Board of County Commissioners • Escambia County, Florida

CITY OF PENSACOLA
URBAN TREE CANOPY STUDY

A Comprehensive Analysis
of the Pensacola Urban Tree Canopy

Prepared For:
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2.0 Executive Summary

From 1994 to 2013, overall tree canopy coverage ranged from 25.96% to 40.34% within the jurisdiction of the City of Pensacola. During this period, the highest percentage coverage occurred in 1994. The lowest percentage coverage was observed in 2007. Periods of canopy loss correlate with landfalling hurricanes. The greatest canopy loss was observed following Hurricane Ivan (2004). An estimated 27.89% of the entire tree canopy was lost due to factors associated with the storm.

Using 2013 high resolution imagery, the 14,462 acre study area was divided into cover values. These values showed 29% tree canopy, 30.7% impervious cover and 35% open (potential) planting space. Less than 20% of the study area is publicly owned with 419 acres of City owned potential planting spaces. Utilizing private property and providing incentives would increase the potential planting space.

Next, planting spaces were prioritized by level of site modification required for planting. Parks within watersheds with low overall canopy coverage and optimum planting space were identified. These sites include the Bayou Texar, Downtown, and Bayou Chico watersheds. Secondary sites include the Pensacola Bay aquatic buffer and gateway corridor streets with less than 2% canopy coverage. These gateway streets include East & West Cervantes Street, North & South Pace Blvd, North Palafox Street, South 9th Ave and West Main Street.

Emphasis should be placed on the concept of "right tree right space" in determining the optimum tree species for a specific locale. All planting should follow the American National Standard-ANSI A300 Standard Practices for Tree Care Operations. The urban tree canopy is a dynamic living resource. Maintaining this resource requires constant inputs. Inputs include new plantings, maintenance (i.e. pruning) removal and replacement of dead and declining specimens. A healthy urban tree canopy brings associated increases in environmental and economic benefits.

3.0 Study Introduction & Project Summary

Urban trees add quantifiable benefits to communities. Urban tree canopy composition (i.e. species, age, size) and distribution (i.e. location, density, and connectivity) can be correlated with improvements to environment and quality of life. These benefits have been documented in numerous scientific studies (Miller 1997, Dwyer 2000, Norak 2006, Escobedo 2007). This new understanding of the values and benefits of the urban canopy has led to an increasing recognition of trees as capital assets. Trees are often viewed by urban planners and officials as on par with other infrastructure considerations, such as streets, sidewalks, and stormwater.

3.1 Importance of Assessment

Trees have been important to the local economy across the Panhandle of Florida for over 150 years. Vast quantities of long leaf pine were harvested from virgin stands, processed at local saw mills, and shipped around the world. Timber from ancient live oaks was harvested for its strength for the production of naval ships. These natural resources distinguished our region as the economic center of Florida until the early 1900s. While the harvest of trees no longer drives the local economy, trees, specifically urban trees, still have value. This value can be measured in more than just economics.

Trees provide value by improving our air, protecting our surface waters, and increasing traffic safety. The presence of trees in cities is associated with a perceived sense of consumer friendliness, promoting increases in consumer shopping and real estate values. Large canopy trees provide the most environmental and economic value. These trees are relatively slow growing, therefore, are not easily replaced. Mortality of urban canopy trees is influenced by many factors including land tenure, development, and storm events. A long-term comprehensive management strategy is a critical part of developing a sustainable plan for managing this vital tree resource (Clark 1997). A management strategy is all but impossible without a clear understanding of the dynamics of existing canopy. An understanding the existing urban tree canopy and quantification of existing benefits requires a comprehensive tree assessment.

Assessments answer questions concerning percentage of canopy coverage, tree density locations, tree ownership, and historic trends. The results from a well-planned assessment greatly aid communities in setting feasible, cost effective urban canopy goals and objectives. Tree planting, pruning, and other urban tree canopy management activities can be planned and prioritized based on these overall objectives.

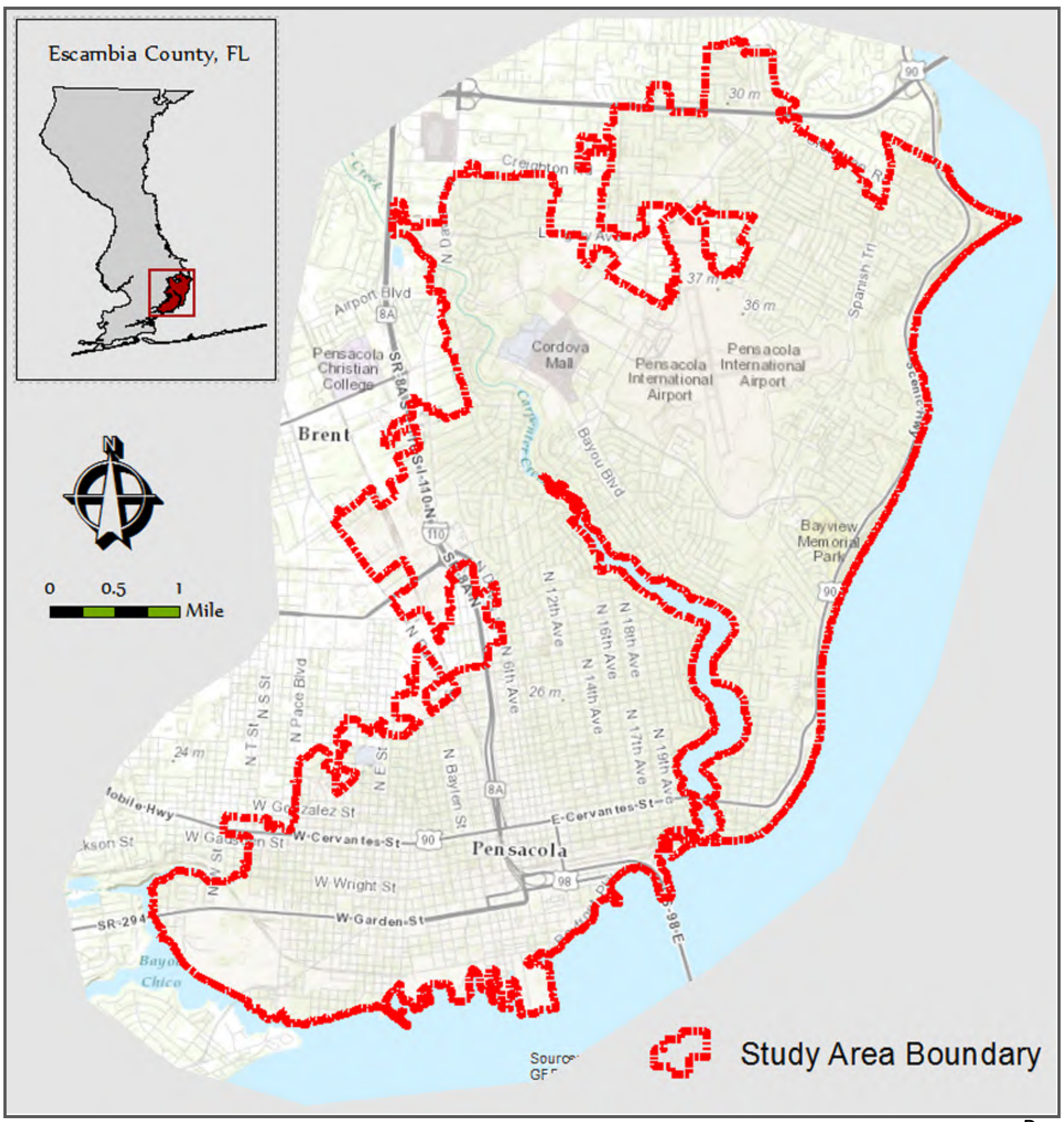
3.2 Project Scope

September 2013, the City of Pensacola issued a task order to Escambia County through an existing Interlocal Agreement to perform a comprehensive analysis of the urban tree canopy within the city's jurisdictional limits. This request was initiated though the City's Environmental Advisory Board and contracted though the City of Pensacola. The purpose of the analysis was to evaluate historic trends, characterize the existing canopy distribution, identify available planting space, and provide specific tree installation and maintenance recommendations. Enhancement objectives were determined and provided by Environmental Advisory Board and City Staff.

Since the focus of the study was limited to terrestrial resources, the project boundary was further refined from the entire jurisdictional boundary of the City of Pensacola to exclude areas below mean high water. Submerged lands within Pensacola Bay, Bayou Chico, and Bayou Texar were excluded. The resulting study area encompassed a total of 14,462 acres.

Project objectives required the use of multiple remote sensing methods. Specific methods utilized to capture historic trends, and identify current canopy distribution are described in detail below in section 4.0.

Figure 1: Depiction of Urban Tree Canopy Study Area



4.0 Methodology

Two separate and distinct remote sensing methods are used to meet project objectives. The first phase uses a series of historic aerial images setting a series of random points producing a statistical estimate of changes in cover. This provides a baseline on past tree canopy and indicates areas of increase or loss over a period of time. The next phase provides a more detailed analysis of the current canopy by classifying high resolution infrared imagery. This process was used to provide estimates of impervious existing canopy, impervious surfaces, and open space. Data generated using this method can be used to determine potential planting locations respective to individual parcels, land use, and ecological boundaries.

4.1 Identification of Historic Trends within the Urban Tree Canopy

Historic trends within the urban tree canopy were identified using a series of seven sets of orthorectified aerial photographs. Key parameters estimated include overall canopy density, canopy coverage and canopy change.

