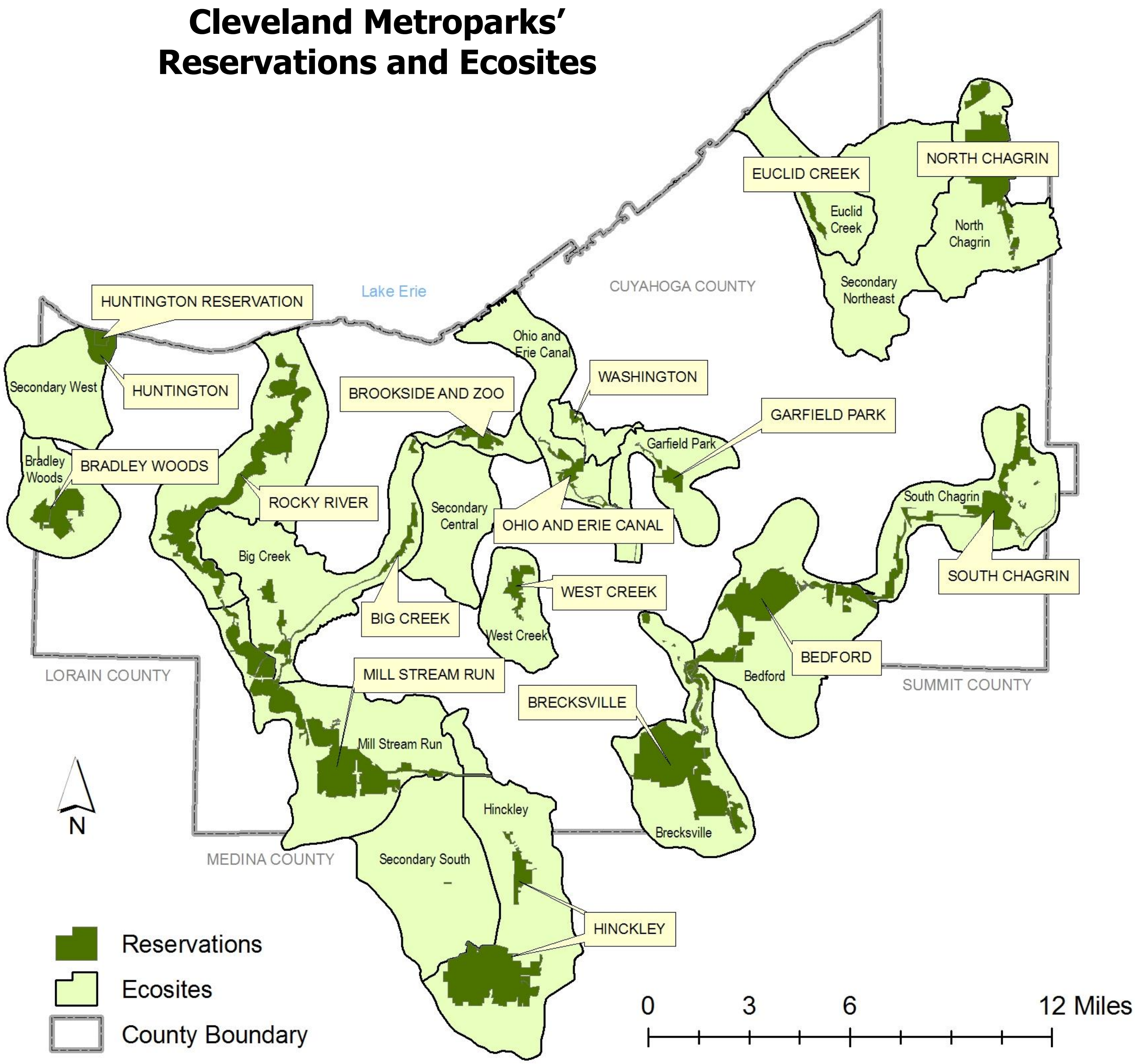
Part 1: Urban Tree Canopy Assessment: Results at a Glance



Key Terms:

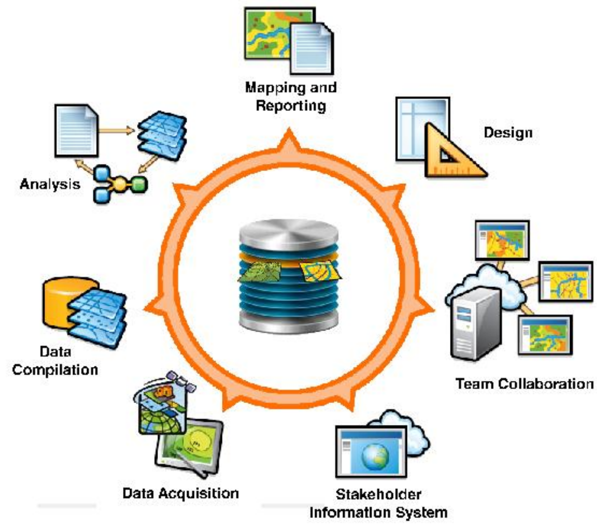
AOI – Area of Interest, referring to the study or project area
Ecosites – watersheds surrounding CMP Reservations
Land Cover* – features on the earth mapped from aerial or satellite imagery, such as trees, grass, bare soil, water, and impervious surfaces
Possible UTC * – grass or shrub area that is theoretically available for the establishment of tree canopy.
Reservations – parks in CMP's jurisdiction
Urban Tree Canopy (UTC)* – the layer of leaves, branches, and stems of trees that cover the ground when viewed from above using aerial or satellite imagery
*Source: USDA Forest Service and/or University of Vermont Spatial Analysis Laboratory (SAL)

Figure 2. Reservation and Ecosite Boundaries



Imagery, Data Requirements, and Land Cover Classification

Figure 3. GIS Life Cycle



Geographic Information Systems (GIS) and remote sensing technologies offer powerful analysis and decision support tools for managing urban natural resources. The life cycle of GIS projects may involve many steps, from data collection design through reporting (Figure 3). All UTC projects have at least 5 main elements in common regarding data inputs and outputs: 1) high-resolution imagery, 2) GIS layers or other data inputs from the community, 3) land cover data, 4) geographic boundaries in which to perform GIS and UTC analyses, and to summarize tree canopy acres and percent cover, and 5) reports or tools that illustrate metrics and results through tables, charts and maps (Figure 4).

Figure 4. UTC Components

Three-band (red, green, blue), 1-meter resolution natural color imagery collected from Summer 2009 was obtained from the USDA National Agricultural Imagery Program (NAIP) and used for classification of the land cover data. LiDAR data for Cuyahoga County was also incorporated into the analysis. Imagery was analyzed using geographic object-based image analysis (GEOBIA) techniques using Feature Analyst software to develop a 5-class land cover dataset that included tree canopy, grass/open space, impervious surfaces, bare soil, and water. The GEOBIA approach provided a highly automated and cost-effective method for feature extraction by using algorithms that leverage spectral, spatial, textural, and contextual features in the imagery, as well as incorporation of datasets provided by Cleveland Metroparks. The classification was refined with a manual quality assurance / quality control (QA/QC) process to finalize the land cover. Figures 5-8 show sample results from this process.

