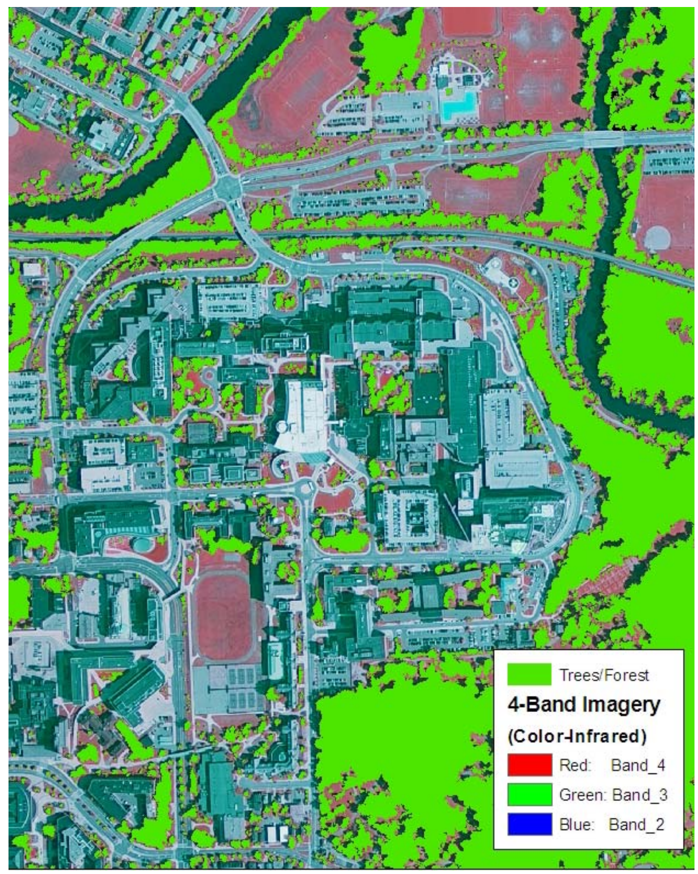
Ann Arbor, Michigan
Urban Tree Canopy (UTC) Assessment
April 2010



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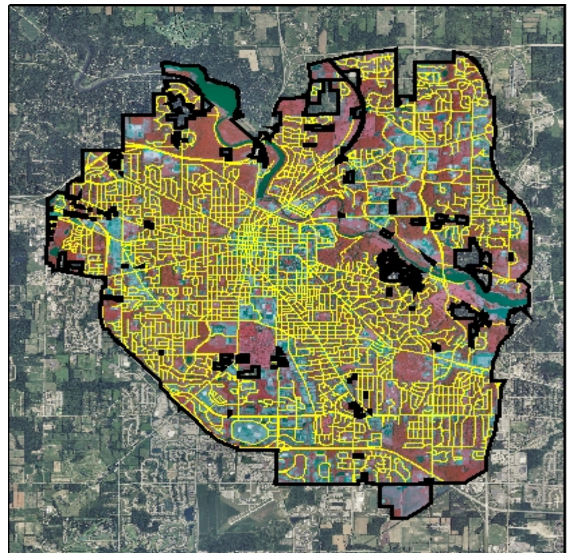
Introduction

Figure 1. Ann Arbor City Boundary showing streets and color-infrared imagery



This assessment was part of an effort between the City of Ann Arbor, Michigan, the Michigan Department of Natural Resources and AMEC Earth and Environmental, Inc (AMEC), with funding assistance from the U.S. Forest Service. The objective was to map and assess the Existing and Possible Urban Tree Canopy (UTC) in Ann Arbor and help prioritize street tree planting opportunities. This information will serve as a benchmark from which to measure the success of planning, development and urban forestry policies and programs. Deliverables included 2-ft resolution multispectral aerial imagery, a 5-class land cover layer (impervious surfaces, tree canopy, bare soil, vegetation, and water), UTC results citywide, by creekshed, census block, and land use, a GIS-based priority tree planting database, a UTC Calculator Tool, a UTC spreadsheet and a PowerPoint presentation. The project covered the city limits of Ann Arbor, an area of approximately 29 square miles. See Figure 1 above.

Ann Arbor's Urban Tree Canopy (UTC) at a Glance

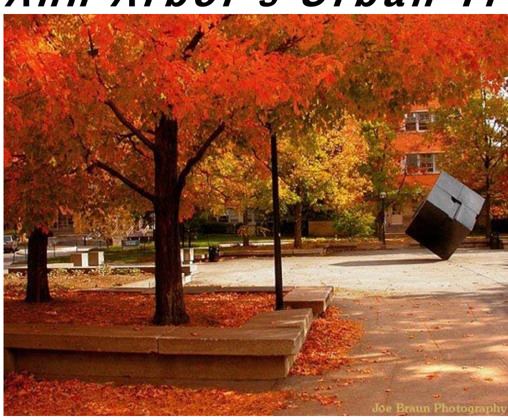


Photo Source: Joe Braun photography

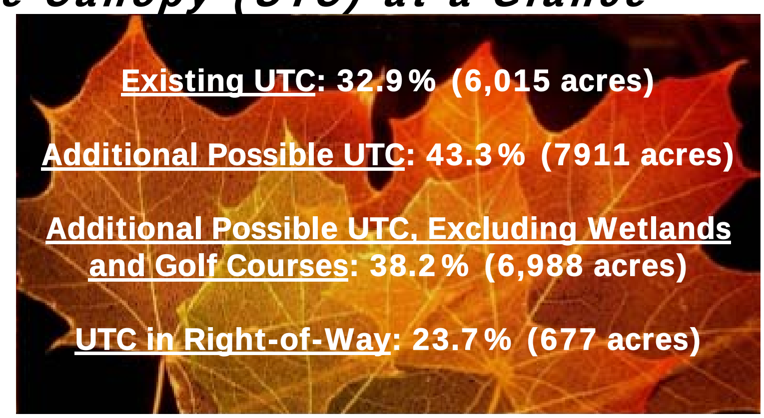


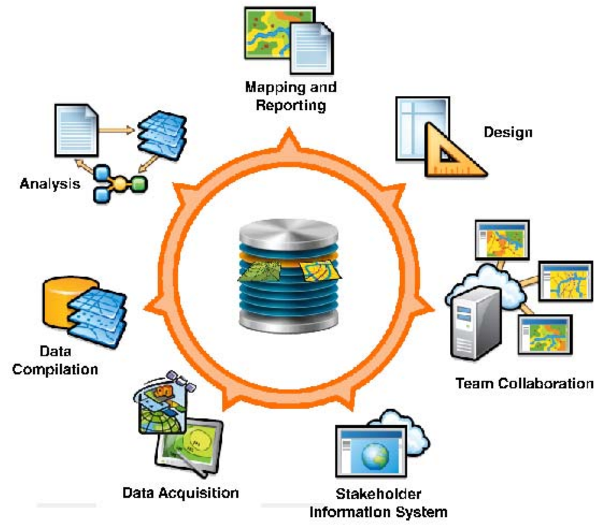
Photo Source: Wikipedia

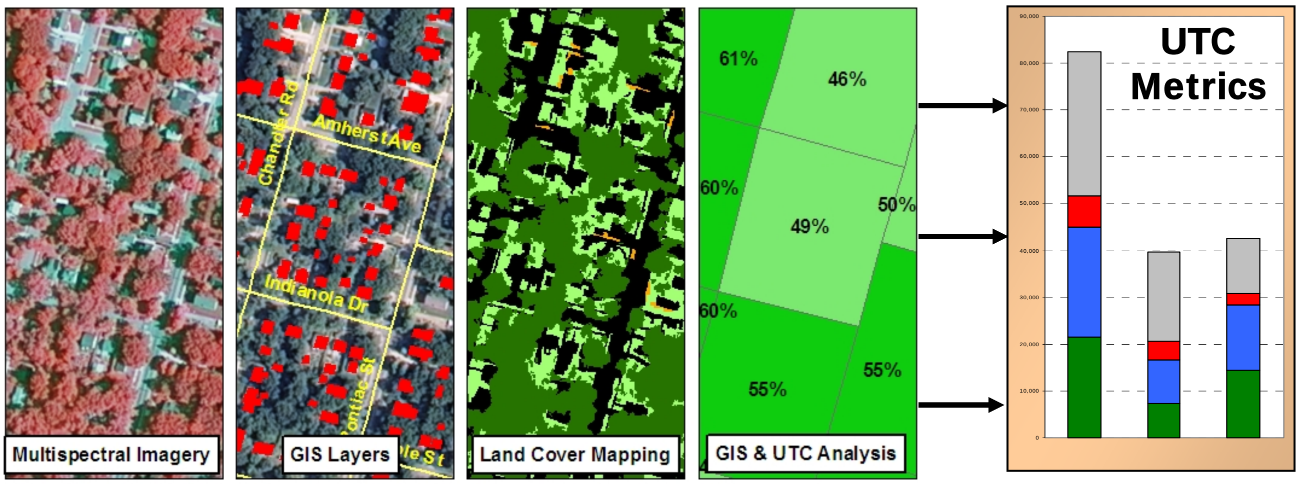
Key Terms:

GIS – Geographic Information Systems
AOI – Area of Interest, referring to the study or project area
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
Land Cover* – features on the earth mapped from aerial or satellite imagery, such as trees, grass, bare soil, water, and impervious surfaces
Possible UTC Vegetation * – grass or shrub area that is theoretically available for the establishment of tree canopy.
Possible UTC Impervious * – remaining area after excluding trees, water, roads and buildings where it is theoretically possible to establish tree canopy (primarily parking lots, driveways, patios, other impervious area)
*Source: USDA Forest Service and/or University of Vermont Spatial Analysis Laboratory (SAL)

Imagery and Data Requirements

Geographic Information Systems (GIS) and remote sensing technologies offer powerful analysis and decision support tools for managing urban natural resources. All UTC projects have at least 5 main elements in common regarding data inputs and outputs. These are: high-resolution imagery, GIS layers or other data inputs from the community, land cover data, geographic boundaries in which to summarize tree canopy acres and percent cover, and reports or tools that illustrate results through tables, charts and maps.