Aerial photographs used in the study cover a span of 19 years (1994-2013). Aerial datasets were obtained from a number of reliable sources. Source data is available below in Table 1. Florida Department of Transportation (FDOT) imagery datasets were chosen as a baseline for image requirements due to their relatively high (1-foot) resolution and excellent temporal availability. Escambia County aerial data sets and the Florida Department of Environmental Protection (FDEP) data sets were chosen for additional image sources on the basis of appropriate orthorectification, data availability, and similar resolution. Sampling dates incorporate pre/post hurricane events and temporal homogeneity within the constraints of data availability.

Table 1: Imagery Sources and Metadata Evaluated for Section 4.1 Methodology

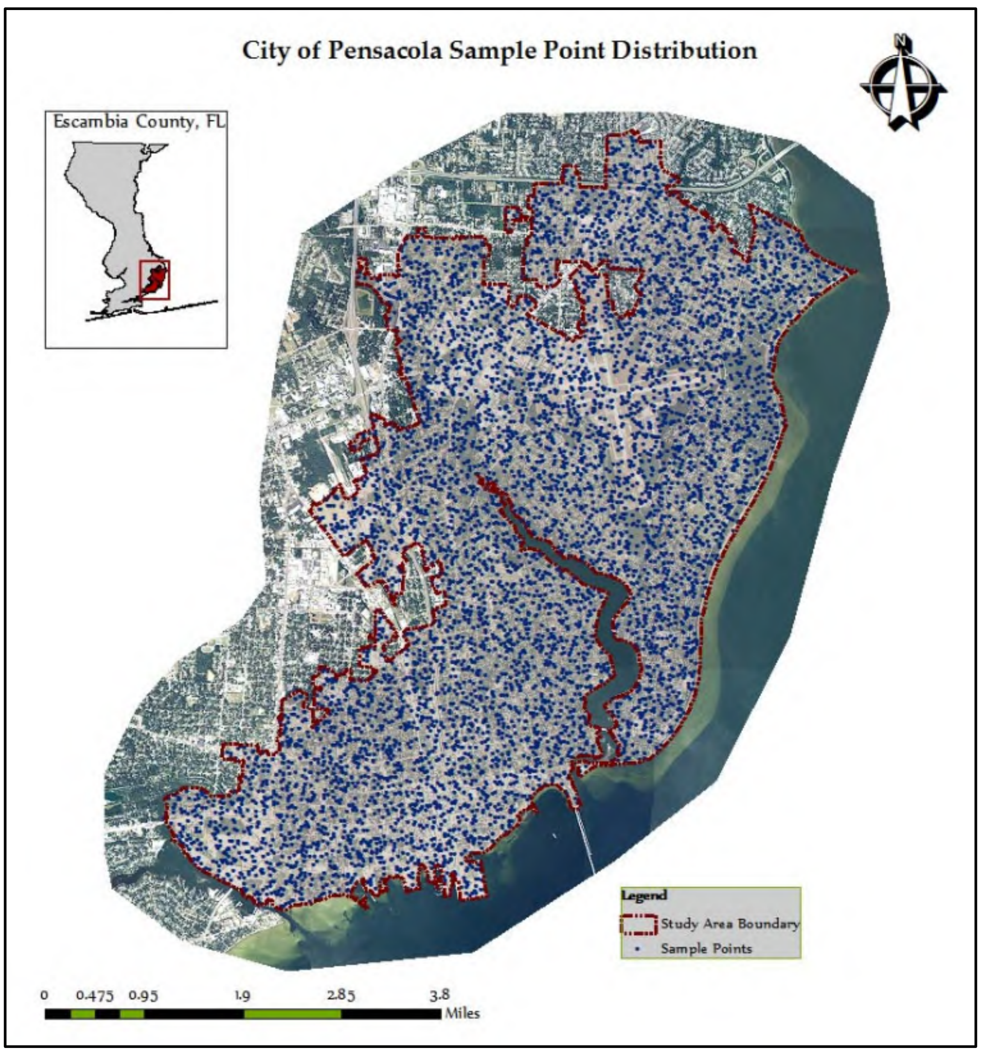
Date	Organization/Image Type	Projection	Datum/Zone	Units/Resolution
Jan-1994	FDEP/Color IR	Albers	NAD83 HARN	Meters/1.0
Jan-1999	Escambia County (Photo Science Inc.)/Color IR	Lambert Conformal Conic	NAD83 HARN/0903 FL North	Feet/0.5
Nov-2003	Escambia County (J.W. Sewell)/Black & White	Lambert Conformal Conic	NAD83/0903 FL North	Feet/1.0
Dec-2004	FDOT/True Color	Lambert Conformal Conic	NAD83/0903 FL North	Feet/1.0
Apr-2007	FDOT/True Color	Lambert Conformal Conic	NAD83/0903 FL North	Feet/1.0
Jan-2010	FDOT/True Color	Lambert Conformal Conic	NAD83/0903 FL North	Feet/1.0
Mar-2013	FDOT/True Color	Lambert Conformal Conic	NAD83/0903 FL North	Feet/1.0

Aerial imagery was acquired and imported into ArcGIS. Datasets were visually checked for projection errors. Once complete, imagery was combined into a single continuous dataset using the mosaic function. Using a single mosaic ensured continuous coverage, balanced color maps, and appropriate image re-sampling for accurate processing.

A dataset of 7,228 sample points was created across the study area using the *Create Random Points* tool in ArcMap in order to assure 90% confidence of a maximum standard error (SE) of ±1% of the final study output. The size of the sample dataset was created based on the assumption of 50% canopy coverage since SE increases as data approaches 50:50. The statistical approach was based on the same methodology utilized by I-Tree Canopy (I-Tree 2014) software developed by the U.S. Department of Agriculture (USDA) et al.

A randomized grid comprised of square mile sections was used to more evenly distribute sample points across the study area minimizing data gaps. The origin of the grid was the northwest corner of Section 21, Township 1S, Range 30. The exact number of points within each grid section was prorated to correspond with the percentage of the section lying within the study area. This step was necessary to maintain uniform coverage. The distribution of the sample dataset is shown below in Figure 2.

Figure 2: Sample Point Distribution of Initial Sample Dataset



Samples were randomly selected from the initial dataset of 7,228 sites generated using the randomized grid discussed above. Sample points were visually classified for each aerial dataset based upon the presence or absence of the underlying canopy. An example of the typical output of this process is presented in Figure 3.

This classification process continued until a ±1% standard error (SE) value was achieved for all sample years. The desired level of certainty required a total of 6,515 sample points. Years approaching 50% canopy required more points to reach desired level of certainty.

Project-specific objectives required all modeling to be performed using ESRI ArcGIS and Visual Sample Plan (VSP). The final 6,515 sample points were run through a *kriging* interpolation tool within ArcGIS Spatial Analyst to fill data voids and aid in the generation of a smooth, interpolated raster image for final canopy modeling. Kriging increased the sample size from 6,515 classified data points per year to 699,975 interpolated data points per year, and reduced average point spacing from approximately 2.2 acres to 0.02 acres.

The ordinary kriging function utilized an exponential semivariogram model to appropriately fit the model's spatial autocorrelation curve as determined in VSP. Final outputs included canopy coverage metrics and raster images showing canopy coverage and density values for each sample year. Additional rasters were generated using the ArcGIS *Raster Math* tool to show change values, highlighting areas of canopy loss and gain between sampling dates.

4.2 Mapping of Current Urban Canopy through Classification of Infrared Imagery

The data collection method described above is capable of producing outputs useful in evaluating trends across the entire study area, or even large subdivisions of the study such as watersheds, but is not adequate for evaluating smaller