Figure 5. Natural Color Aerial Imagery

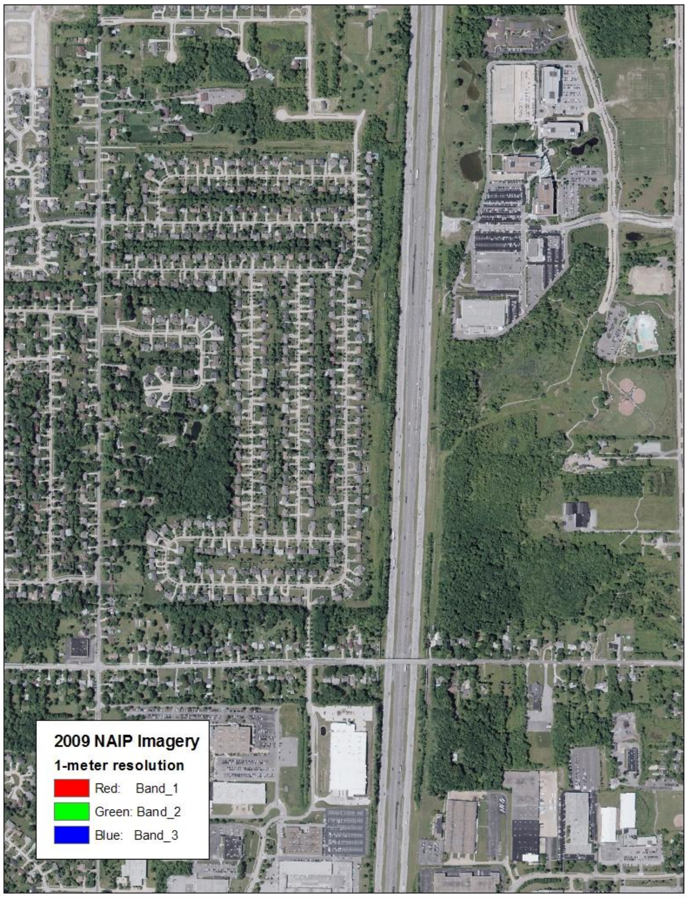


Figure 6. Five-Class Land Cover Data

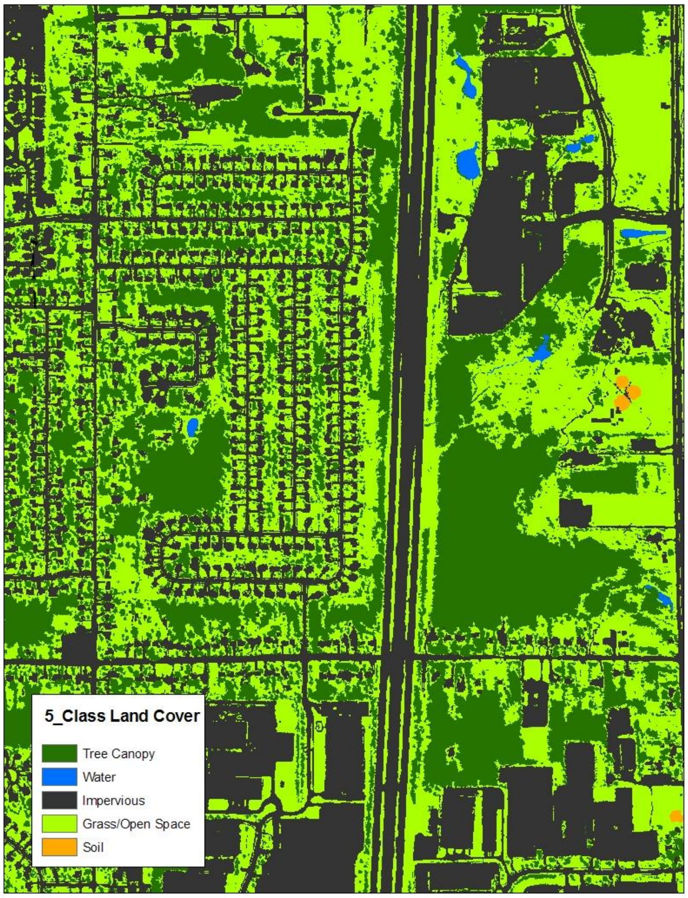


Figure 7. Tree Canopy

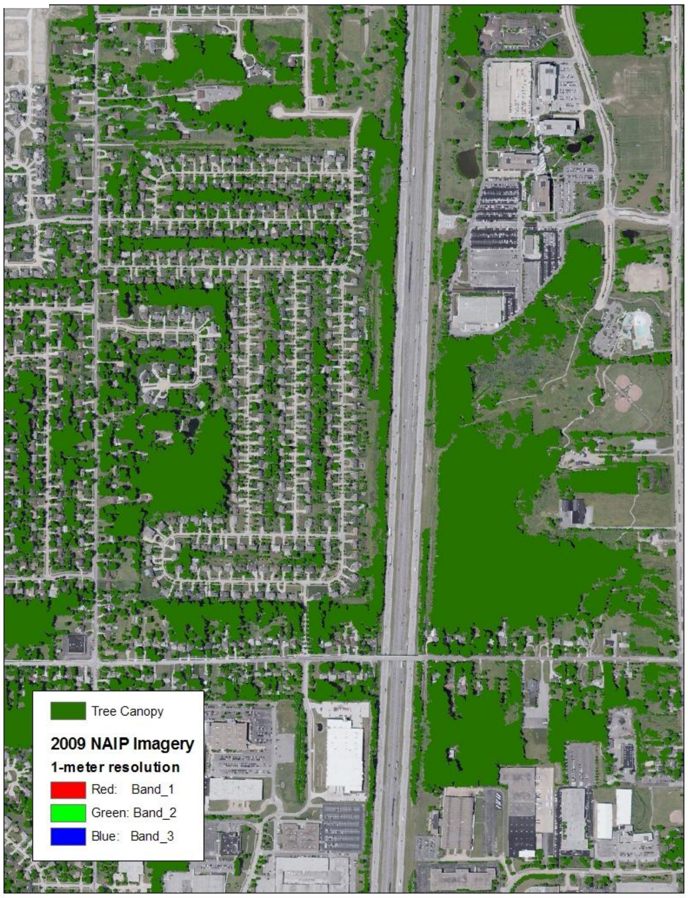


Figure 8. Impervious Surfaces

Mapping five land cover classes from 1-meter resolution 2009 NAIP imagery provides a 90% target overall accuracy within each class at the 90% confidence level. These classes and their associated minimum mapping units are: tree canopy (100-sqft), grass/open space (100-sqft), impervious surfaces (500-sqft), bare soil (1,000-sqft), and water (1,000-sqft).

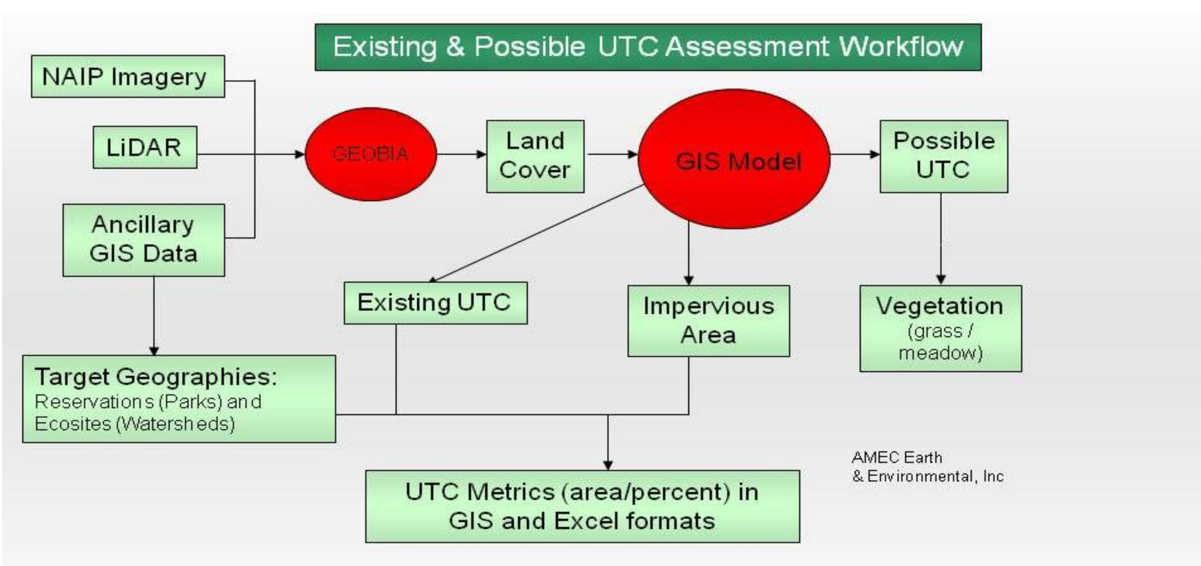
The following GIS layers provided by Cleveland Metroparks were used in the UTC analysis: Ecosite and Reservation boundaries, hydrology (ponds and lakes), and available impervious surfaces (buildings and streets). Impervious area digitized by AMEC for the Northeast Ohio Regional Sewer District (NEORSD) was also incorporated into the process.

Methodology and Assumptions

Using the results of the GIS-based land cover classes described in the previous section, a series of geoprocessing models were created to calculate the area and percent of Existing UTC, Possible UTC Vegetation, and Existing Impervious areas by Ecosite and by Reservation. Existing UTC is defined as all area covered by trees and forest, while Possible UTC is defined as the areas where it is biophysically possible to plant trees, meaning all remaining area after excluding existing trees/forest, buildings, roads and water bodies, leaving primarily grass, meadow, and open space vegetation. Impervious surfaces included road pavement, sidewalks, buildings/structures, and highly-compacted, unpaved soil. UTC results are provided in both GIS and Excel format for both geographic boundaries, Reservations and Ecosites, and are described in the following section.

Figure 9 shows an overview of the UTC GIS modeling work flow. Portions of this model were developed by the US Forest Service Northern Research Station and the University of Vermont Spatial Analysis Laboratory.

Figure 9. UTC GIS Modeling Workflow



Results of the UTC Process

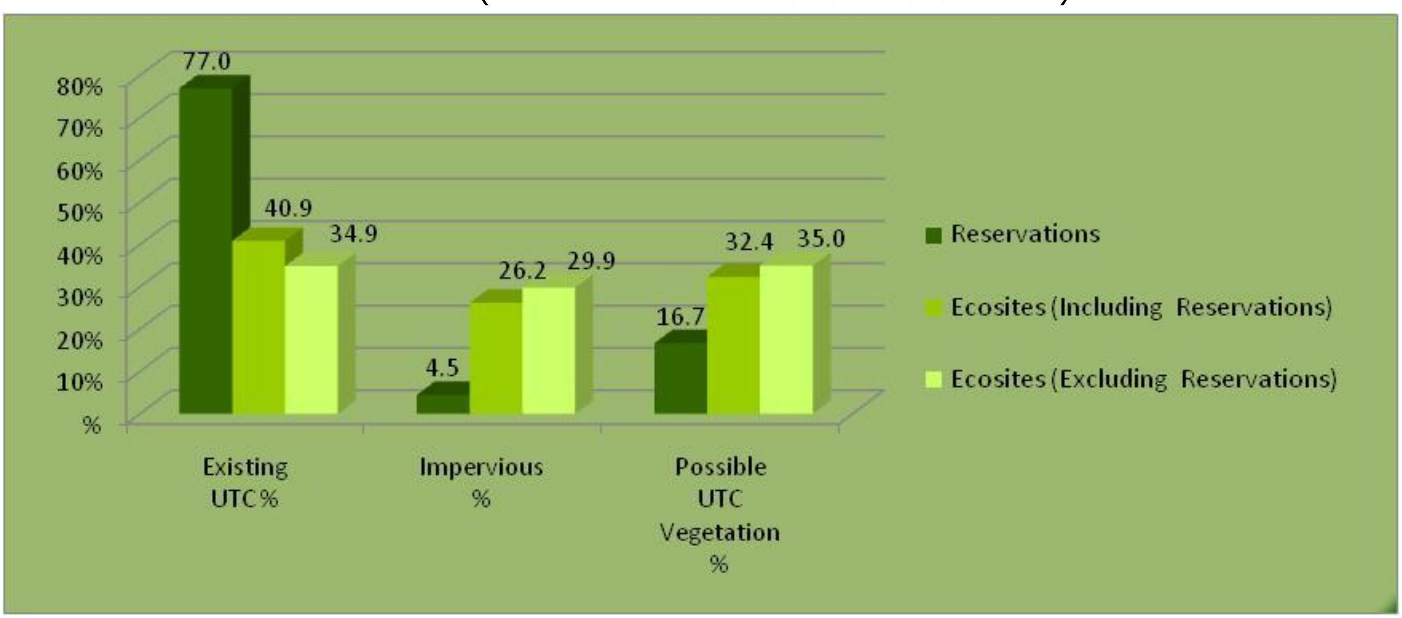
The area and percent of Existing UTC, Possible UTC Vegetation, and Existing Impervious area was calculated for Reservations and Ecosites in the project area. Existing UTC for all Reservations combined was found to be 77%. For all Ecosites combined, with Reservation area included, UTC was found to be 40.9%. Excluding Reservation area, UTC was 34.9%. Possible UTC vegetation for Ecosites (including reservation area) was found to range from 19 – 43%. All but two Ecosites consist of over 25% Possible UTC vegetation. Note that resulting percentages are not intended or designed to add up to 100% due to remaining water and soil land cover area.

Complete results of the UTC analysis can be accessed through the attribute tables of each UTC GIS layer and in the UTC spreadsheet delivered as part of the project. Tables 1 - 5 and Figures 10 – 17 below provide examples of the results in tabular, graph and map-based format.