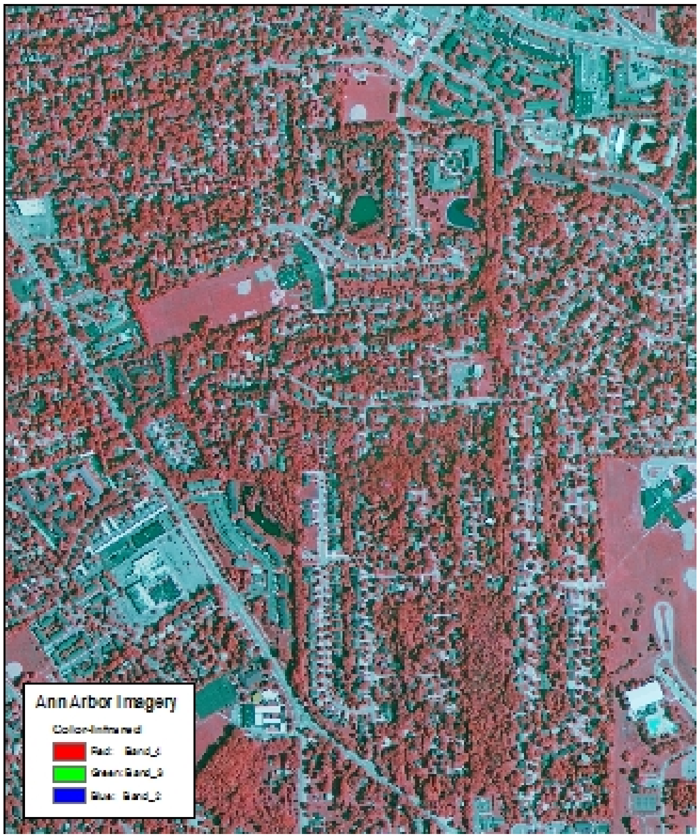


Figures 2 & 3. GIS Life Cycle and UTC Components

For this project, the City of Ann Arbor provided AMEC with the following GIS layers: city boundary, land use, creeksheds, hydrology, and impervious surfaces (pavement, buildings and streets). Summer 2009 imagery from the USDA National Agricultural Imagery Program (NAIP) was purchased from the Surdex Corporation and processed as a 2-foot, 4-band multispectral image for improved classification of land cover data compared to the 3-band natural color imagery which was available for free.

The multispectral imagery was analyzed using geographic object-based image analysis (GEOBIA) techniques to develop a 5-class land cover dataset that included tree canopy, grass/open space, impervious surface area, 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 imagery, as well as incorporation of datasets provided by the City. The classification was refined with a manual quality assurance / quality control (QA/QC) process to finalize the land cover. Recent LiDAR data was not yet available to incorporate. Figures 4-7 show examples of the results from this process.

Figures 4 & 5. Color infrared aerial imagery and 5-class land cover data.



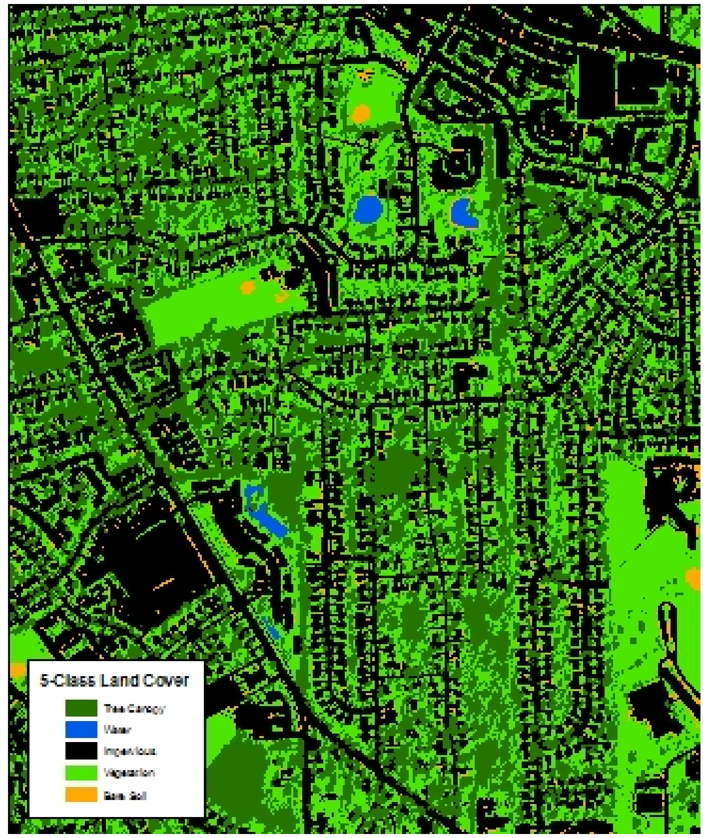
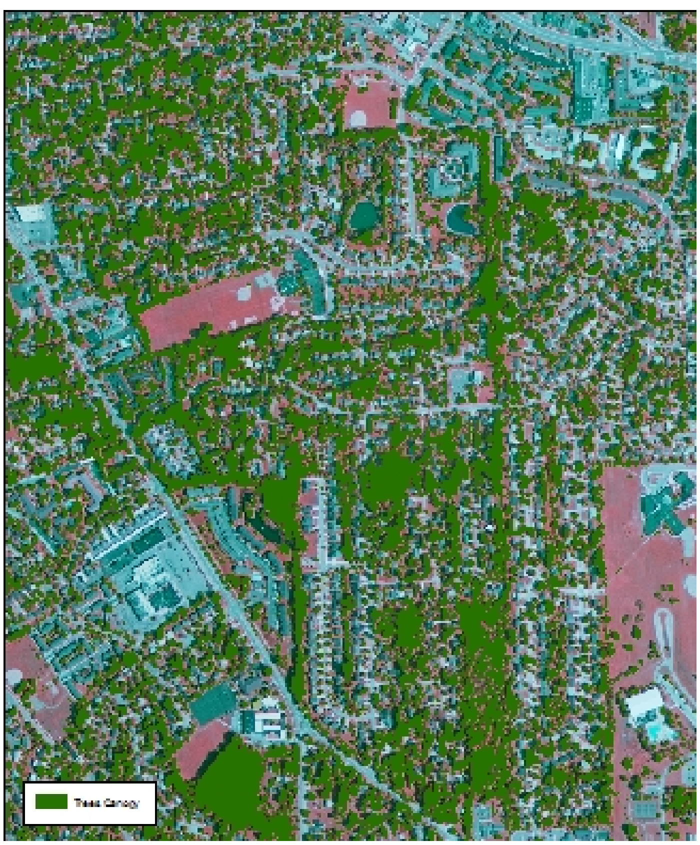


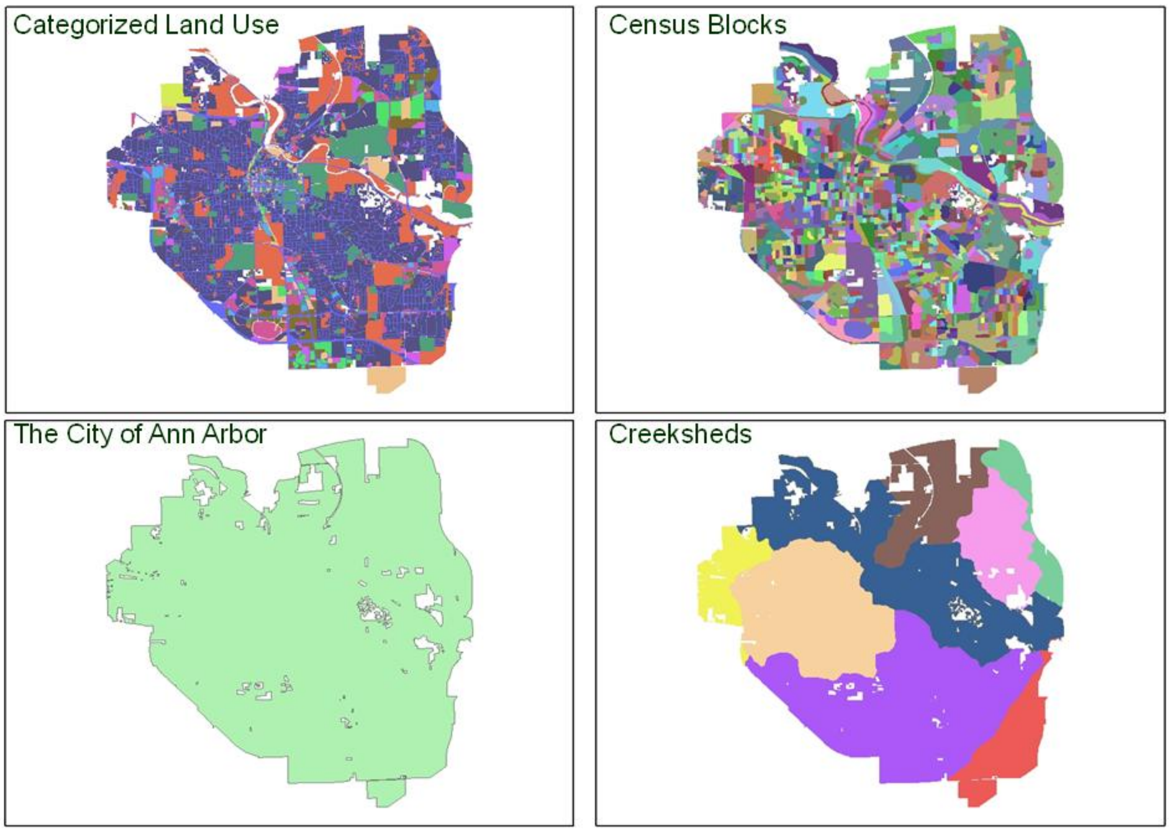
Figure 6 & 7. Trees and Impervious Land Cover Data