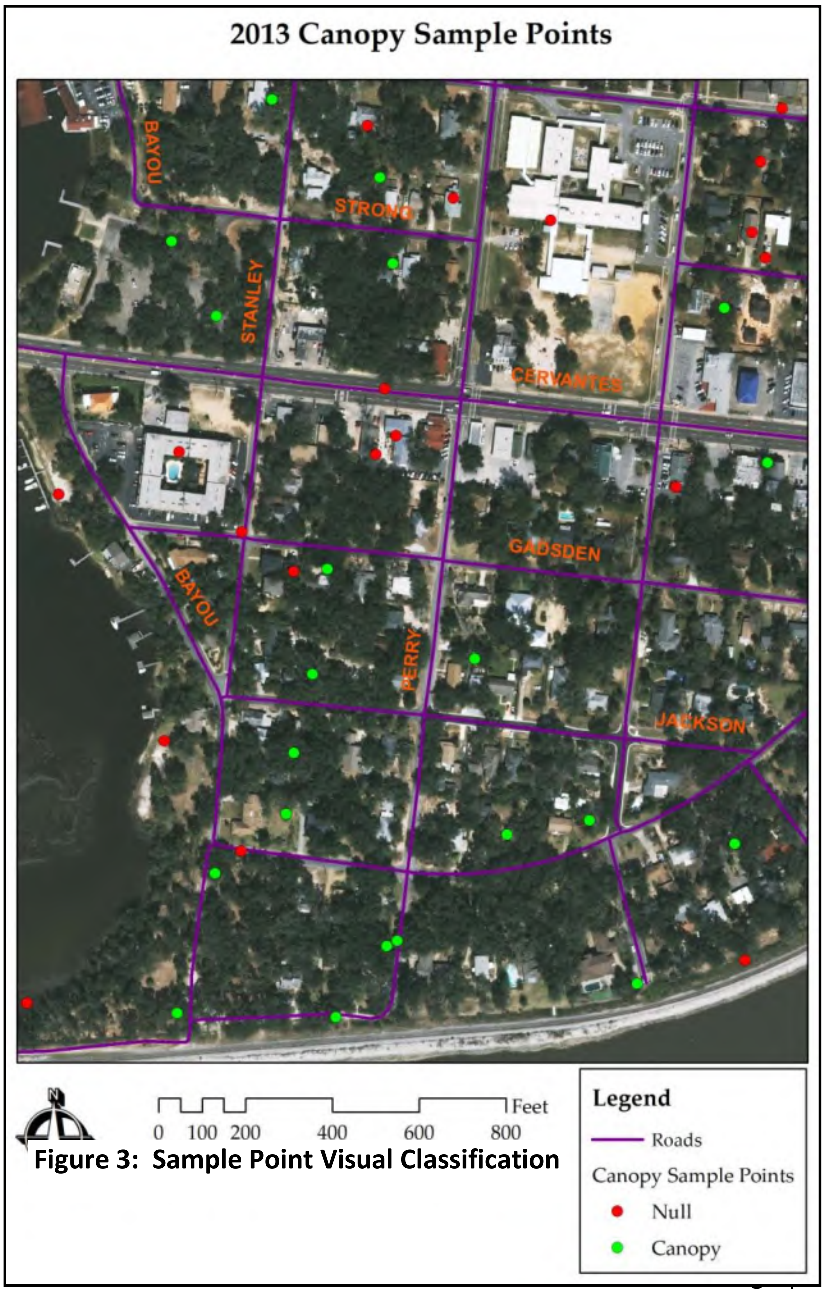


Figure 3: Sample Point Visual Classification

subdivisions within the study area. Using the method described above, smaller or isolated areas contain fewer data points and fewer data points translate to increased error. Therefore, it was necessary to employ a different method to generate a representation of the current canopy that is both accurate and scalable. Multispectral classification using high resolution infrared aerial imagery is scalable from the entire study area down to areas as small as single parcels, all without sacrificing accuracy.

USDA National Agriculture Imagery Program (NAIP) 2013, 4-band color infrared (CIR), orthophotos were acquired through the USDA Aerial Photography Field Office and imported into ArcGIS for processing. Source data is available below in Table 2. Individual images were processed using the mosaic function in ArcGIS using the same method described above in 4.1. A mean color-match operator ensured accurate spectral sampling in areas of image overlap and the addition of a null-data parameter reduced image noise in subsequent processing.

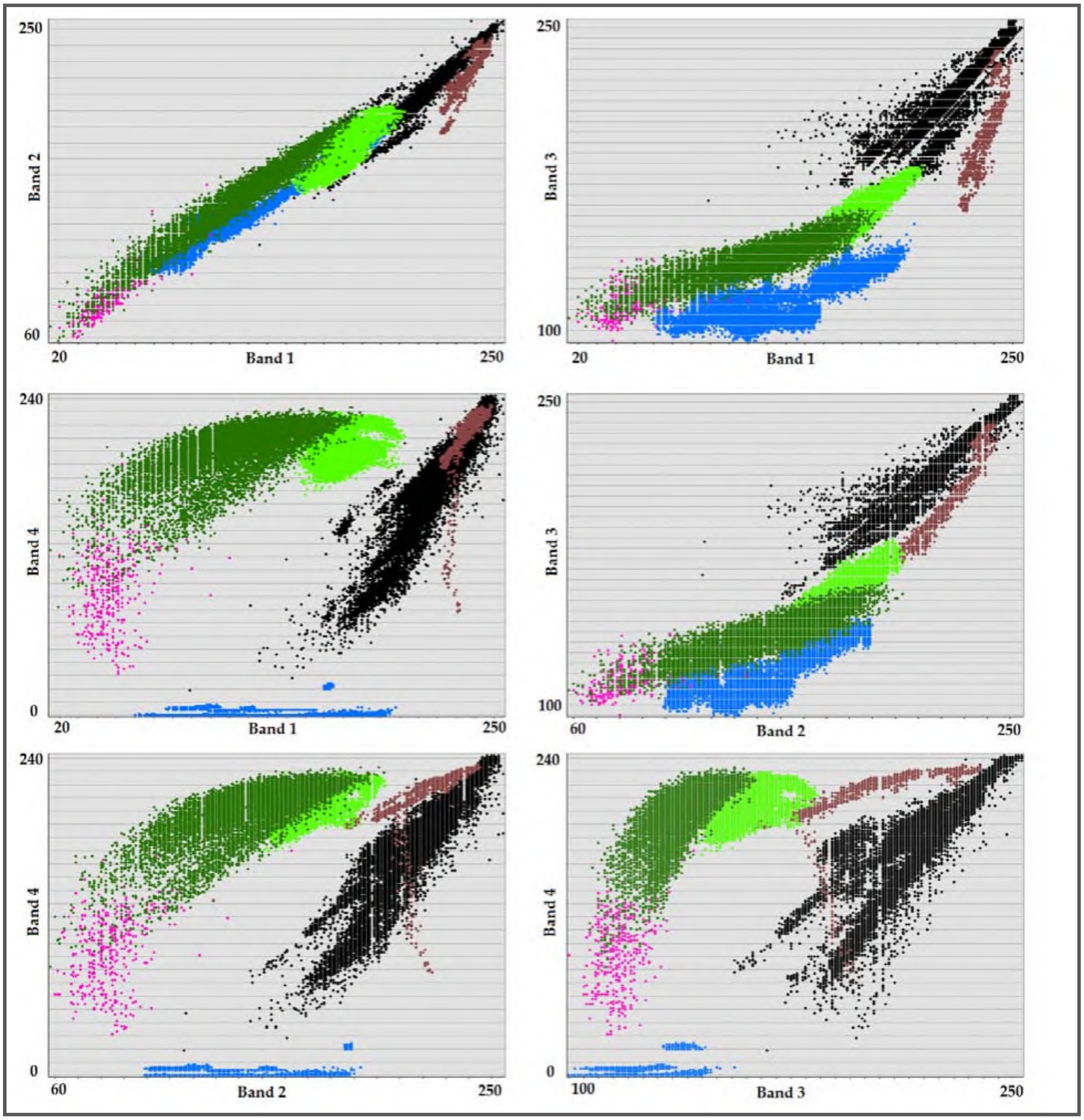
Table 2: Imagery Sources and Metadata Evaluated for Section 4.2 Methodology

Date	Organization/Image Type	Projection	Datum/Zone	Units/Resolution	Horizontal Accuracy
Oct-2013	USDA-NAIP/4- Band Color IR	Universal Transverse Mercator	NAD83	Meters/1.0	±6m

A two step supervised spectral classification was performed on the NAIP imagery set using the *Maximum Likelihood Classification* (MLC) tool in ArcGIS Spatial Analyst to classify tree canopies. The initial classification utilized representative pixel samples of five primary urban cover types (Canopy, Impervious, Soil, Water, and Grass) in order to identify all potential pixel values. Ten separate pixel training samples per cover type were utilized in order to achieve an appropriate representative sample of the study area and the minimum recommendation of 100 pixels for each category (Campbell and Wynne, 2011). Representative pixel training samples for the five cover types were visually classified and analyzed for uniformity utilizing a reflectance frequency diagram.

An initial 5-class MLC utilizing Baye's theorem was run on the NAIP imagery set with an equal priori probability weighting and a reject fraction parameter of 0.5%, avoiding some potential miss-classification of deviating pixels and allowing for a second "correction" classification to be performed. The output 5-class land cover raster was analyzed for data voids and used to create an additional pixel training class, identifying un-classified canopy reflectance values falling within image shadows. The final six training samples were analyzed for heterogeneity utilizing frequency cluster diagrams as in the first classification and a 6-class MLC process was run on the original NAIP imagery to include the previously un-classified canopy shadows in the classification. Final pixel frequency distribution is provided in Figure 4.

Figure 4: Pixel Frequency Distribution for Final 6-Class MLC Process



Class Name	Color
Canopy	
Impervious	
Soil	
Water	
Grass	
Hole	

A final digitized canopy was extracted from the 6-class MLC output and was confirmed for accuracy by comparing metrics with the statistical outputs described above in 4.1. Overall calculated canopy coverage within the 14,462 acre study deviated less than 0.1% between the two methods.

4.3 Acquisition, Creation, and Processing of Other Data Layers

The remaining two land covers (impervious surfaces and open space) were derived through editing and combining of existing datasets from a variety of reliable sources, including City of Pensacola GIS, Escambia County GIS, Escambia County Property Appraiser, FDEP, FDOT, USDA, and U.S. Geological Survey (USGS).

Existing shapefiles representing major pavement areas and building footprints were acquired from the City of Pensacola GIS. A roadway surfaces layer was generated utilizing FDOT road centerlines. All collected layers determined as impervious were visually checked for errors. Limited updates were made to existing shapefiles where more current information was available. Final versions were merged into a single representative coverage representing impervious surfaces within the study area.

Open space was delineated by eliminating all areas considered "un-plantable" within the study area. Un-plantable areas included current tree canopy, stormwater retention ponds, recreation fields, impervious surfaces, airport runways and associated maintained areas, and surface waters. A complete list of land types excluded from open space is provided below in Table 3. The output of this process was visually checked for errors. Limited updates were made to existing shapefiles where more current information was available. The final open space land cover layer was additionally edited to exclude contiguous areas of less than one-hundred square feet. This last edit was made to assure all remaining areas identified as open space were large enough to support successful future tree plantings.