Table 1. Overall Summary of UTC Metrics by Reservation and Ecosite

Area	Total Acres	Existing UTC Acres	Existing UTC %	Impervious Acres	Impervious %	Possible UTC Vegetation Acres	Possible UTC Vegetation %
Reservations	21,502	16,547	77.0	964	4.5	3,592	16.7
Ecosites (Including Reservations)	150,514	61,597	40.9	39,479	26.2	48,802	32.4
Ecosites (Excluding Reservations)	129,012	45,050	34.9	38,515	29.9	45,210	35.0

Figure 10. Comparison of Reservation and Ecosite UTC Metrics (Ecosites with Reservation acres and without)

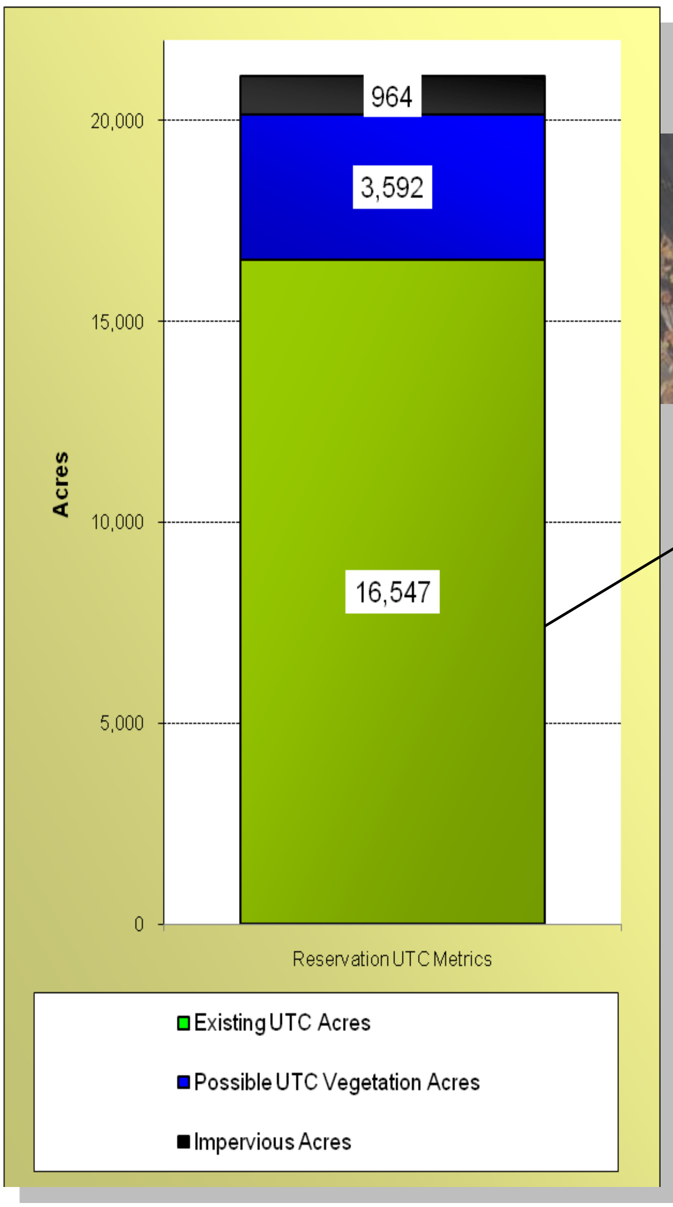


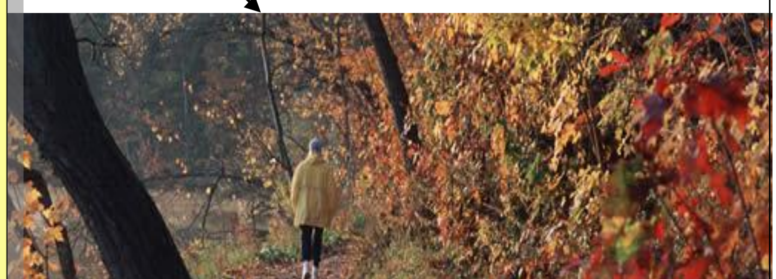
Cleveland Metroparks
UTC Results by Reservation

Table 2. Summary of UTC Metrics for Cleveland Metroparks' Reservations

Area	Total Acres	Existing UTC Acres	Existing UTC %	Impervious Acres	Impervious %	Possible UTC Vegetation Acres	Possible UTC Vegetation %
Reservations	21,151	16,547	77.0	964	4.5	3,592	16.7

Figure 11. UTC Assessment by Reservations



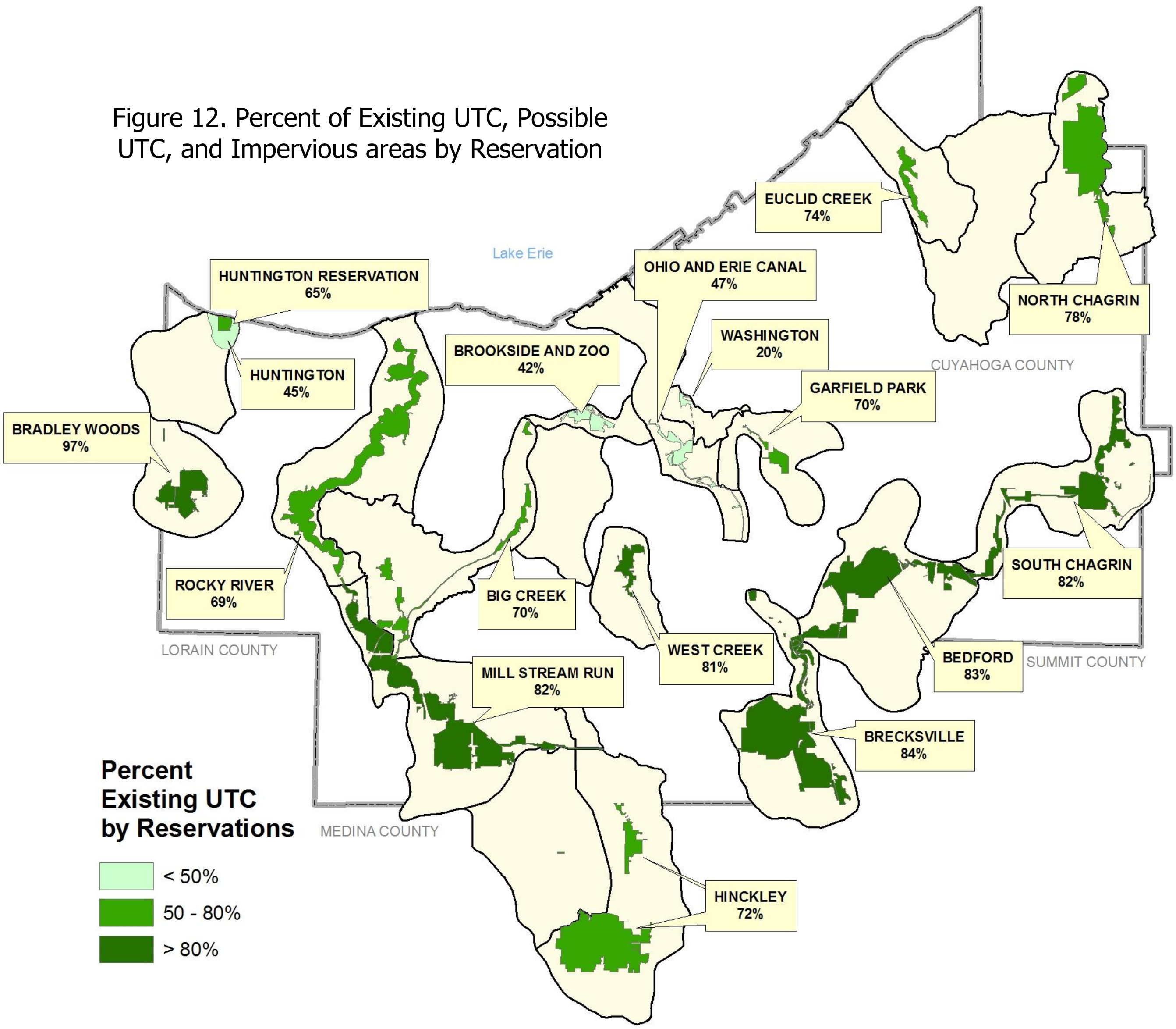


77%, or 16,547 acres, of total Reservation area is covered by trees and forest

Table 3. UTC Metrics for Cleveland Metroparks' Reservations

Reservation Name	Total Acres	Existing UTC Acres	Existing UTC %	Impervious Acres	Impervious %	Possible UTC Vegetation Acres	Possible UTC Vegetation %
Bedford Reservation	2,271	1,878	82.7	71	3.1	309	13.6
Big Creek Reservation	714	500	70.0	46	6.5	155	21.6
Bradley Woods Reservation	801	775	96.8	7	0.9	18	2.2
Brecksville Reservation	3,335	2,798	83.9	85	2.5	433	13.0
Brookside Reservation and Zoo	301	127	42.3	90	29.8	84	27.9
Euclid Creek Reservation	351	258	73.6	29	8.3	57	16.1
Garfield Park Reservation	221	154	69.9	35	16.0	43	19.3
Hinckley Reservation	2,818	2,035	72.2	48	1.7	681	24.2
Huntington	367	164	44.7	100	27.4	118	32.2
Huntington Reservation	104	68	65.3	18	17.3	20	19.3
Mill Stream Run Reservation	3,183	2,608	81.9	84	2.6	439	13.8
North Chagrin Reservation	2,172	1,686	77.6	71	3.3	350	16.1
Ohio and Erie Canal Reservation	367	171	46.7	28	7.6	118	32.3
Rocky River Reservation	2,587	1,793	69.3	168	6.5	493	19.1
South Chagrin Reservation	1,529	1,258	82.3	70	4.6	179	11.7
Washington Reservation	58	12	19.8	8	13.3	39	67.5
West Creek Reservation	324	261	80.5	7	2.1	56	17.2

Figure 12. Percent of Existing UTC, Possible UTC, and Impervious areas by Reservation

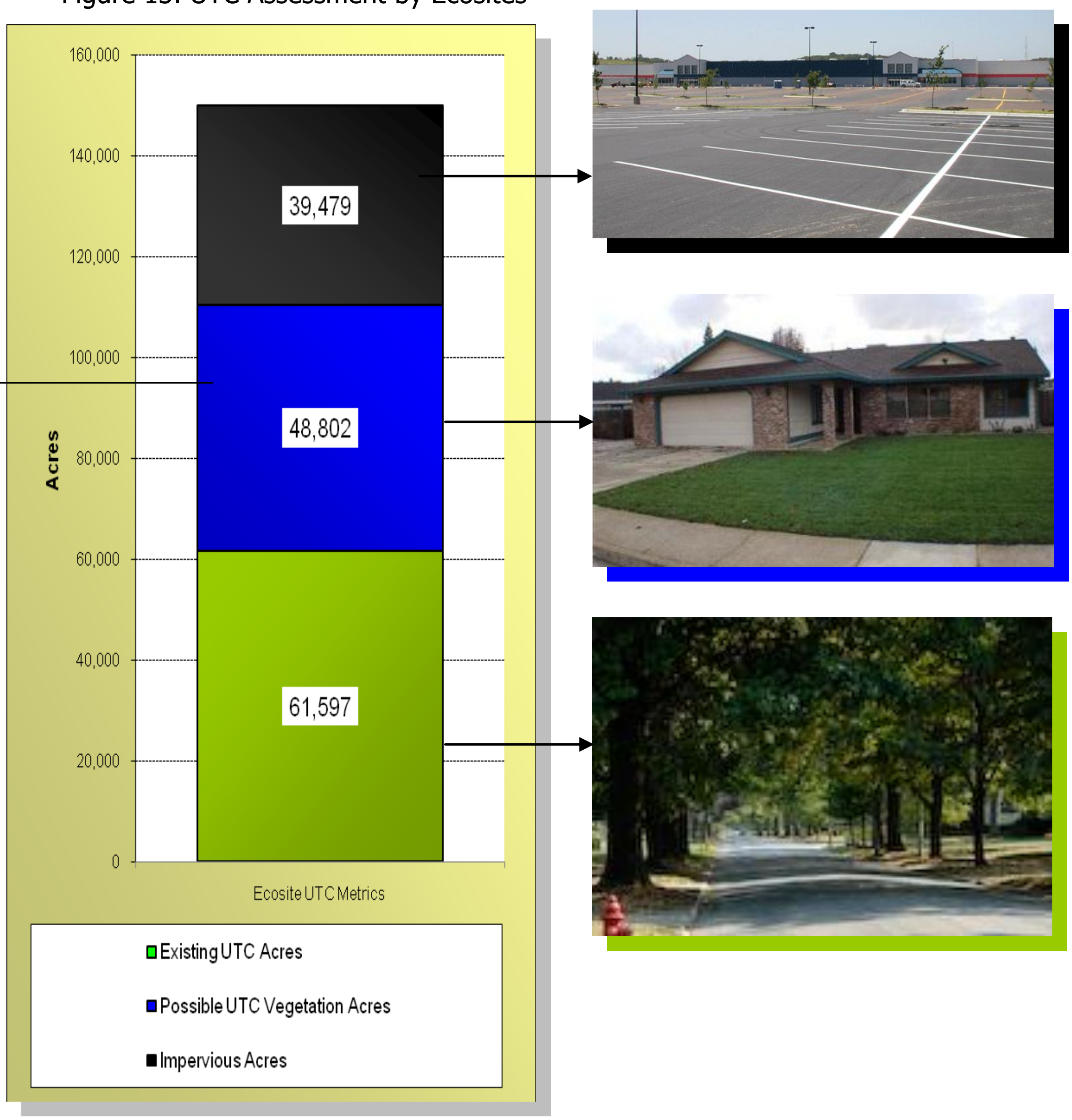


Cleveland Metroparks UTC Results by Ecosite

Table 4. Summary of UTC Metrics for Cleveland Metroparks' Ecosites

Area	Total Acres	Existing UTC Acres	Existing UTC %	Impervious Acres	Impervious %	Possible UTC Vegetation Acres	Possible UTC Vegetation %
Ecosites (Including Reservations)	150,514	61,597	40.9	39,479	26.2	48,802	32.4