UTC Methodology and Assumptions

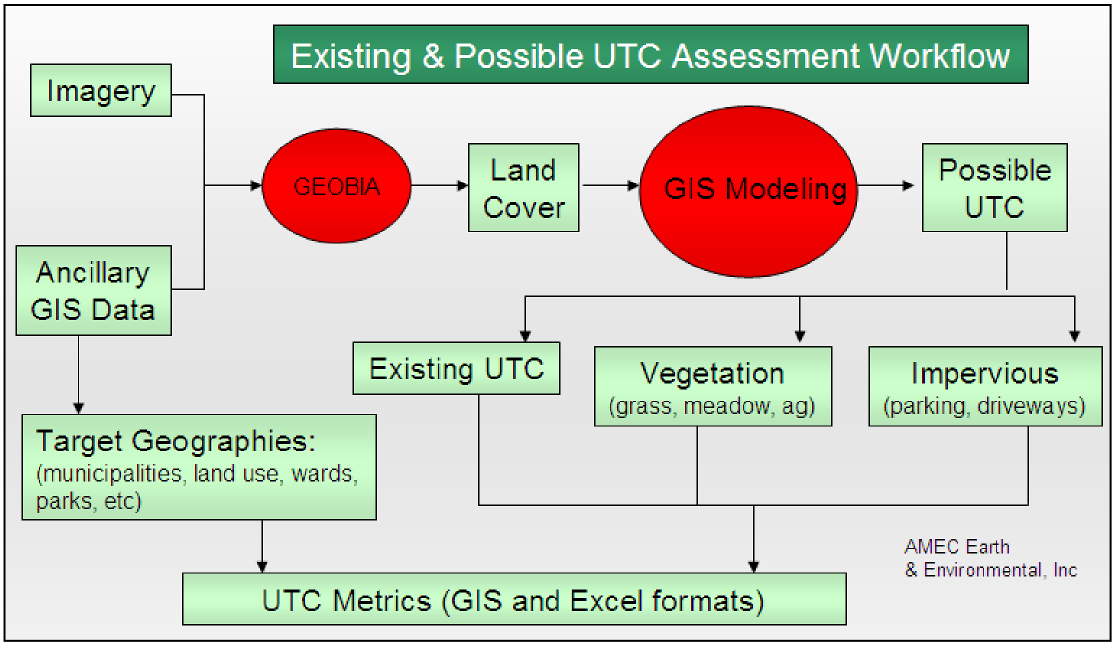
Using the GIS-based land cover classes described in the previous step, a series of geoprocessing models were created to calculate the area and percent of Existing and Possible UTC for the four geographic boundaries seen in Figure 8 below. These were chosen specifically to provide different scales and geographic meaning for planning and monitoring purposes. UTC results were provided in both GIS and Excel format for all of these geographic boundaries.

Figure 8. UTC GIS modeling workflow



Existing UTC was defined as all area covered by trees and forest. Possible UTC was sub-categorized into Possible Vegetation UTC or all grass and open space vegetation, Other Possible UTC comprised of wetlands and golf course vegetation, and Possible Impervious UTC which is defined as the remaining impervious area after excluding trees, buildings, roads and water. In a top-down approach, these areas represent where it is biophysically possible to plant trees. This follows the UTC protocols developed by the US Forest Service Northern Research Station and the University of Vermont Spatial Analysis Laboratory, excluding Other Possible UTC which was determined to be useful specifically for this project. Figure 9 below illustrates the workflow of the UTC Assessment process from imagery to land cover classification to GIS modeling to delivering the UTC metrics per geographic boundary.

Figure 9. UTC GIS modeling workflow



Results of the UTC Process

The area and percent of Existing UTC, Possible Vegetation UTC, Possible Other UTC, Possible Impervious UTC and Not Suitable land was calculated for the different geographic boundaries listed above. Existing UTC in the City of Ann Arbor was found to be 32.9% and Total Additional Possible UTC was 43.3%, comprised of Possible Vegetation UTC (23.7%, 4,327 acres), Other Possible UTC (5.1%, 923 acres), and Possible Impervious UTC (14.6%, 2,660 acres).

While residential and recreation land use properties makeup 58% of the city, they represent 67% of its UTC. Public rights-of-way (PROW) comprise 16% of the City, have 23.7% Existing UTC representing 11% of total UTC, and 577 acres of Total Additional Possible UTC. UTC within creeksheds ranged from 26% to 41%.

The full results can be accessed through the attribute table of each UTC GIS layer or through the UTC Spreadsheet delivered as part of the project. Tables 1-3 and Figures 10-18 below provide examples of the results in tabular, graph and map-based format. Additionally, a “UTC Calculator” spreadsheet tool was provided which enables the City to see the impact of tree planting on canopy cover. For each UTC geography, 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. The tool works at a citywide level and within an individual record, for example, the Calculator can illustrate the number of trees required to reach a UTC goal citywide and in the public right-of-way.

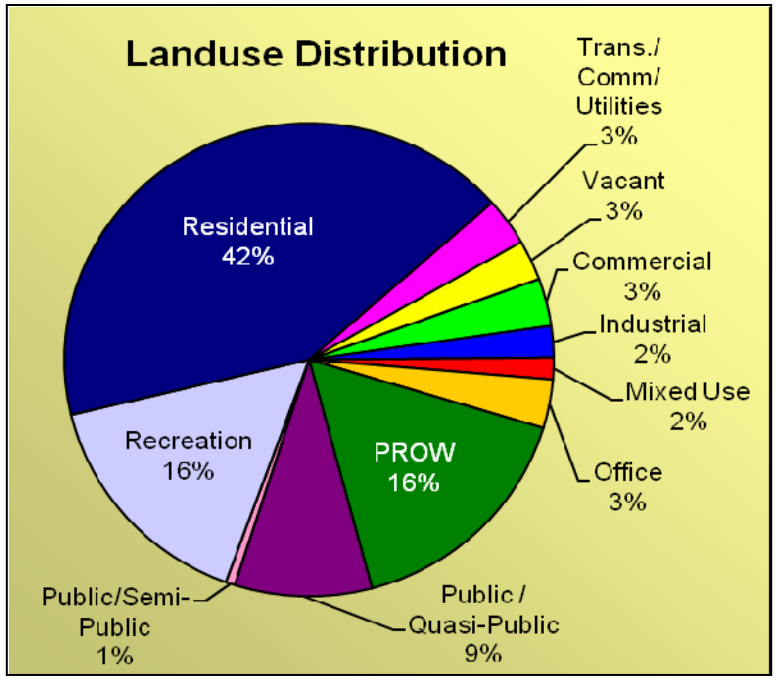


Figure 10. Percent Distribution of Land by General Land Use Types in Ann Arbor

Table 1. UTC Summary Metrics Citywide

Total City Area	Total Acres	Acres Not Suitable	Existing UTC Acres	Existing UTC %	Poss. UTC Veg. Acres	Poss. UTC Veg. %	Poss. UTC Other Acres	Poss. UTC Other %	Poss. UTC Imp. Acres	Poss. UTC Imp. %	Total Poss. UTC Acres	Total Poss. UTC %
Ann Arbor	18,264	4,339	6,015	32.9	4,327	23.7	923	5	2,660	14.6	7,911	43.3

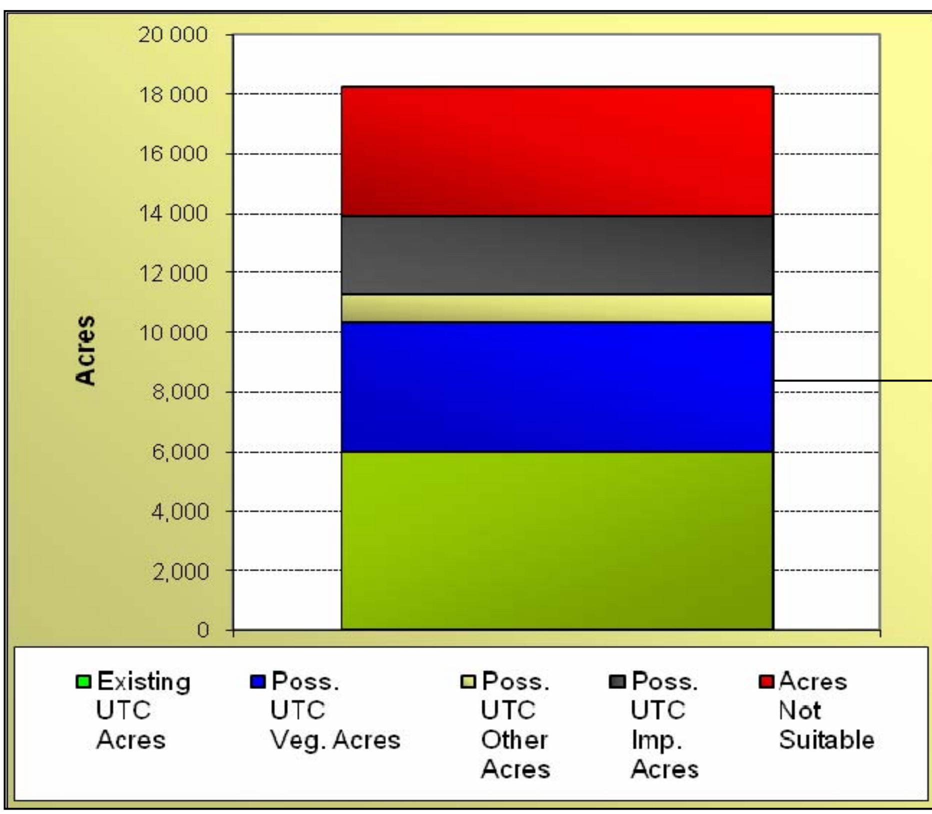


Figure 11. Overall Summary of UTC Assessment

There are 4,327 acres of "Possible UTC Vegetation".