Final outputs provided urban cover metrics showing actual, scalable canopy, impervious surfaces, and open/available planting locations (open space) for the entire study area.

Table 3: Data Utilized in Creating Open Space Coverage

Data Type	Data Source
Airport Runways & Associated Areas	Escambia County
Building Footprints*	City of Pensacola
Major Pavement*	City of Pensacola
Roadways*	FDOT, Escambia County
Railroad Right-of-Ways	Escambia County
Recreational Fields*	City of Pensacola, Escambia County
Stormwater Retention Ponds*	City of Pensacola
Surface Waters*	U.S. Geologic Survey

* Data updated to include more current information

Other data layers either directly acquired or created for the study include land use, watersheds, riparian buffers, public and private lands, parks, and gateway corridors. Each layer was incorporated into the analysis performed for the study to determine trends, evaluate current conditions, and provide recommendations relative to these underlying factors. A complete list of these other data layers incorporated into the study is provided in below in Table 4.

Table 4: Other Data Layers Utilized in Analysis

Data Type	Data Source
Parcel Data (2013)	Escambia County Property Appraiser
City Owned Property	City of Pensacola
Other Government Owned Property	Escambia County Property Appraiser, City of Pensacola
Gateway Corridor Locations*	City of Pensacola
Parks and Recreational Fields*	City of Pensacola, Escambia County
Watersheds*	FDEP
Riparian Areas*	USGS, Escambia County

* Data updated to include more current information

Comprehensive parcel data was acquired through the Escambia County Property Appraiser. Land use classifications were made using Department of Revenue (DOR) codes embedded within the parcel data received. Similar DOR codes were combined to form the following major categories: commercial, government, industrial, institutional, residential, and other. Distribution of land use by DOR code is provided in Appendices A. Parks, City owned property, and other government owned property was first evaluated using DOR codes, and then later refined by using a dataset provided by the City of Pensacola. Gateway corridors were digitized based on data provided by the City of Pensacola. City property falling within fifty feet of defined corridors was classified separately in order to analyze aesthetically prominent city owned land along each priority gateway area.

Watersheds were delineated utilizing FDEP Water Boundary Identification (WBID) data. Subbasins, delineated separately by FDEP for water quality data management purposes, were merged with adjoining areas to create basins representative of the primary drainage patterns within the city. The study area was divided into four main watersheds: Pensacola Bay (WBIDs: 639, 548BB), Bayou Texar (WBIDs: 676, 738, 738AB), Downtown (WBIDs: 740), and Bayou Chico (WBIDs: 846, 846C, 846CB, 848DA). Riparian buffers (100-foot) were delineated within the city jurisdictional boundary utilizing a combination of USGS stream location data (primary riparian zones), and visual classification (open water features clearly visible in 2013 aerial dataset).

4.4 Final Data Analysis

Raster datasets derived using the methodology described above in section 4.1 were split by primary areas of interest to provide detailed temporal and geographical land cover statistics. Outputs allow for evaluation of canopy trends and determination of attainable canopy goals specific for the City of Pensacola.

The 2013 urban tree canopy for the City of Pensacola produced using the methodology described above in section 4.2 was intersected with the datasets described in section 4.3. Outputs allow for determination of maximum attainable urban canopy by land use or ownership, evaluation of gateway corridors for potential improvement to shade and aesthetics, detection of watersheds or riparian corridors lacking adequate canopy coverage for water quality improvement or wildlife habitat utilization, and, therefore, identification and prioritization of optimal tree planting locations.

Data generated using the methods described above is presented below in the Results section below. In addition to information directly included within this report, all final model datasets were provided to the City of Pensacola for future use in planning and assessment initiatives.

5.0 Results

Results obtained in all phases of modeling are presented in this section of the report. Additional maps and project data not directly discussed in the body of this report can be found in the Appendix.

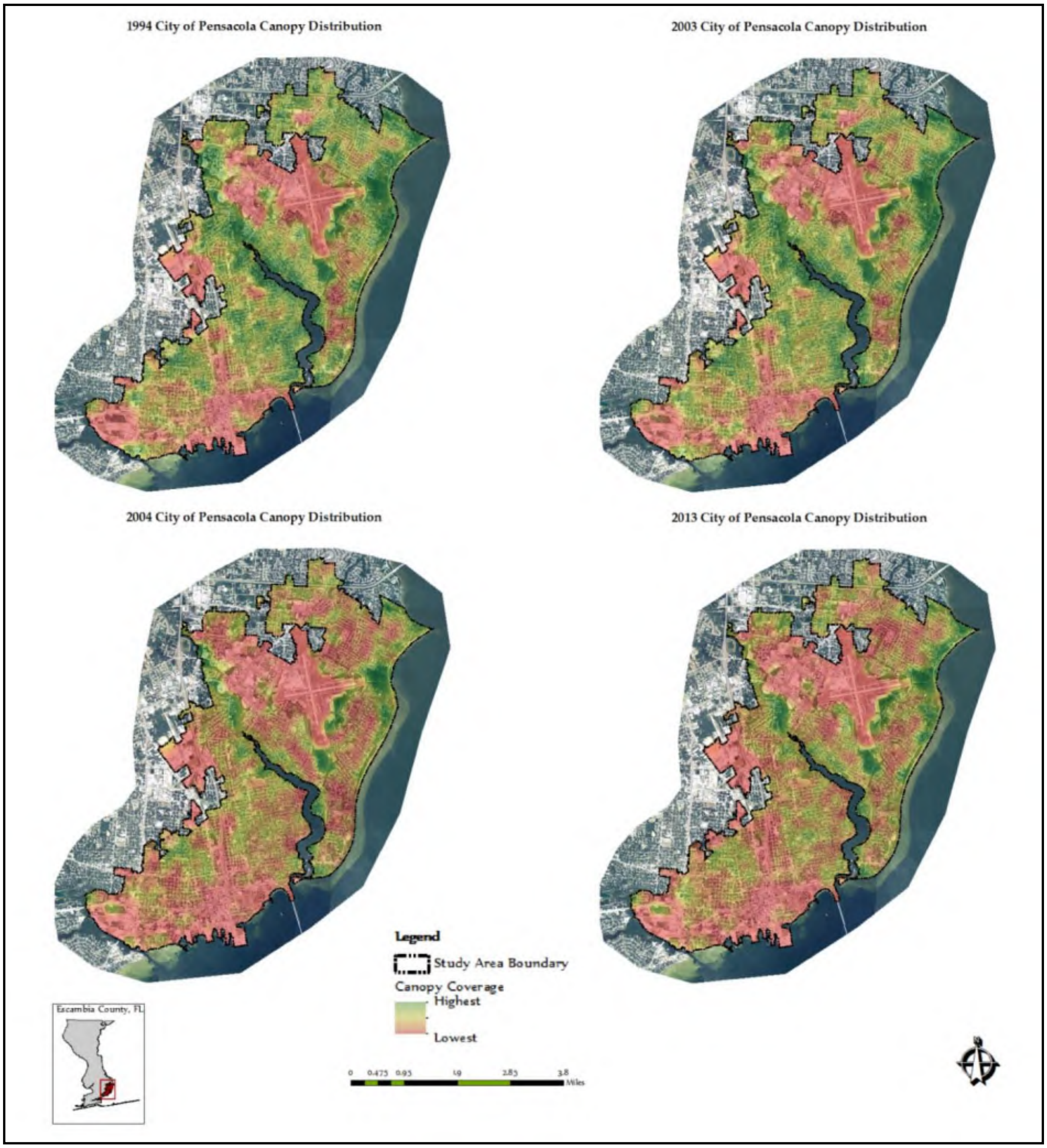


Figure 5: Canopy Trend Model. Detailed canopy trend modeling provides insight into the actual distribution of canopy within the study area. Four representative sample years of specific interest are presented (1994, 2003, 2004 & 2013), covering the nineteen year study window as well as a pre/post major hurricane event (Ivan) to be analyzed. Overall canopy coverage metrics for the sample years in this figure are: 1994 (40.2%), 2003(39.4%), 2004 (28.4%) and 2013 (29.3%).