Figure 13. UTC Assessment by Ecosites



Cleveland Metroparks' Ecosites consist of 48,802 acres of "Possible UTC Vegetation"

Table 5. UTC Metrics for Cleveland Metroparks Ecosites

Ecosite	Total Acres	Existing UTC Acres	Existing UTC %	Impervious Acres	Impervious %	Possible UTC Vegetation Acres	Possible UTC Vegetation %
Bedford	12,921	5,612	43.4	3,383	26.2	3,959	30.6
Big Creek	10,195	2,347	23.0	4,482	44.0	3,387	33.2
Bradley Woods	5,258	2,667	50.7	1,023	19.5	1,586	30.2
Brecksville	9,292	6,971	75.0	487	5.2	1,727	18.6
Brookside and Zoo	1,480	375	25.3	604	40.8	495	33.4
Euclid Creek	4,993	1,608	32.2	2,049	41.0	1,371	27.5
Garfield Park	4,539	1,068	23.5	1,913	42.1	1,578	34.8
Hinckley	14,578	7,180	49.3	1,112	7.6	6,226	42.7
Mill Stream Run	13,648	6,139	45.0	2,752	20.2	4,722	34.6
North Chagrin	9,061	4,587	50.6	2,009	22.2	2,431	26.8
Ohio and Erie Canal	6,704	852	12.7	3,808	56.8	1,687	25.2
Rocky River	11,336	3,783	33.4	3,963	35.0	3,521	31.1
Secondary Central	5,817	734	12.6	3,205	55.1	1,898	32.6
Secondary South	10,423	5,308	50.9	684	6.6	4,288	41.1
Secondary Northeast	10,641	3,279	30.8	3,462	32.5	3,977	37.4
Secondary West	5,593	2,180	39.0	1,536	27.5	1,882	33.6
South Chagrin	8,952	5,665	63.3	1,115	12.5	2,115	23.6
Washington	1,357	164	12.1	818	60.3	371	27.3
West Creek	3,724	1,077	28.9	1,073	28.8	1,582	42.5

Figure 14. Percent of Existing UTC, Possible UTC, and Impervious areas by Ecosite