Ann Arbor UTC Results by Creekshed

- Existing UTC ranges from 26% to 41%

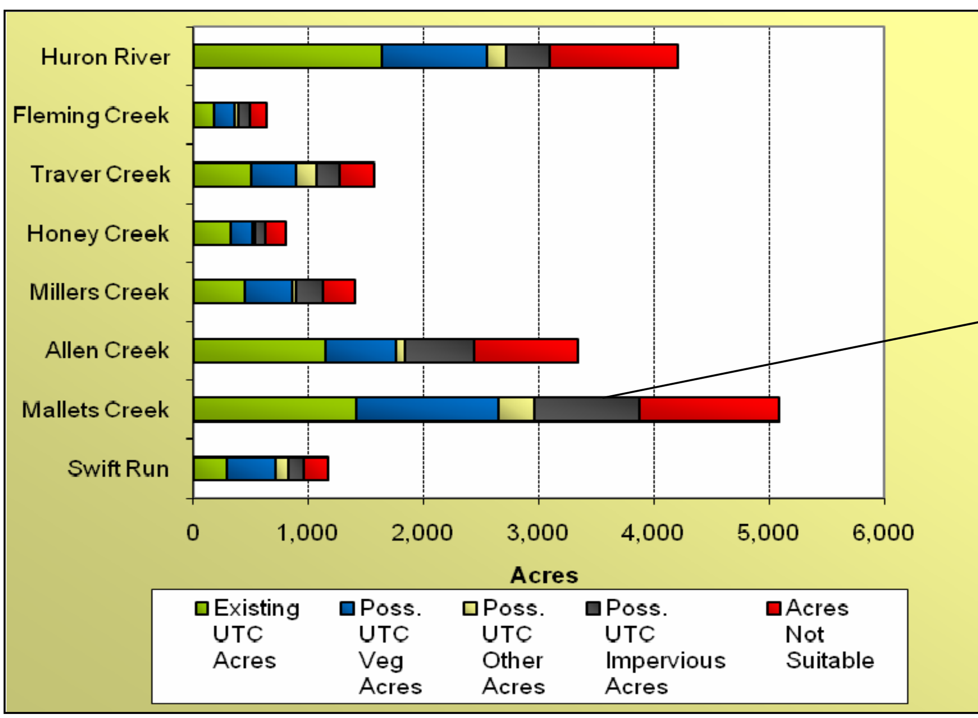
(*excludes a small outlier creekshed)

Table 2. Existing and Possible UTC per Creekshed Boundary

Creekshed	Total Acres	Acres Not Suitable	Existing UTC Acres	Existing UTC %	Total Poss. UTC Acres	Total Poss. UTC %
Huron River	4,213	1,113	1,646	39.1	1,454	34.5
Fleming Creek	642	147	184	28.7	311	48.4
Traver Creek	1,578	296	508	32.2	774	49.0
Honey Creek	815	184	335	41.1	296	36.4
Millers Creek	1,415	286	460	32.5	669	47.3
Allen Creek	3,340	901	1,151	34.5	1,287	38.5
Mallets Creek	5,087	1,209	1,427	28.0	2,451	48.2
Swift Run	1,174	203	303	25.8	667	56.8

Figure 12. Existing UTC for Each Creekshed Boundary (includes only area within city limit)

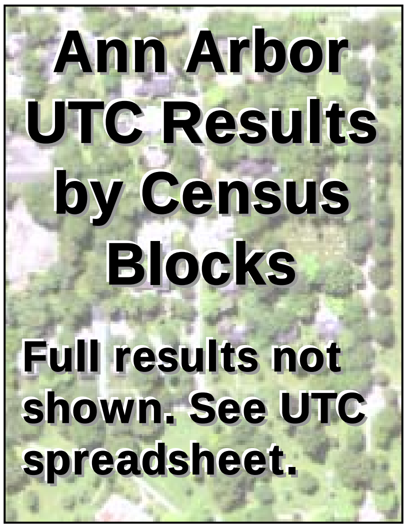
Figure 13. Existing and Possible UTC Metrics by Individual Creekshed Boundary (excludes a small outlier creekshed totaling 0% UTC)



Mallets creekshed has nearly 1,000 acres of Possible Impervious UTC.

Table 3. Existing & Possible UTC Metrics by Census Block (Note: only partial data is shown due to the large number of records)

Census Block	Total Acres	Acres Not Suitable	Existing UTC Acres	Existing UTC %	Poss. UTC Veg. Acres	Poss. UTC Veg. %	Possible UTC Other Acres	Possible UTC Other %	Poss. UTC Impervious Acres	Poss. UTC Impervious %	Total Poss. UTC Acres	Total Poss. UTC %
261614045001008	2.6	1.3	0.2	6.6	0.5	18.8	0.2	5.9	0.5	18.4	1.1	43.0
261614004003005	7.4	2.1	2.9	39.2	1.3	16.8	0.0	0.0	1.1	15.1	2.4	31.9
261614046004002	59.7	18.3	7.9	13.3	2.1	3.6	10.1	16.9	21.2	35.5	33.4	55.9
261614046001006	2.6	1.0	0.5	20.1	0.6	24.3	0.0	0.0	0.4	15.8	1.0	40.2
261614004003009	2.8	1.1	0.8	29.7	0.6	19.7	0.0	0.0	0.3	10.8	0.9	30.5
261614046002005	20.5	4.2	8.4	40.8	0.6	2.7	3.6	17.7	3.8	18.4	8.0	38.8
261614043003000D	12.5	1.1	0.1	1.0	1.3	10.0	0.0	0.0	10.1	80.2	11.3	90.3



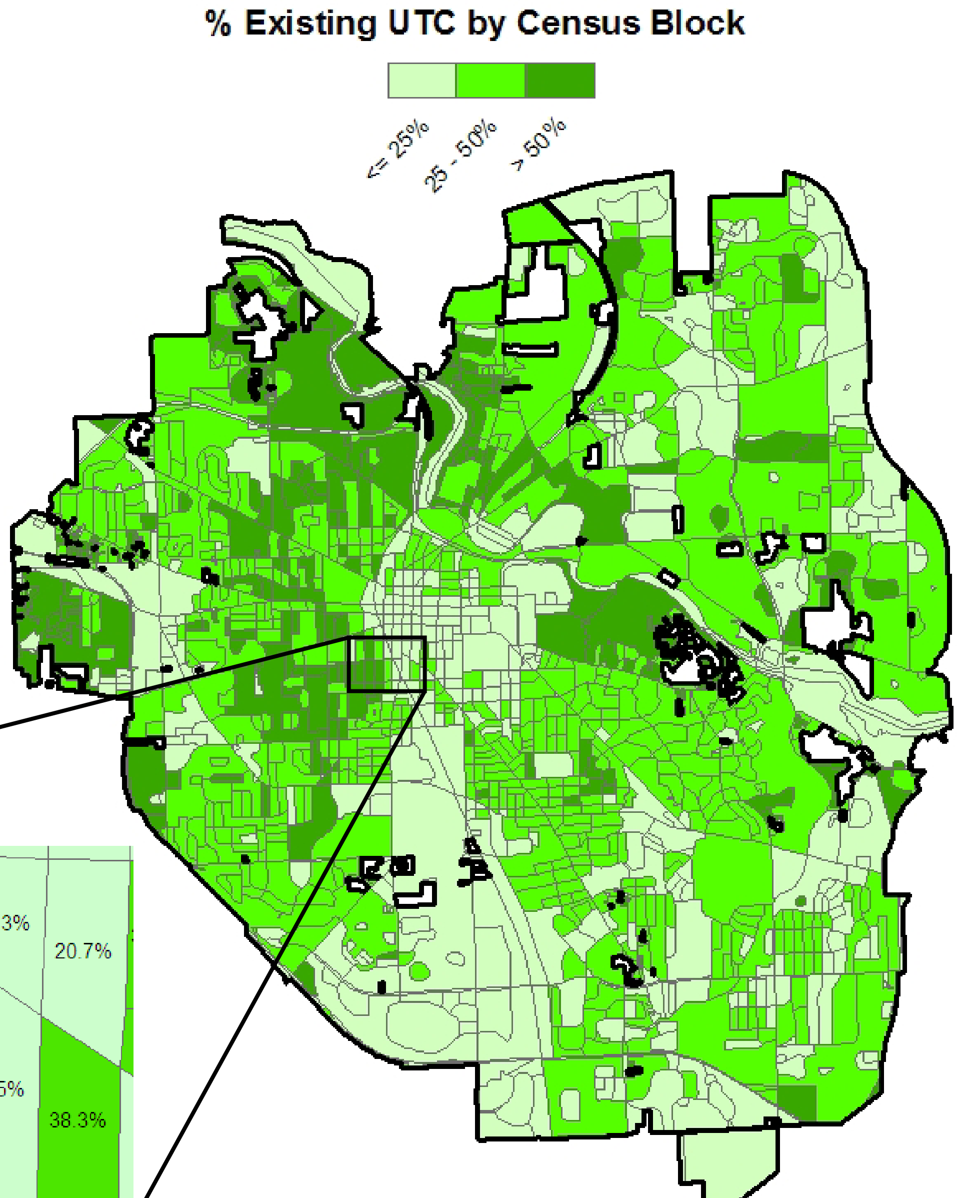
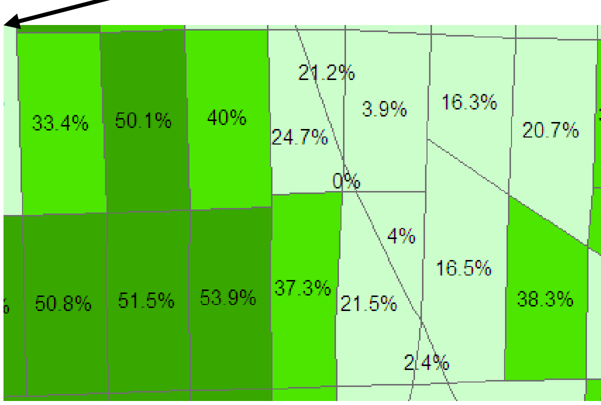


Figure 14. Thematic Display of the Percent Existing UTC by Census Block Boundaries