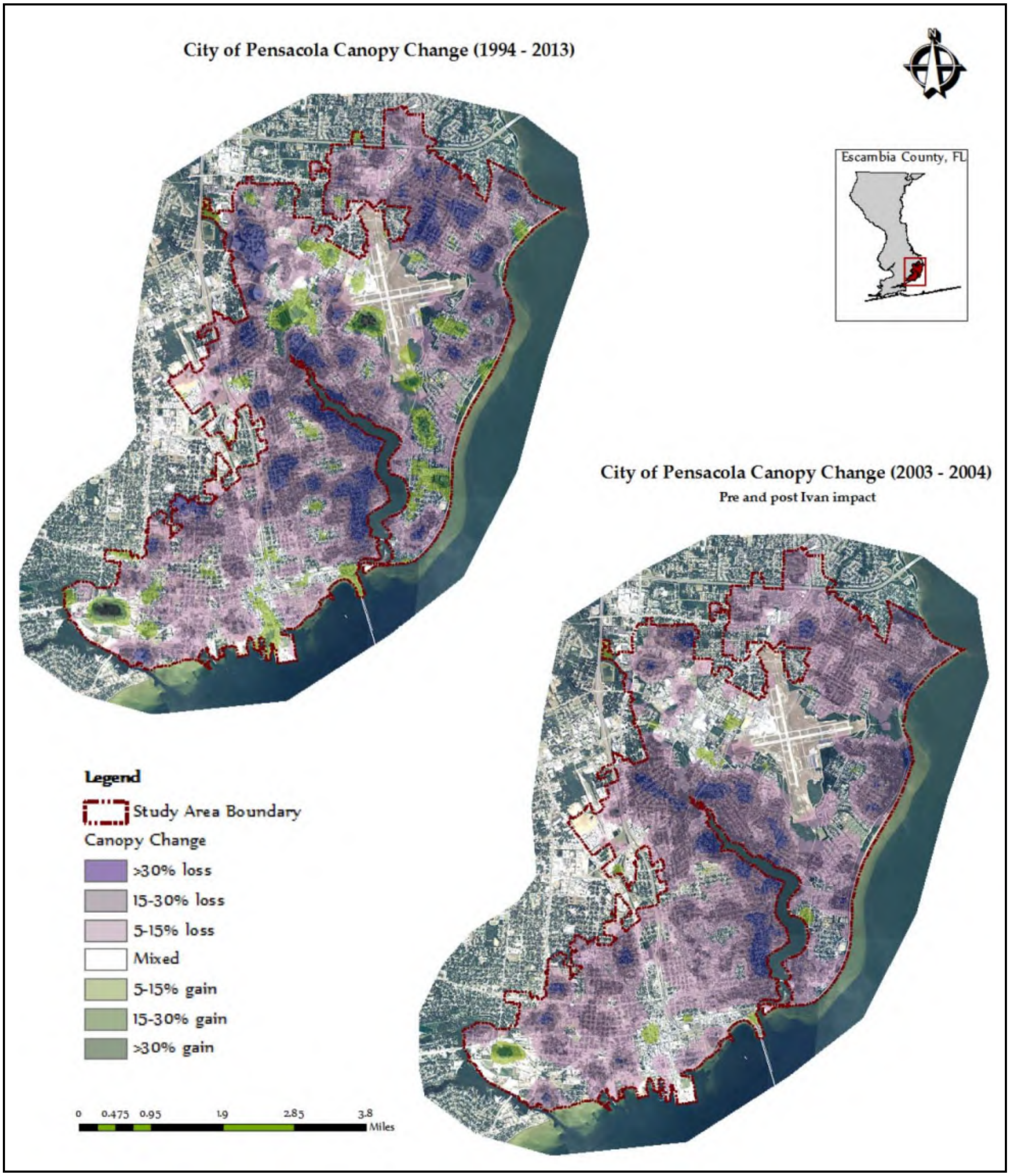


Figure 6. Canopy Changes from 1994 to 2013. These change rasters observe overall, 19 year, canopy changes (1994-2013) as well as Hurricane Ivan related (2003-2004) canopy impacts. Relative changes in canopy coverage are visualized and can be quantified within general areas of interest such as Bayou Texar where extreme losses are apparent as a direct result from Hurricane Ivan.

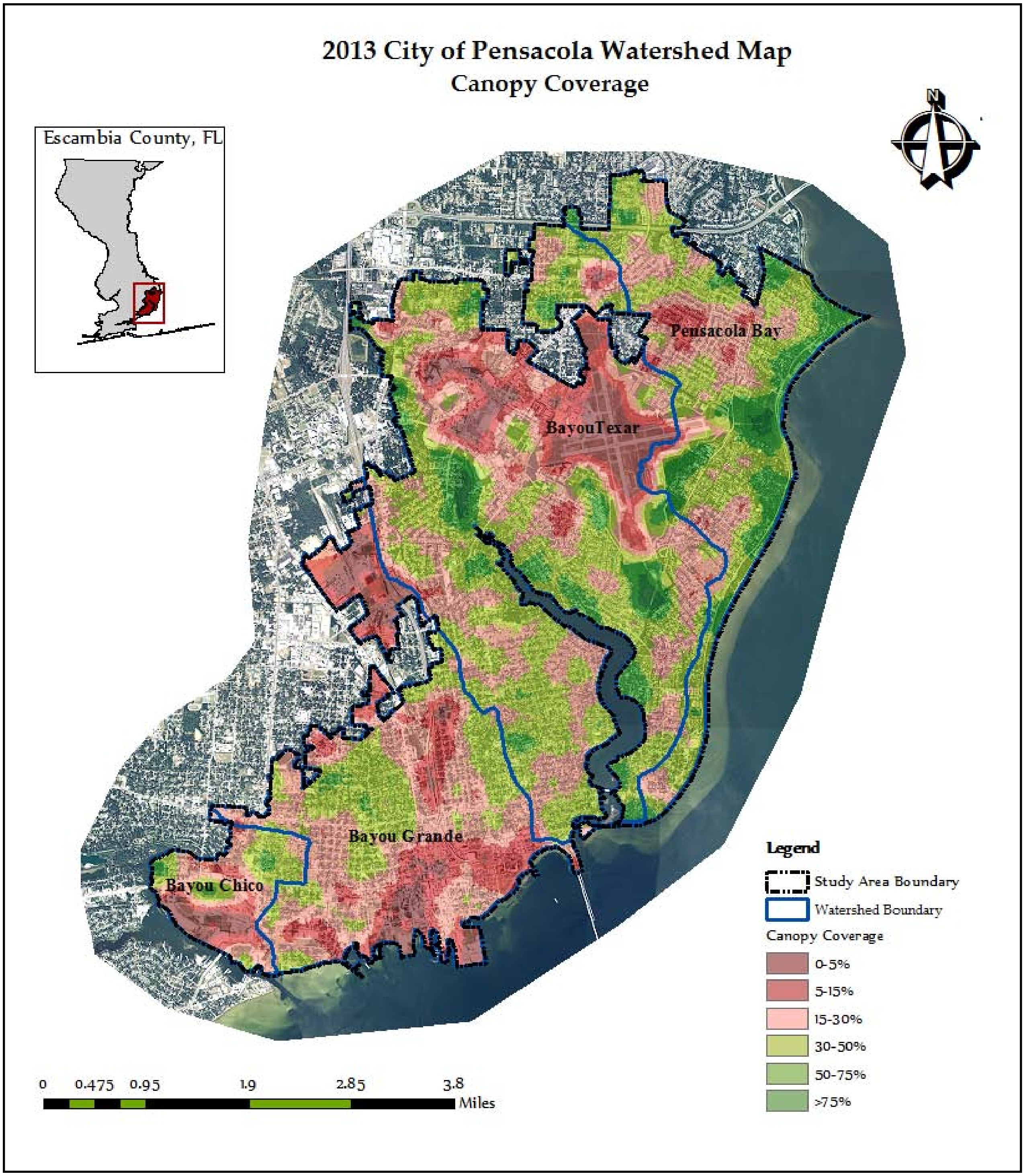


Figure 7. Watershed Map Relative to Canopy Density: Overall 2013 canopy coverage map overlaid onto the City of Pensacola's four watershed delineations. Primary areas of canopy be seen along aquatic buffers, in airport noise buffers and in certain residential and park areas such as the East Hill Neighborhood and Bayview Park. Lowest ratio of tree canopy to land acres is located in the Bayou Texar Watershed and the Bayou Grande (Downtown) Watershed.

Figure 8 Chart illustrating Public vs. Private Land Ownership: Over 80% of all lands in City of Pensacola are privately owned. The remaining properties are divided among other government entities including the City, school board and federal agencies