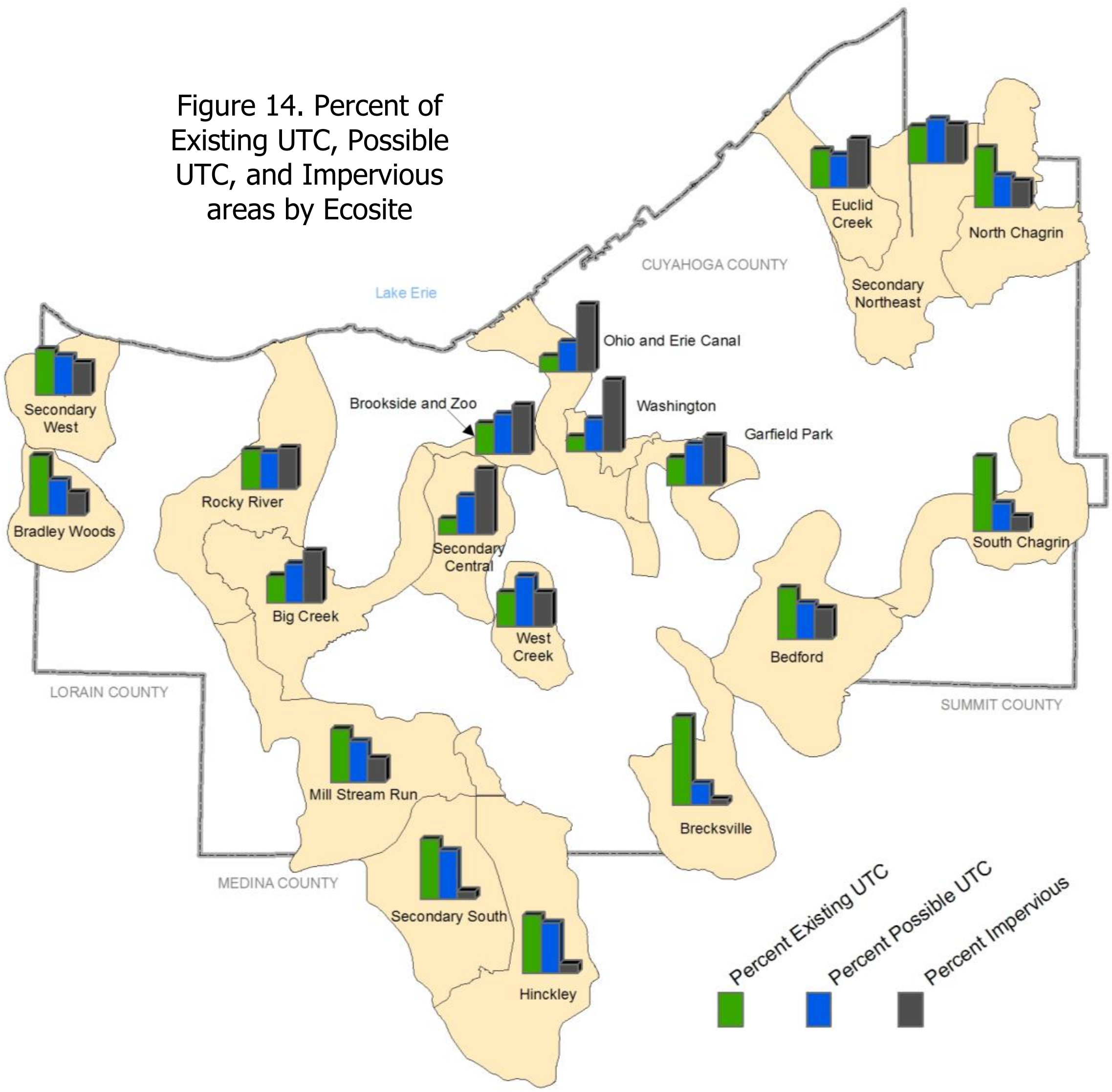


Figure 15. Existing UTC by Ecosite

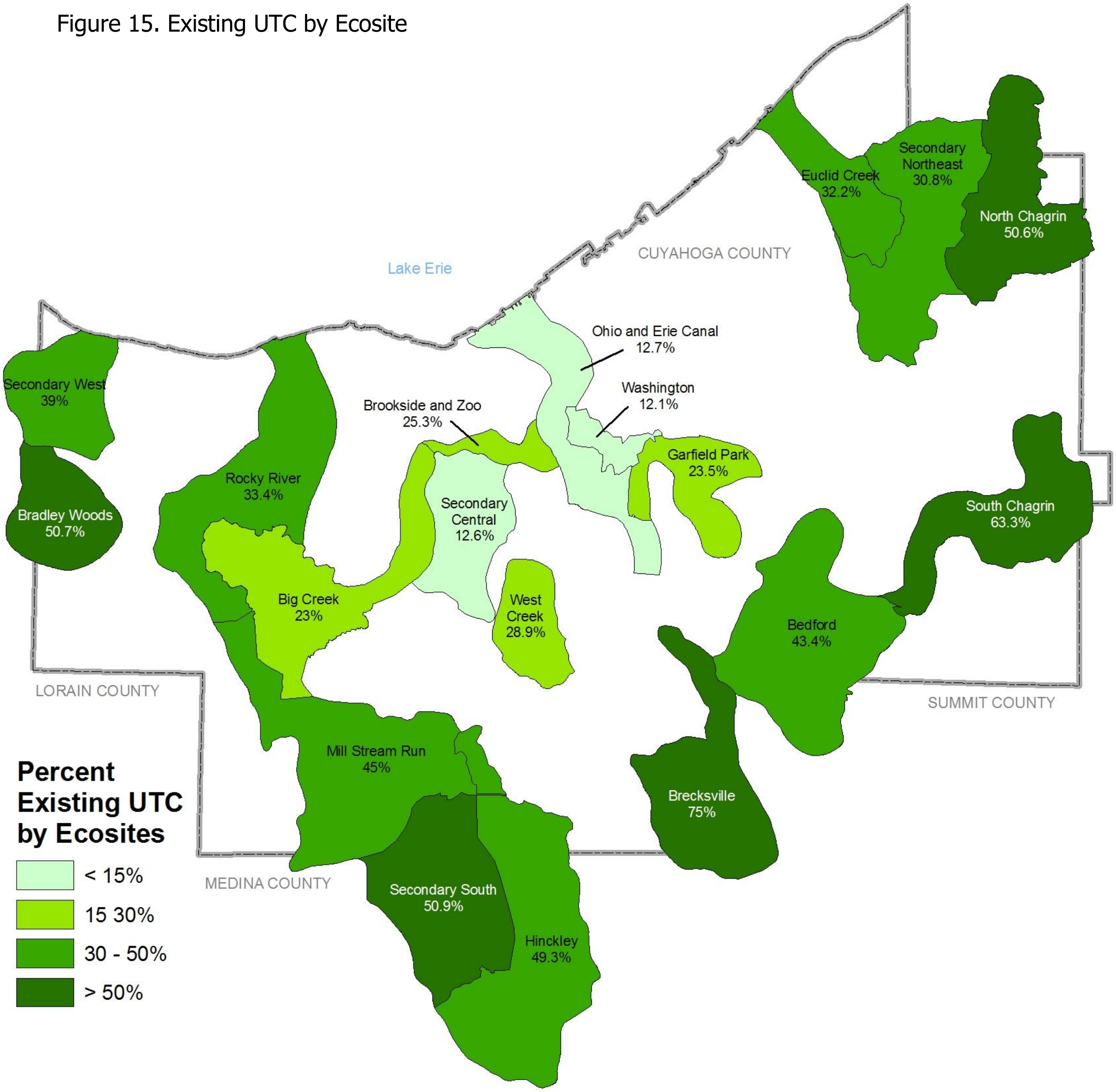


Figure 16. Possible UTC by Ecosite

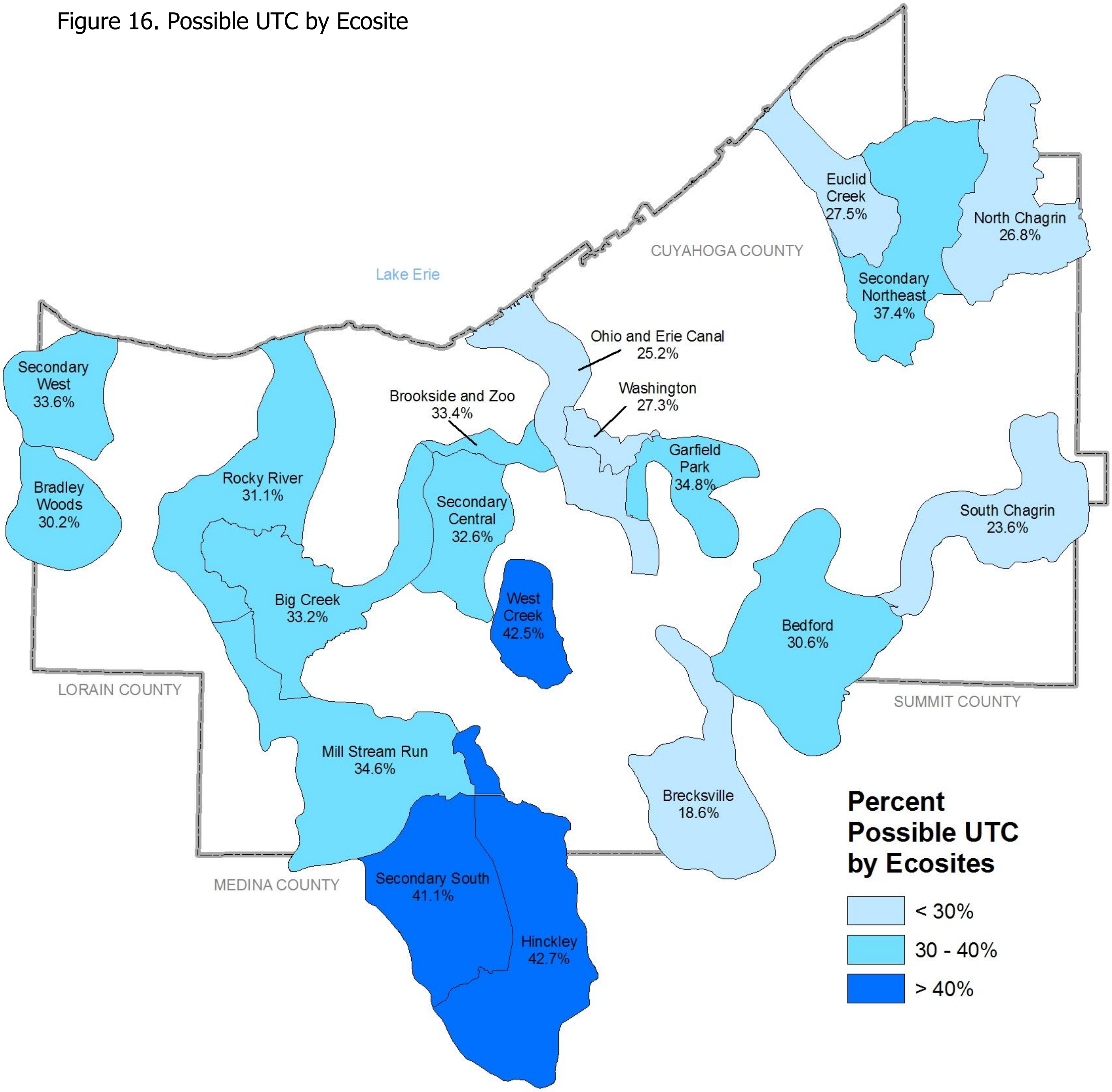
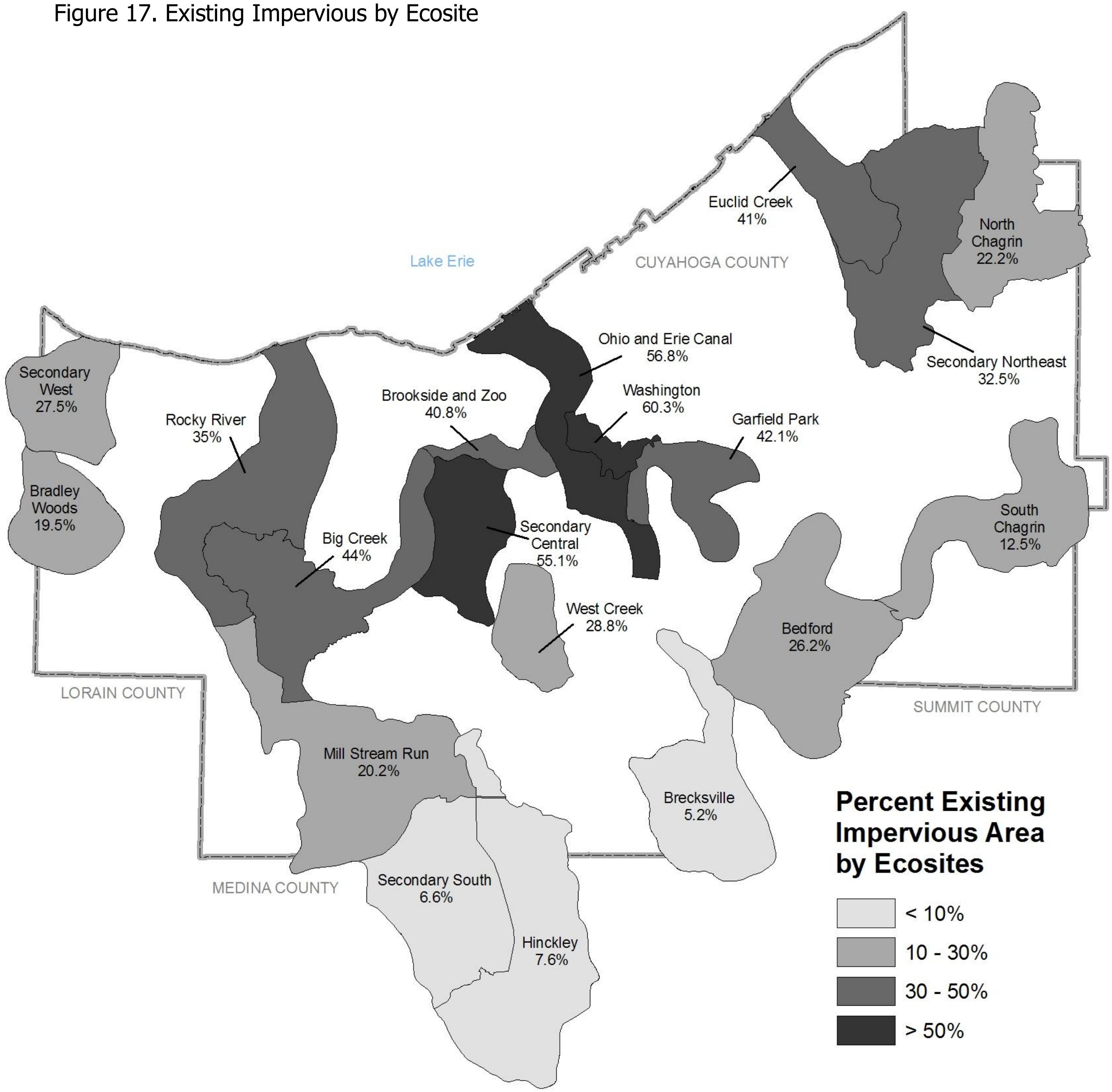
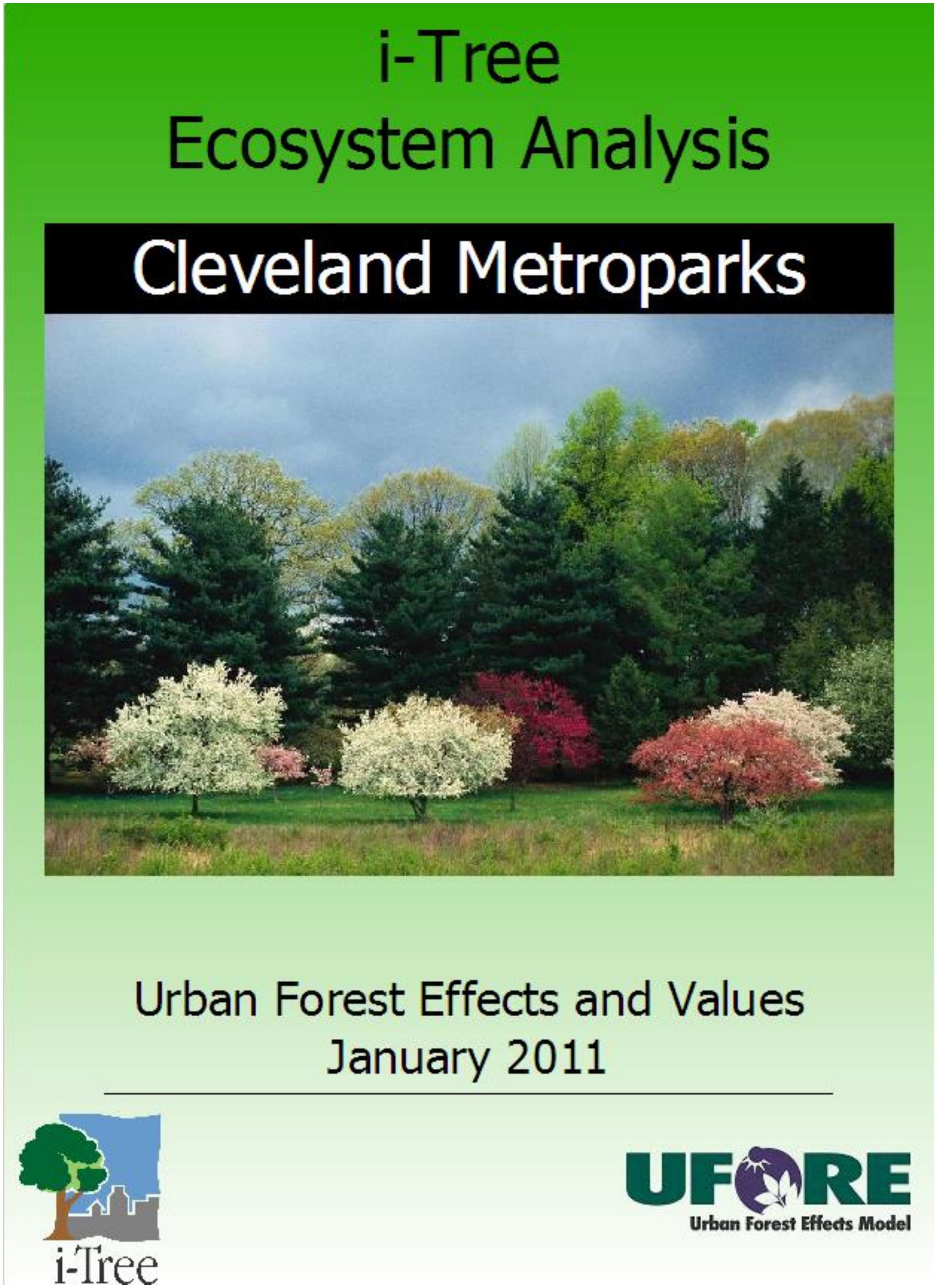


Figure 17. Existing Impervious by Ecosite



Part 2: i-Tree Ecosystem Analysis



i-Tree Eco Summary

Understanding urban forest structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation was conducted during the summer and fall of 2010 within Cleveland Metroparks Reservations. 94 out of 109 field plots were analyzed using the Urban Forest Effects (UFORE) model developed by the U.S. Forest Service, Northern Research Station. Data were not collected on plots outside Park District boundaries in areas termed "Ecosites." This application of the UFORE model was therefore unique in that all plots were collected in naturally growing forests and open space compared to most other applications of the UFORE model in urban/suburban settings where tree growth models better represent open grown tree dimensions. While structural value and ozone mitigation are likely overestimated, this analysis was nonetheless an important first step in evaluating the ecosystem services provided by the forests in CMP's Reservations. These values also appear high in CMP because of the high canopy cover (estimated at 73.1% from the plots and 77.0% from UTC).