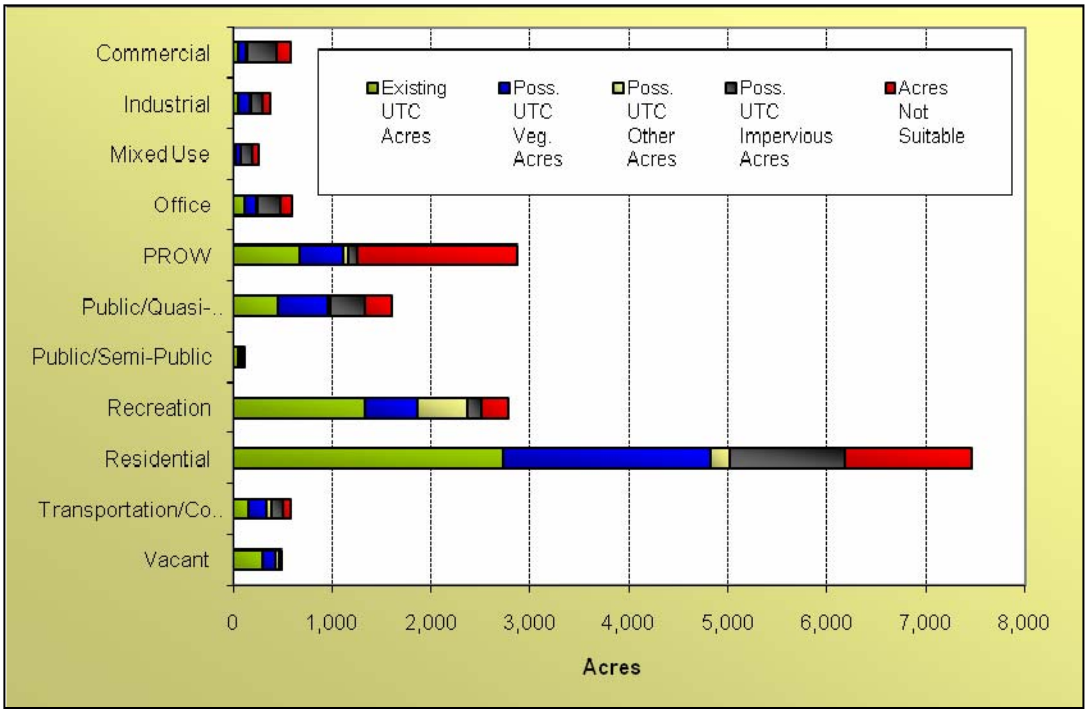
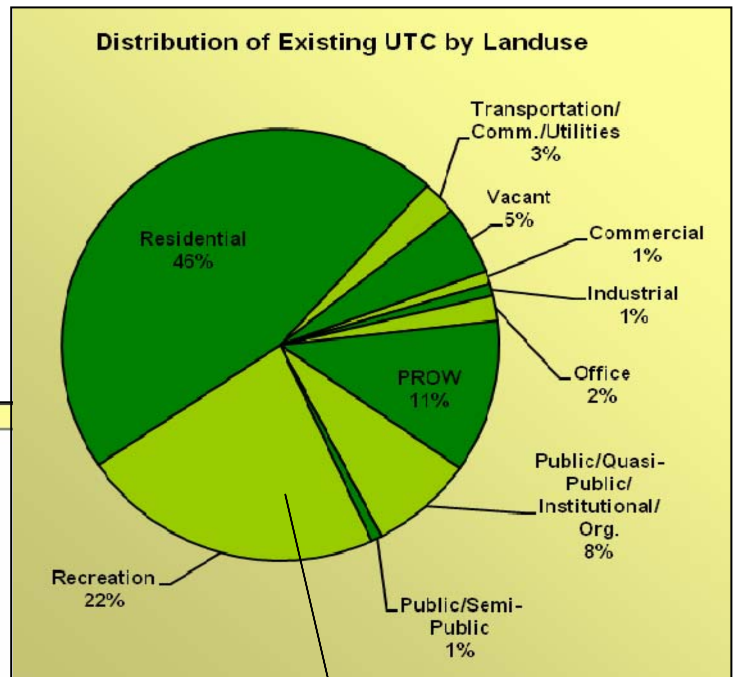
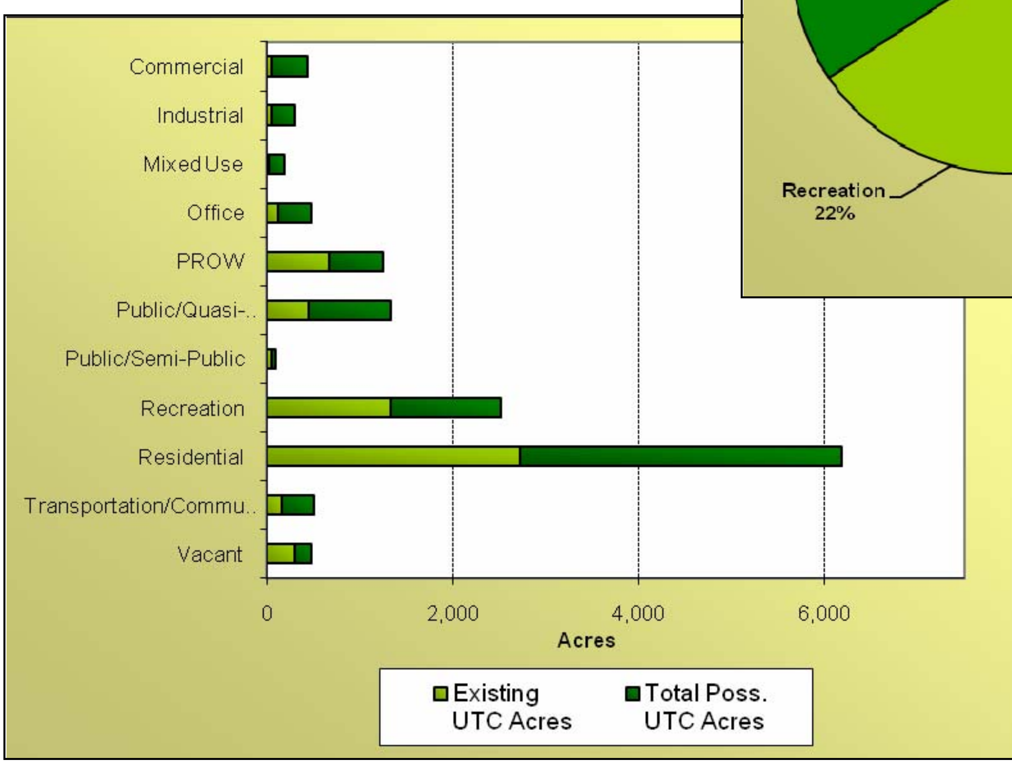


Figure 15. Acres of Existing UTC, Possible Vegetation UTC, Other Possible UTC, Possible Impervious UTC and Not Suitable by Major Land Use Type

Figure 16. Distribution of Existing UTC by Major Land Use Type





* 22% of Ann Arbor's tree canopy is found in recreational land use

Figure 17. Existing and Total Additional Possible UTC Metrics by Major Land Use Type

Figure 18. Example use of the UTC Calculator within Ann Arbor's major land use categories. Note that all cells in beige indicate a user can provide an input, that the average tree crown diameter of 30-feet was used and that all 3 methods (increase UTC by %, update UTC % to, and update number of trees) can be used at the same time for different land use categories.

Ann Arbor Land Use

User Inputs	Increase UTC % By	Update UTC % To	Update Number of Trees
Commercial	20.0%		
Industrial	10.0%		
Mixed Use	20.0%		
Office	20.0%		
PROW			10,000
Public/Quasi-Public/Semi-Public		50.0%	
Public/Semi-Public		50.0%	
Recreation		50.0%	
Residential		50.0%	
Transportation/Communication/	20.0%		
Vacant		75.0%	
Estimated Crown Diameter (ft):	30		
Estimated Crown Areas (Acres)	0.016219		

Warnings and Errors

Reset Cells

Note: Only one of entry is acceptable per row, per column. For example, Commercial may not have entries in "Increase UTC % By" and "Increase UTC % To."

Results

Ann Arbor Land Use	Total Acres	Acres Not Suitable	Existing UTC Acres	Existing UTC %	Total Additional Possible UTC Acres	Total Additional Possible	% Change	Updated %	Updated UTC Acres	UTC Acreage Change	Number of Trees Require
Commercial	577	143	56	9.7	378	65.5	20.0	29.7	171.3	115.3	7,109
Industrial	379	82	54	14.4	242	64.0	10.0	24.4	92.4	37.9	2,337
Mixed Use	264	74	24	9.2	166	62.8	20.0	29.2	77.1	52.7	3,249
Office	588	116	113	19.1	359	61.1	20.0	39.1	230.0	117.5	7,245
PROW	2,864	1,610	677	23.7	577	20.2	5.6	29.3	839.7	162.2	10,000
Public/Quasi-Public/Institutional/Organizati	1,602	267	454	28.3	881	55.0	21.7	50.0	800.9	347.3	21,413
Public/Semi-Public	109	11	48	43.5	51	46.6	6.5	50.0	54.7	7.1	438
Recreation	2,782	268	1,330	47.8	1,183	42.5	2.2	50.0	1,390.8	60.5	3,730
Residential	7,459	1,277	2,727	36.6	3,455	46.3	13.4	50.0	3,729.4	1,002.6	61,816
Transportation/Communication/	578	79	154	26.7	344	59.6	20.0	46.7	269.8	115.6	7,127
Vacant	485	11	302	62.4	172	35.4	12.6	75.0	363.5	61.3	3,780

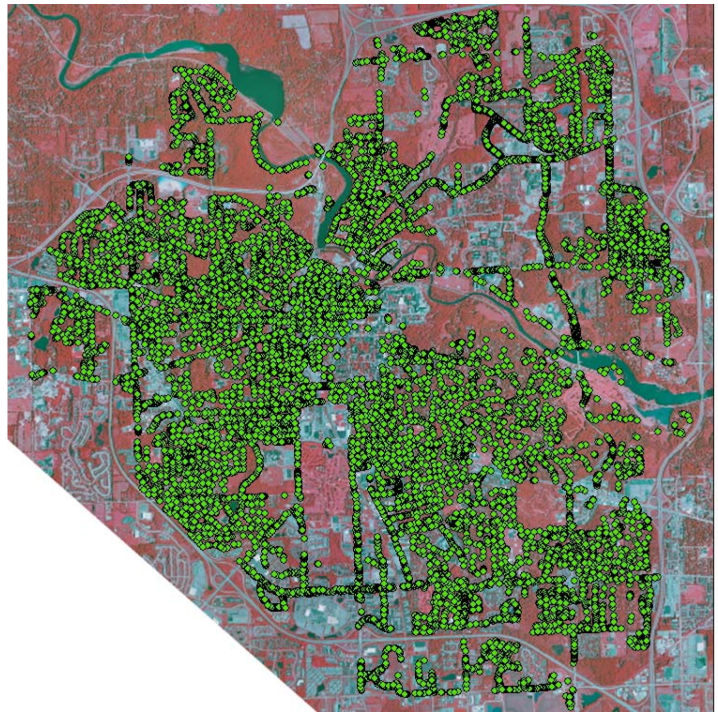
Summary

Target Geography Totals	Geographic Area (Acres)	Existing UTC (Acres)	Existing %	Total Trees Added	Total Trees Added	New UTC Acres	New %
Ann Arbor Land Use	17,686	5,940	34%	128,244	2,080	8,020	45%