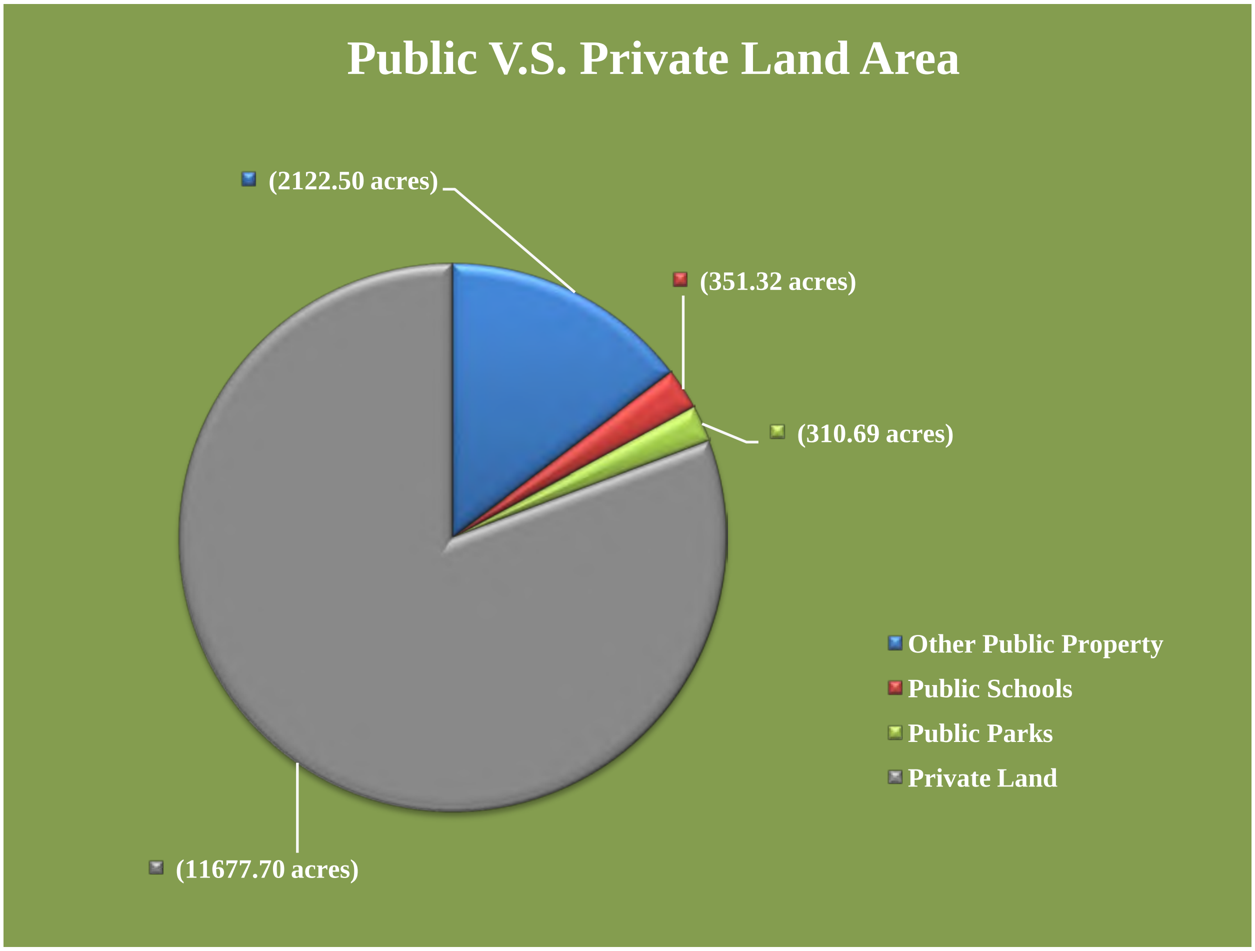


Table 5: Metrics for Public vs. Private Land Ownership: Current (2013) urban cover metrics with acreage and cover values

Data Type	Acres	Canopy	Impervious	Open Space	Total Acres
Other Public Property	2122.50	23.7%	24.5%	20.0%	2122.50
Public Schools	351.32	10.2%	40.2%	41.9%	351.32
Public Parks	310.69	39.3%	2.9%	44.4%	310.69
Private Land	11677.70	30.5%	32.3%	37.2%	11677.70

Table 6: Cover Metrics for the City of Pensacola's 100 ft. Aquatic Buffers

Property Type	100 ft. Aquatic Buffer	Acres	Canopy	Impervious	Open Space
All	Pensacola Bay	167.02	11.5%	16.8%	44.1%
All	Bayou Texar	115.74	42.3%	6.0%	46.9%
All	Bayou Chico	30.79	18.4%	38.6%	38.6%
All	Maggie's Ditch	7.95	42.6%	8.0%	31.8%
All	Carpenters Creek	112.09	74.2%	5.4%	13.3%
All	Other Streams	7.34	80.6%	4.0%	8.7%
All	Graveyard Branch	10.23	70.8%	5.3%	11.0%

Figure 9: Visualizing Primary Urban Cover Values: Showing the open space, impervious and existing canopy within the aquatic buffer for various water bodies within the study area.

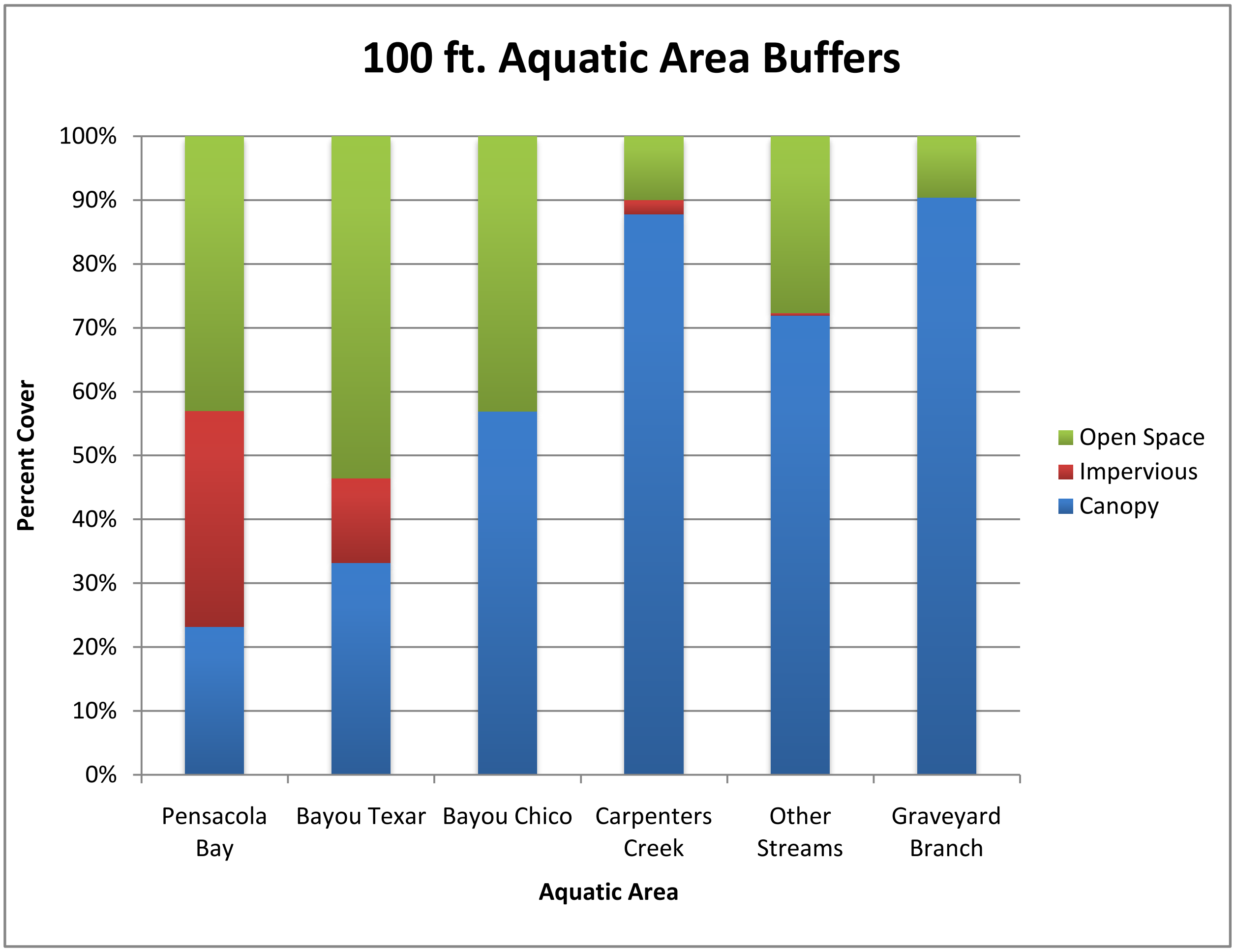
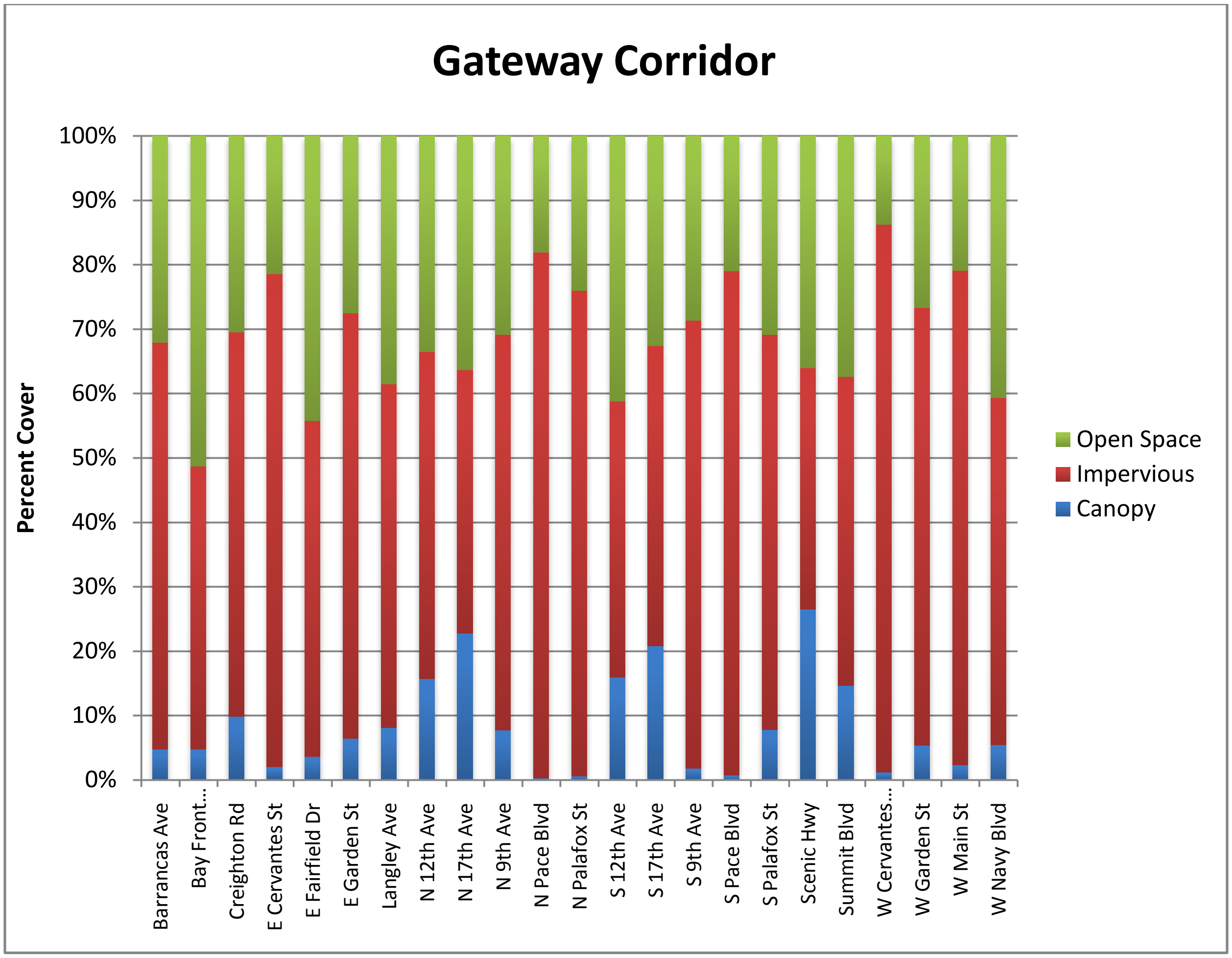
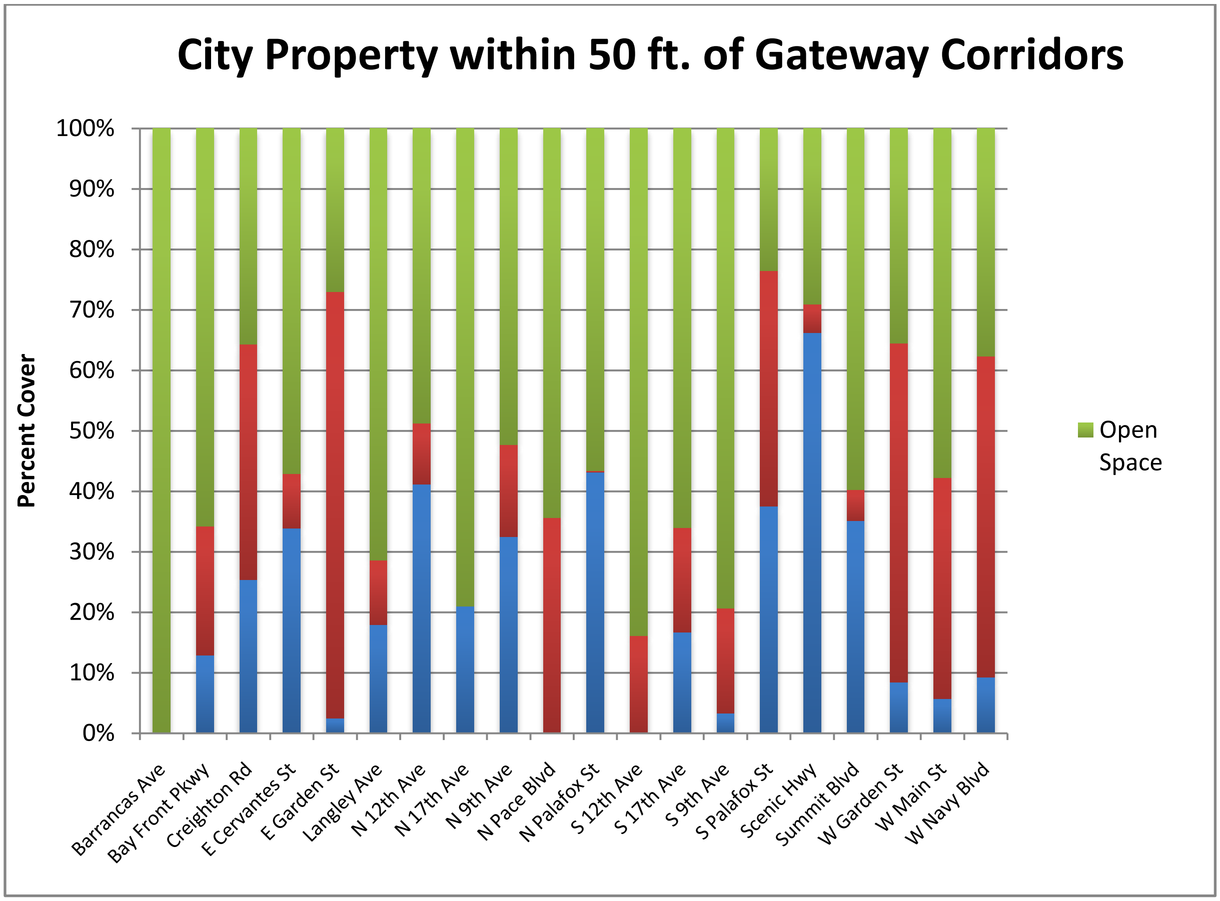