Compared to other applications of the UFORE model, this analysis did not include shrub information or information on stems less than 10cm (4in) at breast height because of time restrictions. No data was collected on buildings for analyzing energy savings provided by trees because of the paucity of structures in the reservations. It is also important to note that the terms UFORE and i-Tree Eco can be used interchangeably.

Key findings

- Estimated total number of trees: 1,339,000
- Tree cover: 73.1% (slightly lower than the 77.0% from the UTC Assessment in Part 1 of this report)
- Most common species: Red maple (*Acer rubrum*) and sugar maple (*A. saccharinum*), and abundance of dead standing hardwood trees
- Pollution removal: 11,200 metric tons/year ($63.9 million/year)
- Carbon storage: 329,000 metric tons ($6.67 million)
- Carbon sequestration: 10,600 metric tons/year ($216 thousand/year)
- Structural values: $2.85 billion

Metric ton: 1000 kilograms
Carbon storage: amount of carbon in the above-ground and below-ground parts of woody vegetation
Carbon sequestration: the removal of carbon dioxide from the air by plants through photosynthesis
Structural value: value based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree)

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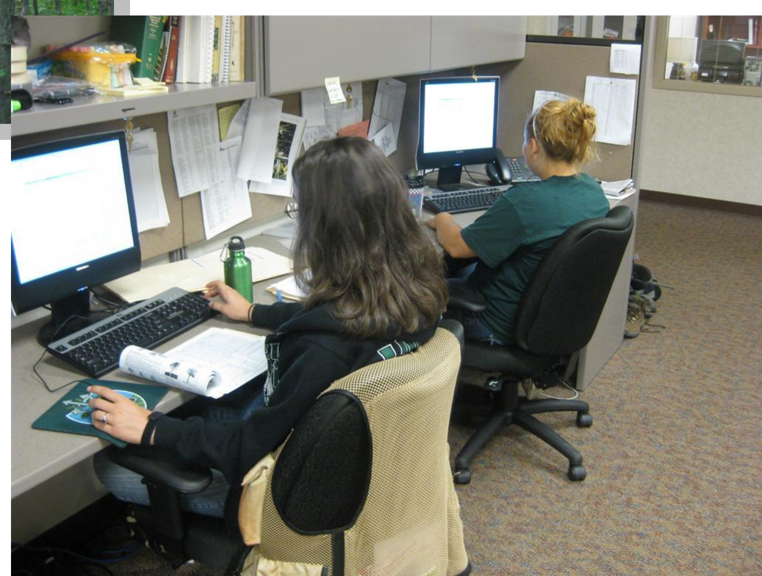


I. Tree Characteristics of the Urban Forest

The urban forest of Cleveland Metroparks has an estimated 1,339,000 trees with a tree cover of 73.1 percent. Trees that have diameters less than 6-inches constitute 28.1 percent of the population. The three most common species are Red maple (16.30 percent), Sugar maple (14.40 percent), and dead standing hardwood trees (Hardwood in Figure 1) (8.44 percent).

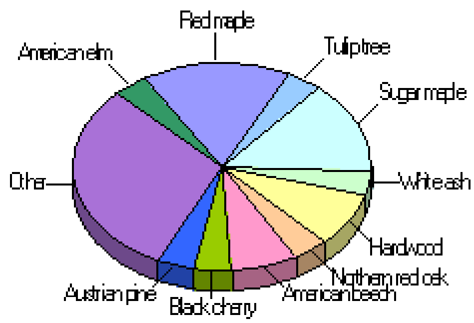


Figure 1. Tree species composition in Cleveland Metroparks

Unlike other Eco projects, metrics could not be generated by major land use categories simply because plots were only collected in parks. The overall tree density in Cleveland Metroparks is 372 trees / hectare (see Appendix III for comparable values from other cities).

Tree diameter distribution follows the typical reverse J-shaped curve typical of uneven-aged forest stands (Figure 3). Note that trees less than 6 inches diameter at breast height (DBH) were not measured in this study to save time in data collection.

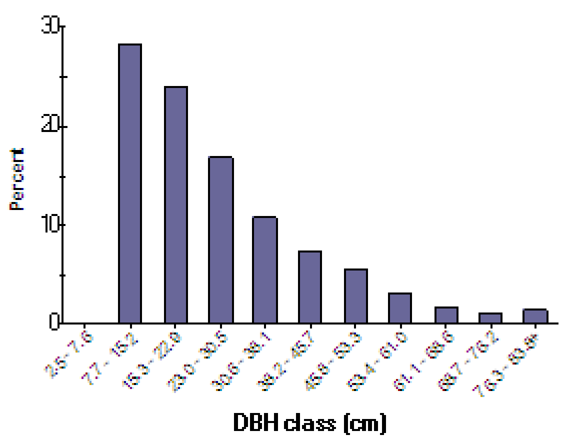


Figure 3. Percent of tree population by diameter class (DBH=stem diameter at 1.37 meter)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Cleveland Metroparks, about 94 percent of the trees are from species native to North America, while 91 percent are native to the state or district. Species exotic to Ohio make up only 6 percent of the population (Figure 4). Most exotic tree species have an origin from Eurasia (4.9 percent of the species). These include Norway maple (*Acer platanoides*) and white willow (*Salix alba*), which have probably escaped from yard plantings, and Austrian pine (*Pinus nigra*), which has been planted throughout the Park District.

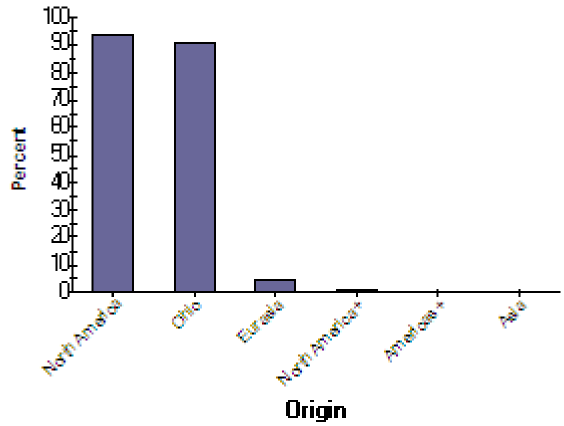


Figure 4. Percent of live trees by species origin

"North America +" = native to North America and at least one other continent except South America
"Americas +" = native to North and South America and at least one other continent

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. In Cleveland Metroparks, the three most dominant species in terms of leaf area are American beech, Sugar maple, and Red maple. Trees cover about 73.1 percent of Cleveland Metroparks, and shrubs cover 34.4 percent (derived from an ocular estimate of cover for all shrubs on plots).

The 10 species with the highest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of relative leaf area and relative composition and reflect abundance and dominance (size) in the forest.

Table 1. Most important species in Cleveland Metroparks

Common Name	*Percent Population*	*Percent Leaf Area*	*IV*
Sugar maple	14.4	15.3	29.6
American beech	7.2	20.7	27.9
Red maple	16.3	10.3	26.6
Tulip tree	3.8	8.4	12.1
Northern red oak	3.9	4.7	8.5
Dead standing hardwood trees	8.4	0.0	8.4
Eastern cottonwood	2.1	5.8	8.0
Black walnut	1.4	5.7	7.1
White ash	3.8	2.5	6.3
American elm	3.7	2.4	6.2

The two most dominant ground cover types are Herbs (43 percent) and Duff/mulch (39.6 percent) (Figure 5).

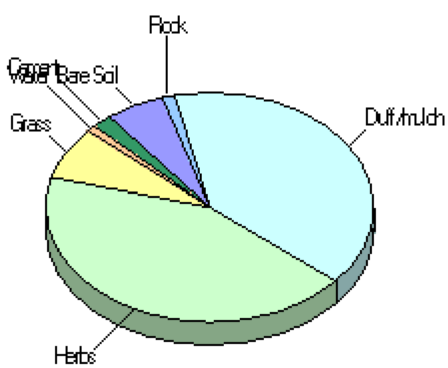


Figure 5. Percent ground cover in Cleveland Metroparks

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to susceptible landscape plants and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power plants. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation [1].

Pollution removal by trees and shrubs in Cleveland Metroparks was estimated using field data and recent pollution and weather data available. Pollution removal was greatest for ozone. It is estimated that trees (over 6 inches DBH) remove 11,200 metric tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 10 microns (PM10), and sulfur dioxide (SO2)) per year with an associated value of $63.9 million (based on estimated national median externality costs associated with pollutants [2]).

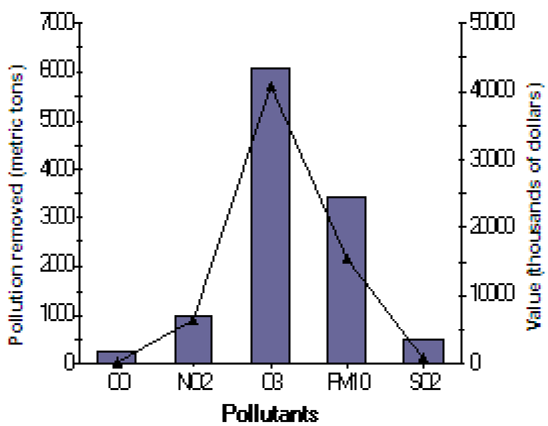


Figure 6. Pollution removal and associated value for trees in Cleveland Metroparks (line graph is value)

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power plants [3].

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Cleveland Metroparks trees over 6 inches DBH is about 10,600 metric tons of carbon per year with an associated value of $216 thousand. Net carbon sequestration in the urban forest is about 6,110 metric tons.