Instructions | Land Use | Creeksheds

Street Tree Prioritization

Figure 19. Map of the 15,504 street tree planting locations included in the prioritization database

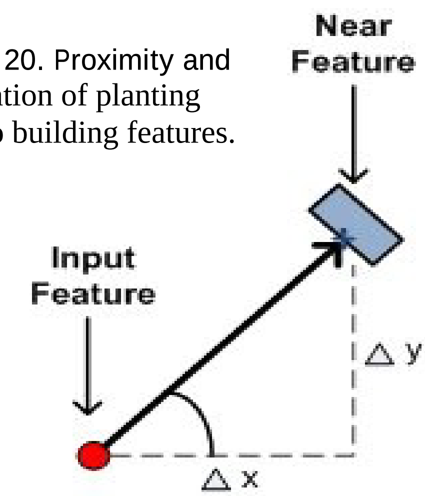


Separately from the UTC Assessment, this project presented an opportunity to help guide Ann Arbor's street tree planting efforts through GIS analysis and a prioritization process to answer the question, "Where should we plant the next 1,000 street trees?" Ann Arbor's GIS-based street tree inventory database contains nearly 57,000 records, of which almost 8,900 are vacant. These vacant sites along with street trees in poor condition or recommended for removal totaled 15,504 trees and became the prioritization database. The planting sites were ranked using four (4) factors in order to influence planting selection. These factors were: ability to impact energy use from shade, surrounding tree canopy and impervious area, and size. Other factors available in the database that could be used for prioritization included the presence of overhead utilities and land use type.

A series of GIS analysis steps were required to prepare the database for ranking. Each potential street tree planting site was buffered by 50-feet (i.e. to a 100-foot diameter) and within this area the percent tree canopy and percent impervious area was calculated, then assigned back to the database as fields for sorting, querying and ranking. Size was already an attribute in the database, therefore these values only needed to be assigned a numeric value in order to be ranked. Sites that already contained a tree but were in poor condition or recommending removal were given a zero (0), while small, medium, and large sized planting sites were given a 1, 2.5 and 3 respectively.

The methodology for energy savings considers the proximity and orientation of the tree points to buildings. For this step, it was assumed that planting sites must be within 60 feet of a building and on its east, west or south side. Two "yes/no" attributes were added to the database; one for sites within 30 feet of a structure and another for sites 31-60 feet, thus providing two levels of potential energy savings for further prioritization purposes. Figure 20 provides an illustration of part of the iterative model created to accomplish part of this task.

Figure 20. Proximity and orientation of planting sites to building features.



Each record in the street tree prioritization database now contains each of these factors in their raw format, for example "yes/no" for energy savings or "vacant site, large" for the size of the planting site. These factors then needed to be converted to a numeric format for prioritization. This Suitability Model approach enables the creation of different Scenarios, and within each Scenario a weighted value between 0 and 10 can be applied to each factor to generate a Suitability Score. 6 Scenarios were created: Planting Plan (the base scenario with all weights set to 5), Holistic, Impervious, Canopy, Energy and Size. With the exception of the Base and Holistic Scenarios, a stronger weight was applied to the factor that the scenario was named after, for example, in the Impervious Scenario the impervious percentages were given a weight of 10 while energy values were given a 1. The model then generated a Suitability Score between 0 and 100 for each tree planting site in each Scenario.

Figure 21. An example of weights applied to each factor for the Impervious Scenario.

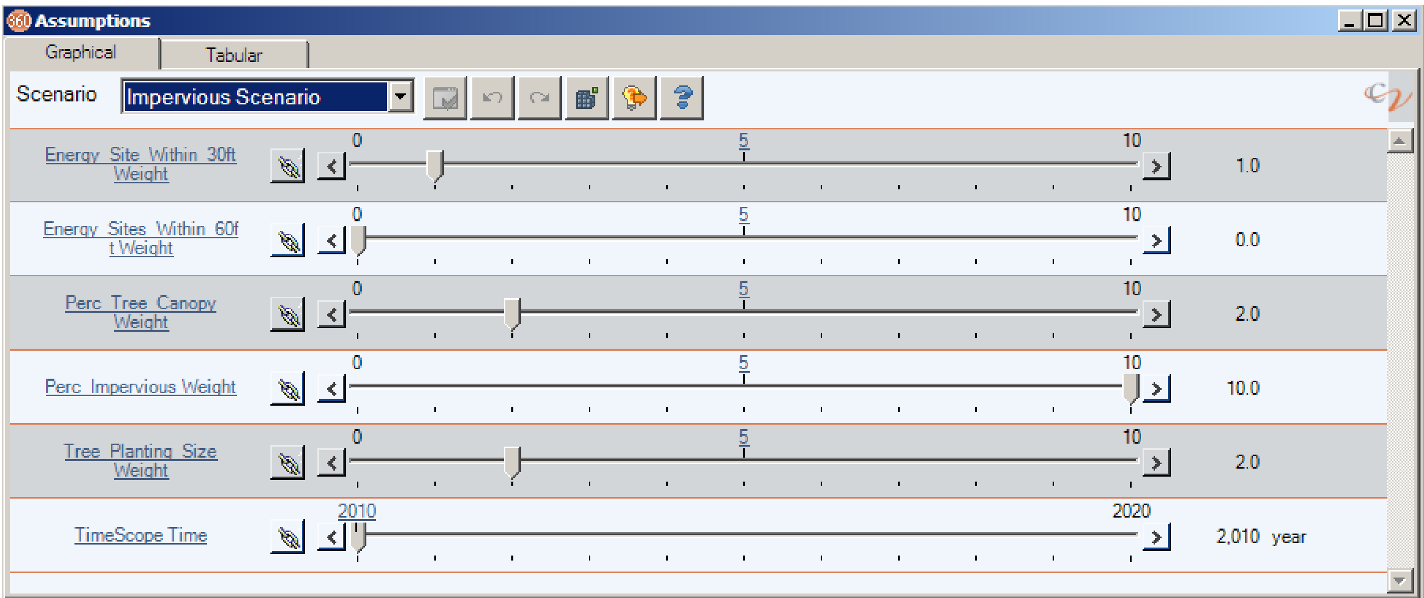


Figure 22. Actual weights applied to each factor (rows) for each Scenario (columns). Note that a weight of 10 was applied to the factor that a Scenario was named after, and that a weight of 10 was chosen for the impervious factor for the Holistic Scenario given the city's interest in prioritizing planting sites in highly impervious areas. In general, tree size and percent canopy were given the next highest weights.

Name	Units	Planting Plan	Holistic Scenario	Impervious Scenario	Canopy Scenario	Energy Scenario	Tree Size Scenario
Energy_Site_Within_...		5	4	1	1	10	3
Energy_Sites_Within...		5	2	0	0	8	1
Perc_Tree_Canopy ...		5	5	2	10	3	4
Perc_Impervious Wei...		5	10	10	3	1	4
Tree_Planting_Size ...		5	5	2	5	5	10
TimeScope Time	year	2010	2010	2010	2010	2010	2010

There are several ways to utilize this street tree prioritization database. The Suitability Score can be queried in a GIS selection or sorted from 100 to 0, leaving the most suitable sites for a particular Scenario on top. The Score can be symbolized into quantified thematic categories, for example 0-25, 26-50, 51-75 and 76-100, and displayed on a map by color and/or size. This process can assist in determining the top 10% of planting sites or the best 1,000 sites for the City's next planting year. The Suitability Score can also be used to distribute and allocate planting locations to a particular year based on the desired number of trees to be planted per year for a particular period of time (e.g. 10-years, 30-years, etc.). Figures 23 and 24 below provide examples of the attributes within the planting sites database.

Figure 23. An example of planting sites thematically displayed by Suitability Score for the Impervious Scenario (weights not shown, see Figures 21 and 22 above). *Note that although the COMMONNAME = "stump" which results in a lower score than small, medium or large tree planting sites, this site still ranked in the top 25% (Suitability Score = 80) because the site is surrounded by 94.3% impervious area which was weighted more heavily in this Scenario.*