Figure 10: Coverage metrics within the Gateway Corridor. Coverage values represent percentage of impervious areas, existing canopy and impervious areas within the Gateway Corridors



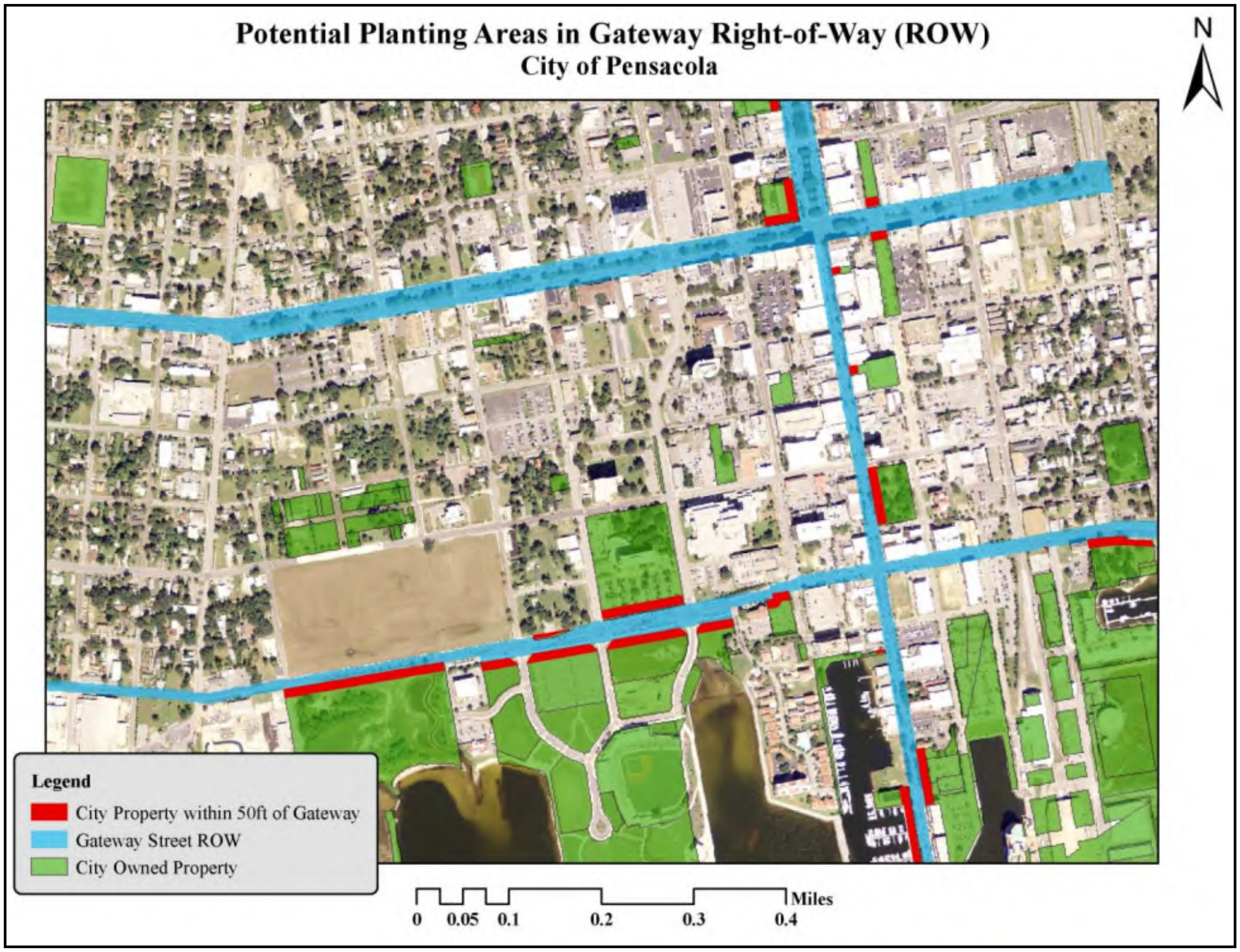
Property Type	Gateway Area	Acres	Canopy	Impervious	Open Space
All	All Gateways	522.15	10.4%	56.5%	33.6%
All	Barrancas Ave	25.16	3.8%	50.1%	25.5%
All	Bay Front Pkwy	26.13	4.6%	42.3%	49.4%
All	Creighton Rd	20.26	13.1%	78.8%	40.3%
All	E Cervantes St	22.47	2.0%	76.7%	21.4%
All	E Fairfield Dr	39.03	3.6%	52.3%	44.3%
All	E Garden St	5.88	6.4%	66.3%	27.6%
All	Langley Ave	25.65	8.1%	53.8%	38.9%
All	N 12th Ave	48.20	16.1%	51.9%	34.3%
All	N 17th Ave	14.83	23.8%	42.7%	37.9%
All	N 9th Ave	68.93	7.9%	62.8%	31.5%
All	N Pace Blvd	6.20	0.3%	81.8%	18.1%
All	N Palafox St	9.16	0.6%	75.6%	24.1%
All	S 12th Ave	4.15	16.4%	44.0%	42.3%
All	S 17th Ave	6.18	20.6%	46.1%	32.3%
All	S 9th Ave	7.73	1.8%	70.2%	28.9%
All	S Pace Blvd	8.16	0.7%	76.3%	20.5%
All	S Palafox St	15.14	8.0%	62.7%	31.6%
All	Scenic Hwy	64.43	26.6%	37.6%	36.1%
All	Summit Blvd	32.91	15.1%	49.5%	38.6%
All	W Cervantes St	16.99	1.2%	85.6%	13.8%
All	W Garden St	22.84	5.4%	68.3%	26.8%
All	W Main St	16.09	2.0%	65.5%	17.8%
All	W Navy Blvd	23.16	5.3%	52.3%	39.5%

Figure 11: Current (2013) Urban Cover Metrics for City Owned Property within 50 feet of the Gateway Corridor. Property areas are within 50 feet of a gateway right-of-way area. These properties could be considered for improvements associated with improvements in the Gateway Corridor. A visual example of the area is shown in figure 12.