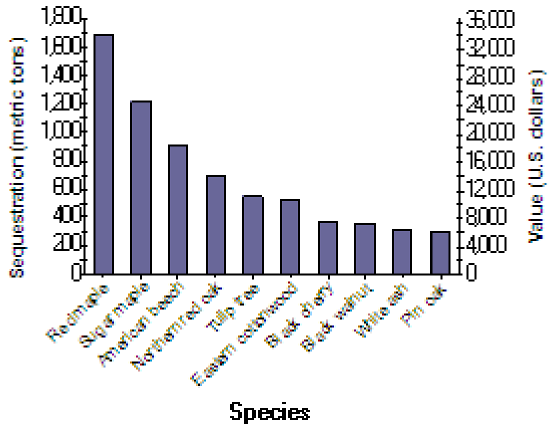


Figure 7. Carbon sequestration and value for species with greatest overall carbon sequestration in Cleveland Metroparks

As trees grow they store more carbon as wood. As trees die and decay, they release much of the stored carbon back to the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be lost if trees are allowed to die and decompose. Trees in Cleveland Metroparks are estimated to store 329,000 metric tons of carbon ($6.67 million). Of the species sampled, red maple stores and sequesters the most carbon (approximately 13.7% of the total carbon stored and 27.4% of all sequestered carbon) because it is the most common species.

V. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings [4], however for this project this data was not collected because of the paucity of structures in CMP Reservations.

VI. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree). They also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees [6]. Annual functional values also tend to increase with increased number and size of healthy trees, and are usually on the order of several million dollars per year. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Structural values are set at a base of $150 per transplantable tree, and modified upwards or downwards based on tree size, species, placement, and condition [6]. Because of its abundance, red maple ranks highest in structural value (Figure 8). However, Northern red oak ranks third in structural value mainly because of it is a more valuable urban tree species. The absolute values are high estimates because trees were categorized as "park" trees with an associated higher value multiplier. If these trees had been categorized at "forest" trees, the value would have been decreased by a value of approximately one-third [6].

<u>Structural values:</u>

- Structural value: $2.85 billion
- Carbon storage: $6.67 million

<u>Annual functional values:</u>

- Carbon sequestration: $216 thousand
- Pollution removal: $63.9 million
- Lower energy costs and carbon emission reductions: $0 (Note: negative value indicates increased energy cost and carbon emission value)

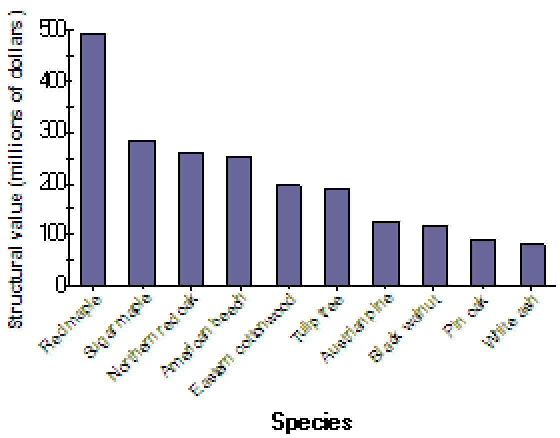


Figure 8. Structural value of the 10 most valuable tree species in Cleveland Metroparks

VII. Potential Pest Impacts

Insects and diseases can infest urban forests, potentially killing trees and reducing the health, value and sustainability of the urban forest. As pests tend to have a different range of tree hosts, the potential damage or risk of each pest will differ. Four exotic pests were analyzed for their potential impact on Cleveland Metroparks trees: Asian long-horned beetle (ALB), gypsy moth (GM), emerald ash borer (EAB), and Dutch elm disease (DED).

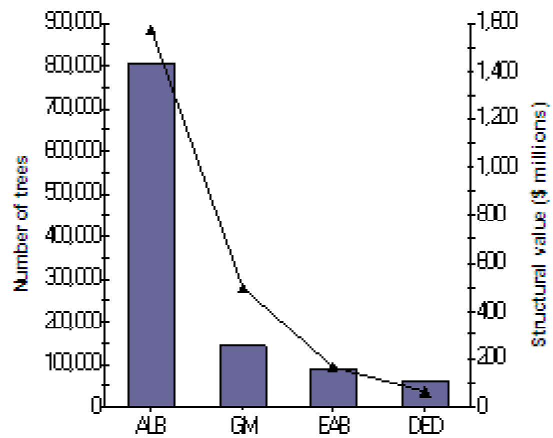


Figure 9. Number of susceptible Cleveland Metroparks trees and structural value by pest (line graph is structural value)

The Asian long-horned beetle (ALB) [7] is an insect that bores into and kills a wide range of hardwood trees species including maples, buckeyes, willows, elms, birches and sycamores. Because of this wide host range, ALB is estimated to inflict the highest economic damage to trees in the Park District (Figure 9). ALB poses a threat to 60.3 percent of the Cleveland Metroparks urban forest, which represents a loss of $1.57 billion in damage to the structure. The ALB has been introduced into New York City, New Jersey, Chicago, and Worcester, Massachusetts, and Ohio is considered an at risk state (http://beetlebusters.info/).

Gypsy moth (GM)[8] is a defoliator mostly of oaks and aspen, but it can feed on hundreds of species causing widespread defoliation and tree death if outbreak conditions last several years. This pest threatens 10.8 percent of the population, which represents a loss of $497 million in structural value. Past Gypsy moth outbreaks have caused mortality to oak trees in Cleveland Metroparks.

Emerald ash borer (EAB)[9] has killed thousands of ash trees in parts of the United States, especially near the epicenter of the original introduction near Detroit. EAB has the potential to kill all ash species throughout North America, including 6.6 percent of the total tree population in Cleveland Metroparks ($164 million in structural damage; approximately 89,000 trees over 6 inches DBH). EAB is present in Cleveland Metroparks, and mortality is already occurring.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) [10]. Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Cleveland Metroparks could possibly lose 4.4 percent of its trees to this pest ($62.2 million in structural value). DED continues to affect elm trees in Cleveland Metroparks.

VIII. Next Steps for Cleveland Metroparks

As with any quantitative estimates based on sampling, the accuracy of the estimates increases with the number of samples collected. Even though the estimates in this project compare favorably with independent estimates from other vegetation sampling in the Park District, 109 plots are a relatively small sample for the variable nature of the Park District. Moreover, if information is desired by forest cover type or by reservation, then additional plots are needed in each of these strata. Further, now that information is available for Cleveland Metroparks, similar information is needed at city, county and regional levels for comparison purposes. The Plant Community Assessment Program initiated in 2010 by Cleveland Metroparks Natural Resources Division provides a spatially balanced, randomized, plot-based experimental design to accomplish just such a task. We will work with cooperators to determine if such data collection is feasible through urban forest granting agencies such as the US Forest Service.

While the sample sizes are small, we intend to analyze this dataset by reservation and are currently working with US Forest Service personnel to accomplish this task. Moreover, additional analyses will be performed using other tree classification variables other than "park" to give better estimates of carbon, pollution, and tree value characteristics.

Conclusions and Recommendations

Other Urban Tree Canopy (UTC) Assessments and i-Tree Eco projects conducted throughout the U.S. tend to occur at the city or countywide scale, making this project with CMP unique in that its extent was based on highly forested park land and watershed boundaries comprised mostly of urban/suburban development. CMP clearly maintains a leadership role in the stewardship of forestry, parks and natural resources in the Cleveland metropolitan region as seen through this project and the interest in gaining more information not only within their own Reservations but also in the watershed boundaries (Ecosites) surrounding Reservations. This project identified existing tree canopy and impervious surface area as well as quantified structural and functional forest values in CMP Reservations, which collectively provide benchmarks on current conditions, ecosystem structure and services provided by CMP Reservations and data for analysis of land use and water resources practices in or around Reservations.

With a total project area of nearly 151,000 acres and over 21,000 acres occupied by CMP Reservations, approximately 14% of the project area was in parks. UTC for this project can best be compared with other metropolitan areas using the metrics of 41% UTC for the overall area and 34.9% UTC specifically within Ecosites (excluding Reservations), to avoid comparing directly to other projects that were not centered on large park areas. As seen in the "UTC Comparison" chart in the Appendix, both 41% UTC for the project area and 34.9% UTC for the Ecosites are above the average of other metro areas. Comparing the metric of 77% Existing UTC in Cleveland Metroparks Reservations would be more difficult as similar project data was not available. A comparison of Possible UTC was not feasible; however, available planting space was mapped and assessed for Reservations and Ecosites that illustrates where and how much additional tree canopy could be added with consideration of the amount of impervious surface area in a given watershed. Clearly, a focus on preserving tree canopy in Reservations is important to sustain functional benefits.

General Findings and Recommendations:

- Sorting the UTC spreadsheet by Existing UTC and Possible UTC identifies Ecosites with low Existing UTC, high Possible UTC, and high impervious surface area. This provides a starting point for targeting increases in UTC and other stormwater management practices. CMP may consider assessing land cover at a finer scale such as the municipal, neighborhood or parcel level for results that are most meaningful for planning and management. Ultimately, potential partners should be identified to set a UTC Goal at the watershed scale, where further prioritization could include the use of vacant or abandoned lands and areas prone to flooding, crime, erosion, and water quality issues.

- The three Ecosites with lowest Existing UTC %, Ohio and Erie Canal, Secondary Central, and Washington, each have over 25% Possible UTC. These Ecosites also have over 50% impervious area. Tree canopy improvements could be targeted in these and other Ecosites in tangent with green infrastructure initiatives to mitigate the amount of nonpoint source pollution runoff to streams and lakes. Other benefits include a reduction in the urban heat island effect and improved aesthetics & property values.
- AMEC has developed a sophisticated "UTC Calculator" spreadsheet tool that provides the ability to "plug and play" with UTC metrics to gauge the impact of tree planting on canopy cover at various scales. For each UTC geography, in this case Reservations and Ecosites, a user can input a number of trees, a percent canopy target, or a percent canopy increase and see the effects on UTC. The average tree crown diameter can also be adjusted to show the impact of larger trees and growth over time. The UTC Calculator can illustrate the number of trees required to reach a UTC goal within a given Ecosite or municipality.
- CMP may consider modeling stormwater and water quality in a scenario where Reservations were replaced by commercial and residential development to illustrate the value that the green space currently provides both within park boundaries and downstream in other development. Additionally, the results of this project could be used to model additional UTC on a watershed basis to quantify the subsequent local and regional water quality improvement. This could include a GIS analysis of Existing and Possible UTC along riparian corridors for targeted restoration. Options for modeling software include the USFS i-Tree Hydro model to be released end of 2010 and EPA's SWMM LID module recently released.
- These results can also be used to educate on the importance of species selection, pruning and the enforcement or strengthening of existing tree-related ordinances. The results and data products provided can be used to engage the public and other stakeholders, and provide the basis for more detailed environmental studies, comprehensive planning, GIS analyses and targeted urban forestry implementation/outreach programs.
- A similar study should be conducted in 5-10 years to monitor UTC and other land cover change.

There are several benefits of a UTC project, including low cost, rapid turnaround, integration with existing GIS resources and resulting datasets that meet multiple agency and department needs. A UTC project will never replace the more detailed information collected through a traditional street tree inventory, as specific species are not identified and no attempt is made to qualify the existing canopy in terms of its sustainable and diverse species. Nonetheless, it is an effective method for establishing canopy cover goals, estimating broad ecosystem services, and assessing the urban forest with results that are easily communicated with project stakeholders and the community at large.

Acknowledgements

CMP would like to thank the Ohio Department of Natural Resources and the U.S. Forest Service for supporting the design and development of this project, as well as for providing 50% of the funding through the Northeastern Area State and Private Forestry Competitive Grant Initiative. This project was one of several UTC studies done in the states of Ohio and Michigan through a grant proposal titled "Regional Urban Tree Canopy Assessment and Implementation."