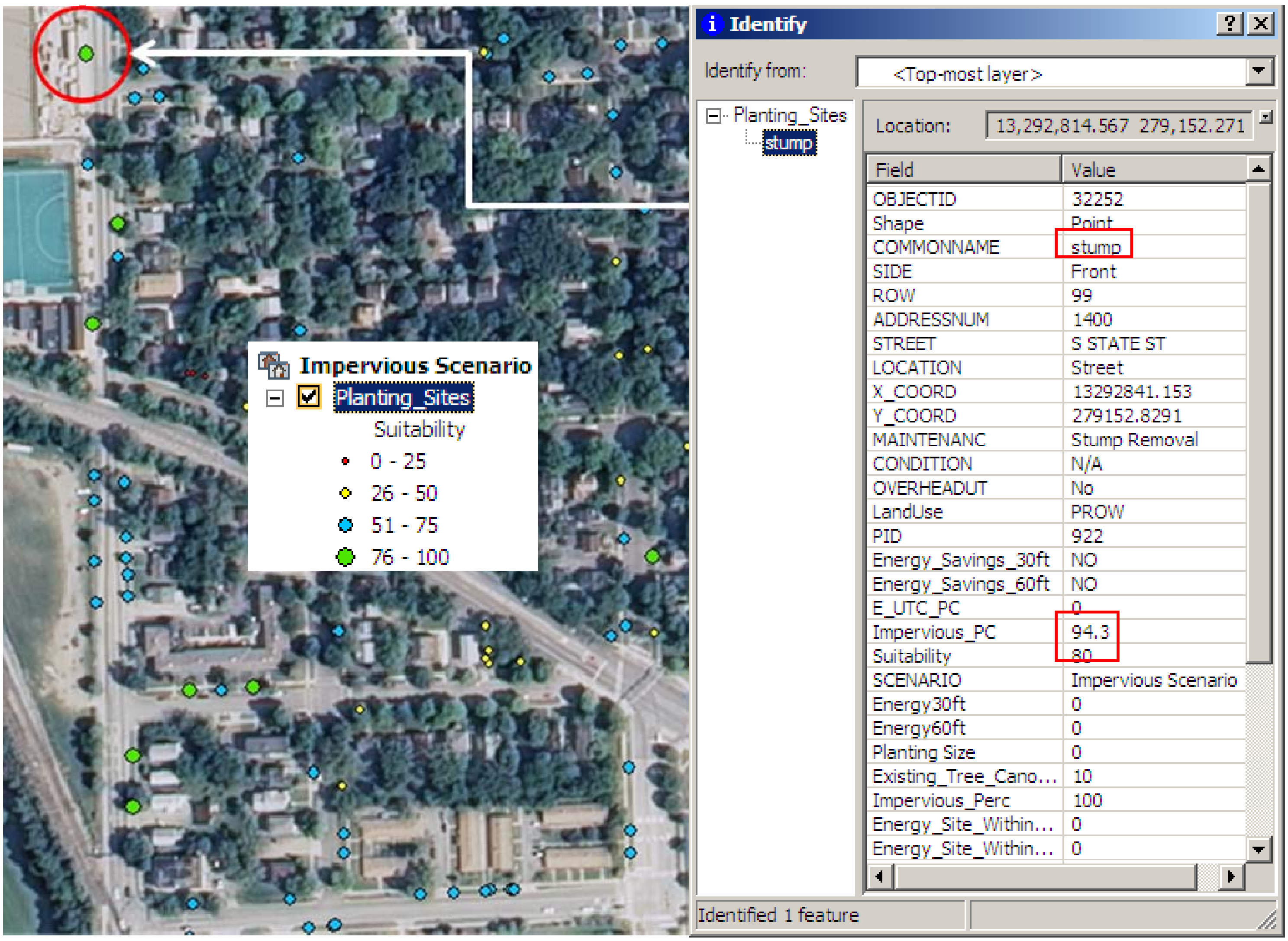
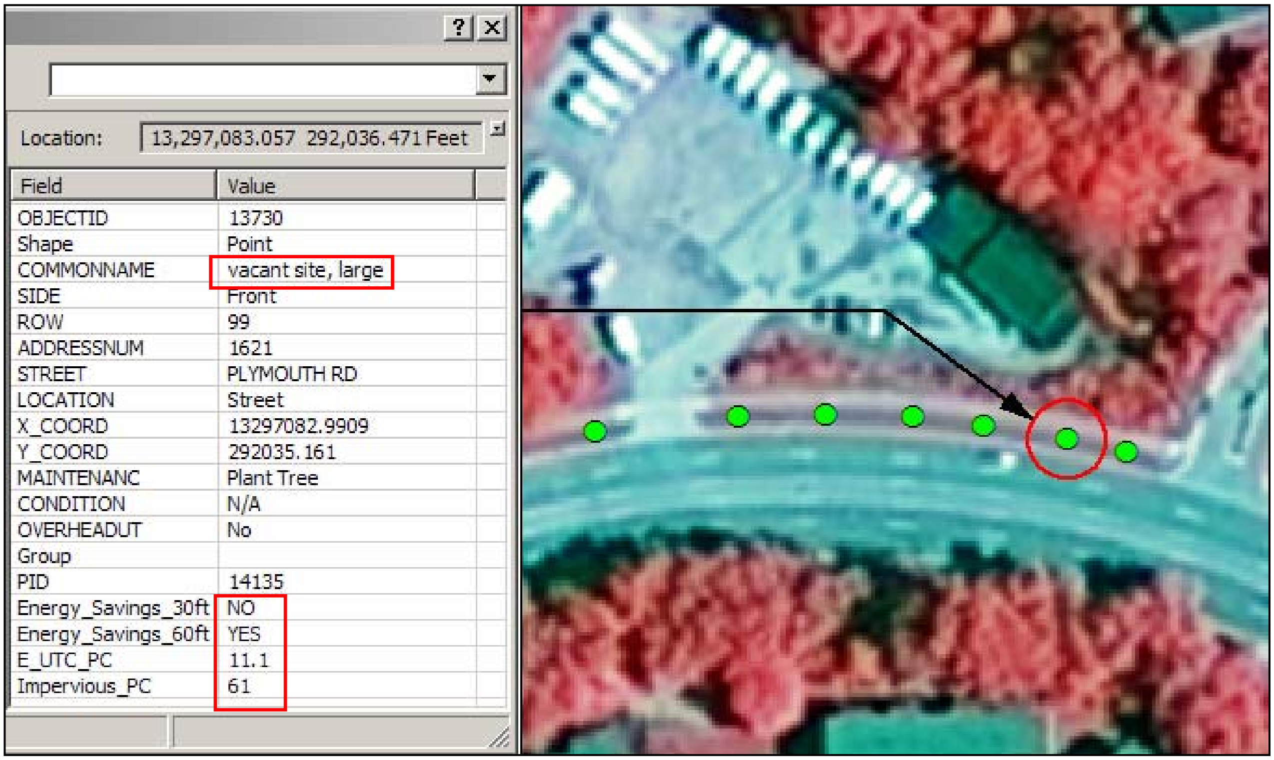


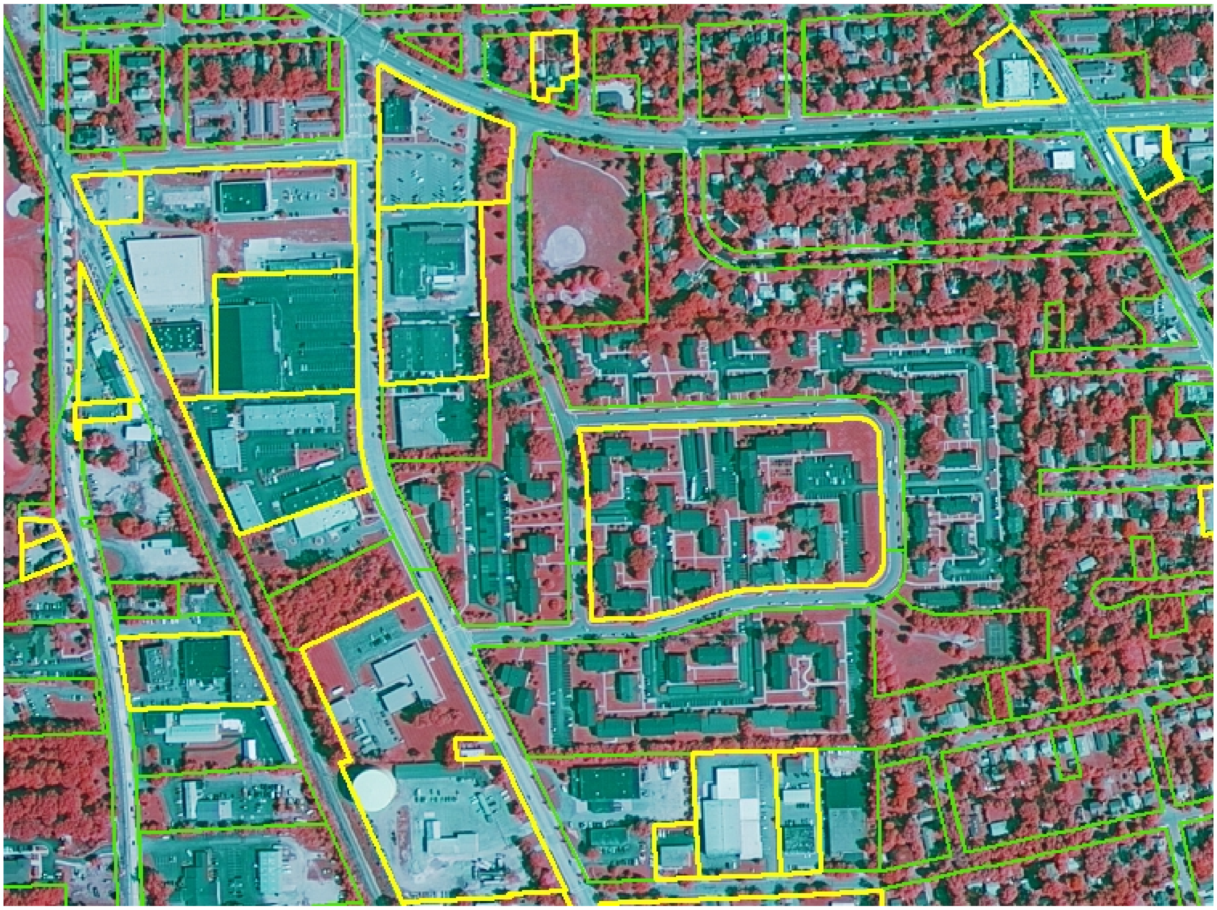
Figure 24. Illustration of vacant planting sites along the Public right-of-way (PROW) from Ann Arbor's street tree inventory database. Attributes originally in the database included the maintenance recommendation, the address of the planting site, and the presence of overhead utility lines. AMEC added attributes such as the potential to impact energy savings (Energy_Savings_30ft; Energy_Savings_60ft) and the percent existing UTC and impervious % (E_UTC_PC; Impervious_PC) within 50-feet of the planting site.



Conclusions & Recommendations

With 33% Existing UTC, the city of Ann Arbor has average or above-average tree canopy cover compared with other small and medium-sized communities in the United States (see “UTC Comparison” chart in the Appendix). With this percent canopy cover, Ann Arbor should focus on maintaining and preserving tree canopy to sustain functional benefits while also targeting areas for improvement. Along with values on the environmental and economic benefits of Ann Arbor’s trees quantified from a recent STRATUM study, maps and charts of Existing vs. Possible UTC provide a compelling argument of where the city is and where they could be in regards to UTC. See Figure 25 below. 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. These results and data products should 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.

Figure 25. Parcels after being aggregated by major land use type (green). Ones highlighted in yellow have less than 10% Existing UTC and more than 50% Total Possible (Additional) UTC. This selection was done through a simple GIS query of the “Land Use Detailed UTC” shapefile provided as one of the UTC GIS deliverables.