About Cleveland Metroparks

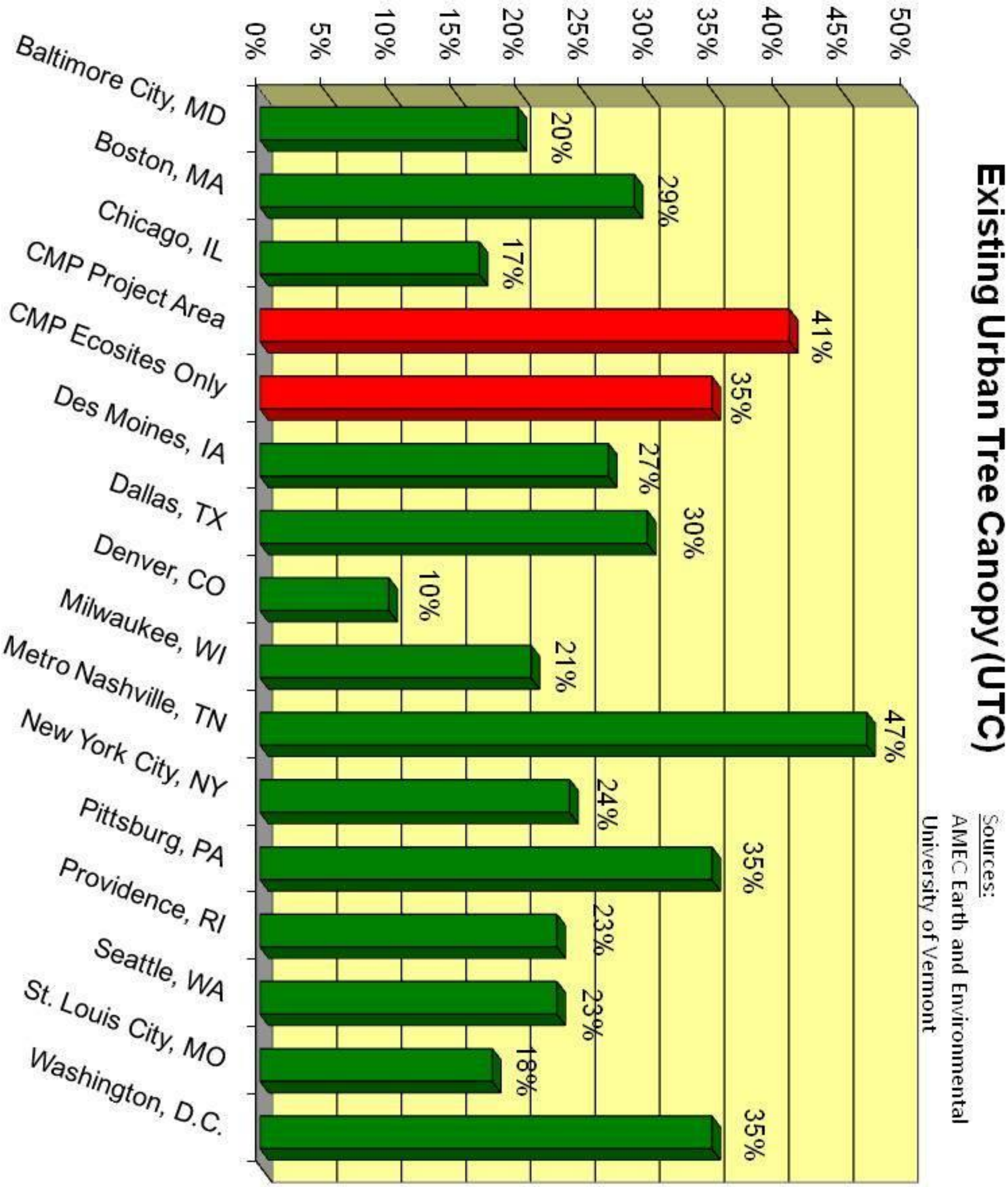
Cleveland Metroparks is a separate political subdivision of the state of Ohio. The Park District is governed by Cleveland Metroparks Board of Park Commissioners, composed of three citizens who serve three-year terms without compensation. Board members are appointed by the presiding Judge of the Probate Court of Cuyahoga County. Cleveland Metroparks' mission statement: Cleveland Metroparks will conserve significant natural resources and enhance people's lives by providing safe, high-quality outdoor education, recreation, and zoological opportunities. Further, Cleveland Metroparks Zoo is committed to improving the future for wildlife.

About AMEC Earth & Environmental

AMEC Earth & Environmental, Inc. (AMEC) is a leading full-service environmental engineering and construction/remediation services firm in North America, providing environmental and geotechnical engineering and scientific consulting services.

AMEC is a focused supplier of high-value consultancy, engineering, and project management services to the world's energy, power and process industries. We are one of the world's leading environmental and engineering consulting organizations. Our full service capabilities cover a wide range of disciplines, including environmental engineering and science, geotechnical engineering, water resources, materials testing and engineering, surveying, information management (GIS, remote sensing, database/application development) and program/project management.

Appendix I. Comparing % UTC in Cleveland to Other Cities



Appendix II. Land Cover Classification Accuracy Assessment

Cleveland Metroparks performed an independent accuracy assessment of the land cover classification data produced by AMEC Earth & Environmental, Inc. CMP produced separate accuracy assessments for the data within Reservations, within Ecosites, and for the combined datasets. Overall accuracy was found to be 96.5%. The combined datasets assessment is provided below.

Combine datasets: Sample Group 1 and Sample Group 2 dataset

		Reference Clasification						
		Tress	Water	Impervious	Other Vegetation	Bare Soil	TOTAL	(ii)
AMEC CLASSIFICATION	Trees	134	0	0	3	1	138	97.10
	Water	0	3	0	0	0	3	100.00
	Impervious	0	0	36	1	0	37	97.30
	Other Vegetation	2	0	1	47	0	50	94.00
	Bare Soil	0	0	0	0	1	1	100.00
	column sum	136	3	37	51	2	229	
	Column cum x (i)	18768	9	1369	2550	2	22698	
	sum diagonal =	221						
	N =	229						
	N ^2=	52441						
	k=	0.93841						
	overall accuracy =	96.51						

Appendix III. UFORE Model and Field Measurements

UFORE is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects [5], including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by Asian long-horned beetles (ALB), emerald ash borers (EAB), gypsy moth, and Dutch elm disease.

In the field 0.040 hectare plots were randomly distributed. Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Within each plot, typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings [11].

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations [12]. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models [13, 14]. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature[15,16] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere [17].

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described the literature [4] using distance and direction of trees from residential structures, tree height and tree condition data.

Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers [8], which uses tree species, diameter, condition, and location information [18].

Appendix IV. Relative Tree Effects

The urban forest in Cleveland Metroparks provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions [19], average passenger automobile emissions [20], and average household emissions [21].

<u>Carbon storage is equivalent to:</u>
- Amount of carbon emitted in the surrounding Cleveland area in 22 days
- Annual carbon (C) emissions from 217,000 automobiles
- Annual C emissions from 109,000 single-family houses

<u>Carbon monoxide removal is equivalent to:</u>
- Annual carbon monoxide emissions from 1,140 automobiles
- Annual carbon monoxide emissions from 4,750 single-family houses

<u>Nitrogen dioxide removal is equivalent to:</u>
- Annual nitrogen dioxide emissions from 66,400 automobiles
- Annual nitrogen dioxide emissions from 44,300 single-family houses

<u>Sulfur dioxide removal is equivalent to:</u>
- Annual sulfur dioxide emissions from 784,000 automobiles
- Annual sulfur dioxide emissions from 13,100 single-family houses

<u>Particulate matter less than 10 micron (PM10) removal is equivalent to:</u>
- Annual PM10 emissions from 10,100,000 automobiles
- Annual PM10 emissions from 975,000 single-family houses

<u>Annual carbon sequestration is equivalent to:</u>
- Amount of carbon emitted in the surrounding Cleveland area in .7 days
- Annual C emissions from 7,000 automobiles
- Annual C emissions from 3,500 single-family houses

Note: estimates above are partially based on the user-supplied information on human population total for study area

Appendix V. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the UFORE model.

I. City totals for trees

City	*% Tree Cover*	*Number of trees*	*Carbon storage (m tons)*	*Carbon Sequestration (m tons/yr)*	*Pollution removal (m tons/yr)*	*Pollution Value ($US)*
Calgary, Canada	7.2	11,889,000	404,000	19,400	296	1,611,000
Atlanta, GA	36.8	9,415,000	1,220,000	42,100	1,508	2,534,000
Toronto, Canada	20.5	7,542,000	900,000	36,600	1,100	6,105,000
New York, NY	21	5,212,000	1,226,000	38,400	1,521	8,071,000
Baltimore, MD	21	2,627,000	541,000	14,600	390	2,129,000
Philadelphia, PA	15.7	2,113,000	481,000	14,600	523	2,826,000
Washington, DC	28.6	1,928,000	474,000	14,600	379	1,956,000
Cle. Metroparks	73.1	1,339,000	329,000	10,600	11,200	63,900,000
Boston, MA	22.3	1,183,000	289,000	9,500	258	1,426,000
Woodbridge, NJ	29.5	986,000	145,000	5,000	191	1,037,000
Minneapolis, MN	26.5	979,000	227,000	8,100	277	1,527,000
Syracuse, NY	23.1	876,000	157,000	4,900	99	268,000
Morgantown, WV	35.9	661,000	85,000	2,700	60	311,000
Moorestown, NJ	28	583,000	106,000	3,400	107	576,000
Jersey City, NJ	11.5	136,000	19,000	800	37	196,000
Freehold, NJ	34.4	48,000	18,000	500	19	133,000

II. Per hectare values of tree effects

City	*No. of trees*	*Carbon Storage (metric tons)*	*Carbon sequestration (kgs/yr)*	*Pollution removal (kgs/yr)*	*Pollution Value ($US)*
Calgary, Canada	164.8	5.60	0.13	4.0	22.2
Atlanta, GA	275.8	35.64	0.62	44.2	74.1
Toronto, Canada	119.4	14.35	0.29	17.5	96.6
New York, NY	65.2	15.24	0.24	19.1	101.1
Baltimore, MD	125.5	25.78	0.35	18.6	101.8
Philadelphia, PA	61.8	14.12	0.21	15.2	82.8
Washington, DC	121.1	29.81	0.46	23.8	122.8
Cle. Metroparks	153.9	37.82	1.22	1287.4	7344.8
Boston, MA	82.8	20.18	0.33	17.9	99.8
Woodbridge, NJ	164.3	24.21	0.42	31.8	173.0
Minneapolis, MN	64.7	15.02	0.27	18.4	101.1
Syracuse, NY	134.7	24.21	0.38	15.2	41.3
Morgantown, WV	295.8	38.11	0.60	26.7	139.1
Moorestown, NJ	153.2	28.02	0.45	28.2	151.5
Jersey City, NJ	35.3	4.93	0.11	9.6	51.2
Freehold, NJ	95.1	35.87	0.49	37.7	263.4

Appendix VI. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are [22]:

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities [23]. Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include [24]:

Strategy	***Result***
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix VII: i-Tree Eco References

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20. Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) divided by total miles driven in

2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

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