Noteworthy opportunities for increasing UTC in the City of Ann Arbor include:

- Only 4.7% of the impervious surfaces in Ann Arbor are covered by tree canopy. There are significant opportunities to increase UTC over impervious surfaces which would decrease urban heat island effect and stormwater runoff, improve water quality and increase quality of life and aesthetics.
- Individual census blocks provided detailed UTC metrics at a scale that is finer than the neighborhood scale. UTC results at the census level could be further analyzed based on demographic data, for example how UTC compared across varying income levels, in order to evaluate socio-economic conditions in relation to tree canopy establishment and sustainability.
- All land use categories include significant opportunity for increasing tree canopy, however goals could be focused in Public Right-of-Way (PROW) where the City likely has the most control, or on residential properties with low Existing UTC where targeted rebate programs may provide incentive.
- Commercial, Industrial, Mixed Use, and Office land use categories each have over 60% Possible Additional UTC.

Other recommendations:

- Use the UTC Calculator provided through this project to set canopy cover goals within land use classes or creeksheds and justify the need for a robust street tree planting program and education programs/incentives.
- Incorporate STRATUM values into the street tree database to rank or query planting sites by their potential environmental and economic benefit
- An urban forest "report card" assessment could rate other criteria and indicators that are important to Ann Arbor's sustainability, including species diversity, condition, funding sources, policy, and public support.
- This urban tree canopy assessment should be performed again in 5 to 8 years to monitor development and effectiveness of programs, codes and ordinances.
- To address creekshed health and function, more specific field and GIS-based assessments could be conducted utilizing the land cover data generated from this project to identify opportunities that provide the greatest benefit for the investment made. This could include modeling through the U.S. Forest Services' i-Tree Hydro model or the U.S. EPA's new SMWW-5 LID module.

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 & Additional Information

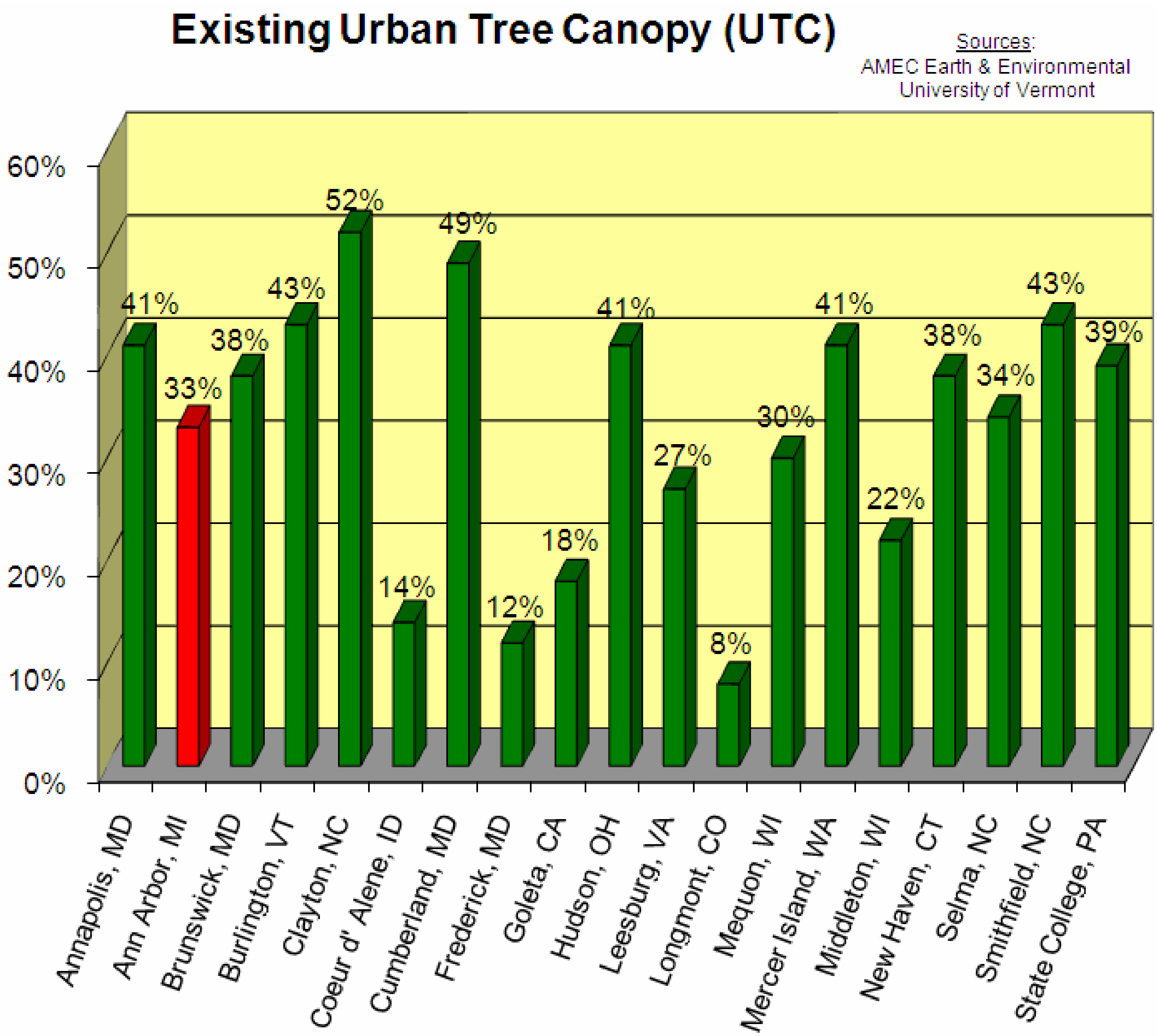
The City of Ann Arbor would like to thank the Michigan Department of Natural Resources and the U.S. Forest Service for supporting the design and development of this project, as well as for providing 50% of the funding through the Northeastern Area State and Private Forestry Competitive Grant Initiative. This was 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 AMEC Earth & Environmental, Inc.

AMEC Earth & Environmental (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

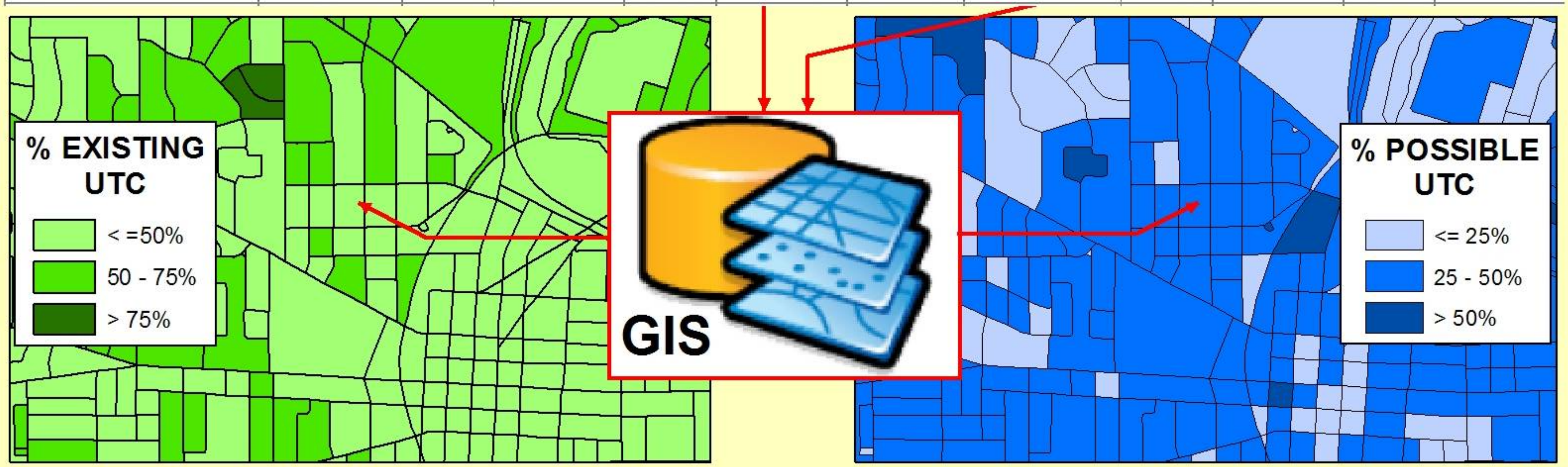
Comparing Ann Arbor's Existing UTC to that of comparable U.S. communities



CENSUS BLOCK DATABASE FIELD KEY

P_TOT_PC — Percent total possible UTC
P_TOT — Acres of total possible UTC
P_IMP_PC — Percent possible impervious UTC
P_IMP — Acres of possible impervious UTC
P_OTHER_PC — Percent possible other (wetlands, golf couses) UTC
P_OTHER — Acres of possible other (wetlands, golf courses) UTC
P_UTC_PC — Percent possible vegetation UTC
P_UTC — Acres of possible vegetation UTC
E_UTC_PC — Percent existing UTC
E_UTC — Acres of existingr UTC
TOT_ACRES Acres in census block

BLKIDFP	TOT_ACRES	E_UTC	E_UTC_PC	P_UTC	P_UTC_PC	P_OTHER	P_OTHER_PC	P_IMP	P_IMP_PC	P_TOT	P_TOT_PC
261614023002009F	2.03	0	0	0.88	43.3	0	0	0.05	2.5	0.93	45.8
261614041003009	0.33	0	0	0.04	12.1	0	0	0.04	12.1	0.08	24.2
261614056001003	0	0.06	0	0	0	0.2	0	0.05	0	0.25	0
261614560001000C	0	0	0	0	0	0	0	0	0	0	0
261614033003025B	0	0	0	0	0	0	0	0	0	0	0
261614001002014	1.56	0	0	0.15	9.6	0	0	0.22	14.1	0.37	23.7
261614006001007	0.42	0	0	0.13	31	0	0	0	0	0.13	31
261614025001006	0.01	0	0	0	0	0	0	0	0	0	0
261614055001003	1.03	0	0	0.14	13.6	0	0	0.02	1.9	0.16	15.5



Thematic display of the percent Impervious (at right) and percent UTC (below) in Ann Arbor using a random evenly spaced 250-foot grid.