Property Type	Gateway Area	Acres	Canopy	Impervious	Open Space
City (within 50ft)	Barrancas Ave	0.06	0.0%	0.0%	100.0%
City (within 50ft)	Bay Front Pkwy	3.83	11.9%	19.6%	60.4%
City (within 50ft)	Creighton Rd	0.37	26.2%	40.3%	36.8%
City (within 50ft)	E Cervantes St	2.00	34.8%	9.2%	58.7%
City (within 50ft)	E Garden St	0.18	2.5%	71.5%	27.4%
City (within 50ft)	Langley Ave	5.83	14.2%	8.4%	56.5%
City (within 50ft)	N 12th Ave	8.35	37.2%	9.1%	44.1%
City (within 50ft)	N 17th Ave	0.61	20.8%	0.0%	78.3%
City (within 50ft)	N 9th Ave	0.73	34.0%	16.0%	54.7%
City (within 50ft)	N Pace Blvd	0.17	0.0%	35.6%	64.4%
City (within 50ft)	N Palafox St	0.69	42.5%	0.2%	55.7%
City (within 50ft)	S 12th Ave	0.32	0.1%	12.9%	67.3%
City (within 50ft)	S 17th Ave	1.37	16.0%	16.6%	63.4%
City (within 50ft)	S 9th Ave	1.49	3.3%	17.4%	79.6%
City (within 50ft)	S Palafox St	3.23	38.0%	39.3%	23.8%
City (within 50ft)	Scenic Hwy	13.02	65.0%	4.6%	28.5%
City (within 50ft)	Summit Blvd	9.06	34.9%	5.1%	59.3%
City (within 50ft)	W Garden St	0.22	8.7%	57.3%	36.3%
City (within 50ft)	W Main St	3.60	5.5%	35.5%	56.2%
City (within 50ft)	W Navy Blvd	0.83	8.5%	48.7%	34.6%

Figure 12: A Visual Example of City Owned Properties within the Gateway Corridor. Gateway is highlighted with blue. The 50 feet of gateway right-of-way areas is shown in red. Areas highlighted in green are City owned properties. Electronic data of all areas was provided to the City.



6.0 Discussion

6.1 City of Pensacola Urban Canopy Trends

Canopy coverage is not a static measurement. Estimates, even good estimates, only represent a snapshot in time. Urban forests are dynamic systems. Many factors simultaneously contribute to either expansion or contraction. Growth and decline coexist. Rates determine overall trends. Temporal trends in urban tree coverage for the City of Pensacola observed through this study are summarized below in Figure 14.

Factors contributing to increases in canopy coverage may include annual growth of existing trees, community planting efforts, or even rapid flush from new volunteers after land disturbance. Factors contributing to decreases in canopy coverage may include storm events, urban development, disease, and loss of mature trees.

6.2 Canopy Trends Relating to Hurricanes and Tropical Storms

The effects of tropical storms on the urban canopy have been well-documented. Strong sustained winds, and even stronger wind gusts, cause tree failures including crown damage, stem breakage, and uprooting. As expected, studies have found positive correlations between increasing wind speed and canopy loss (Tanner et al. 1991). In addition to strong winds, storms bring considerable rainfall. Studies have also found saturated soils caused by intense rainfall leading up to storm events contribute to tree mortality mainly by increasing chances of trees uprooting (Creamer et al. 1982). Both factors are directly related to the relative position to the landfall location since the heaviest rainfall and strongest winds are generally found in the northeast quadrant (right front side relative to direction of movement) of tropical storms and hurricanes forming in the northern hemisphere.

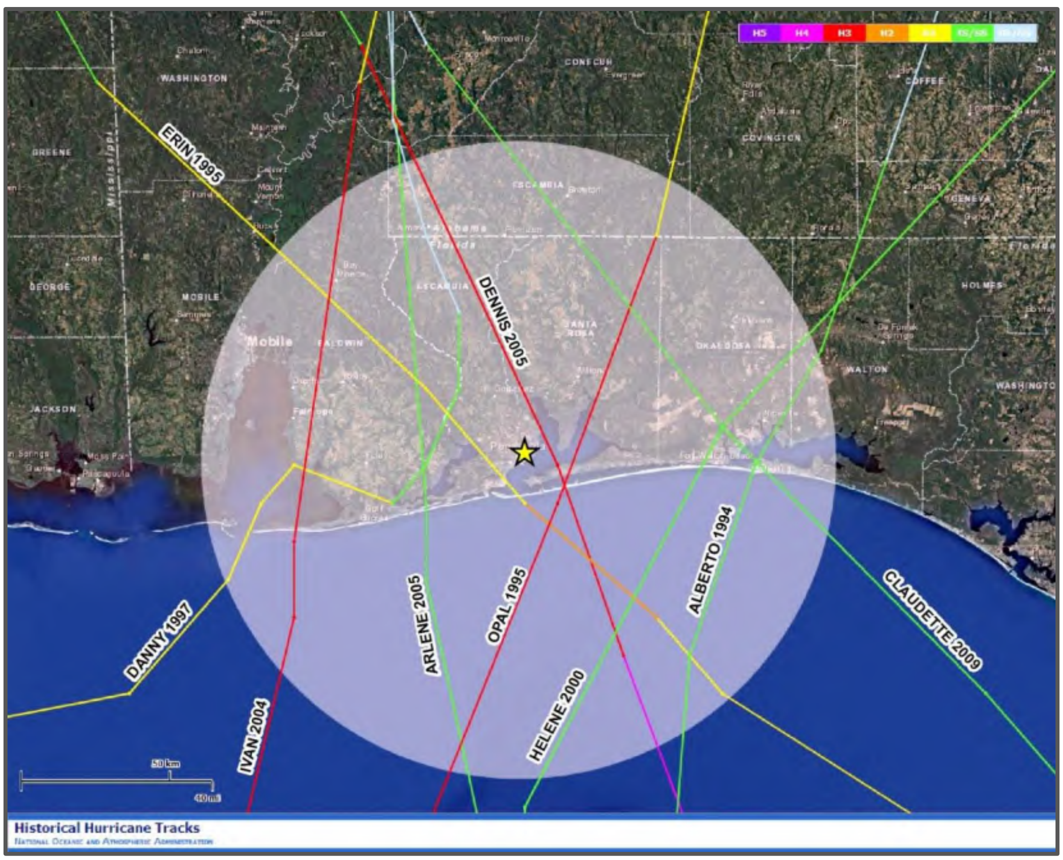
Canopy loss due to storms is also a function of tree characteristics. Other factors include wood density, crown shape, crown density, and size (Duryea et al. 2007). Not all tree species posses the same storm resistant qualities. Native trees generally have a higher survival rating than many exotic species (Duryea et al. 1996). Future canopy loss can be mitigated, at least in part, thorough proper selection of wind resistant trees. Cultural practices, such as proper routine pruning and planting procedures, can also increase survivability (Duryea et al. 2007).

Since 1994, nine named tropical cyclones have made landfall within 50 nautical miles of Pensacola. Maximum sustained winds at landfall ranged from 35 to 105 knots (40 – 120 mph). A list of those storms is provided below in Table 7. Corresponding storm tracks and landfall locations are also graphically depicted below in Figure 13.

Table 7: Hurricanes and Tropical Storms Making Landfall within 50 Nautical Miles of Pensacola (1994-2013)

Date	Storm	Landfall Location	Landfall Winds (kts)
August 2009	Claudette	Fort Walton Beach, FL	40
July 2005	Dennis	Pensacola Beach, FL	105
June 2005	Arlene	Perdido Key, FL	60
September 2004	Ivan	Gulf Shores, AL	105
September 2000	Helene	Fort Walton Beach, FL	35
July 1997	Danny	Mullet Point, AL	65
October 1995	Opal	Pensacola Beach, FL	100
August 1995	Erin	Pensacola Beach, FL	75
July 1994	Alberto	Destin, FL	55

Figure 13: Storm Tracks and Intensity of Hurricanes and Tropical Storms Making Landfall Within 50 Nautical Miles of Pensacola (1994-2013)



Map Source: National Oceanic and Atmospheric Administration (NOAA) - National Hurricane Center

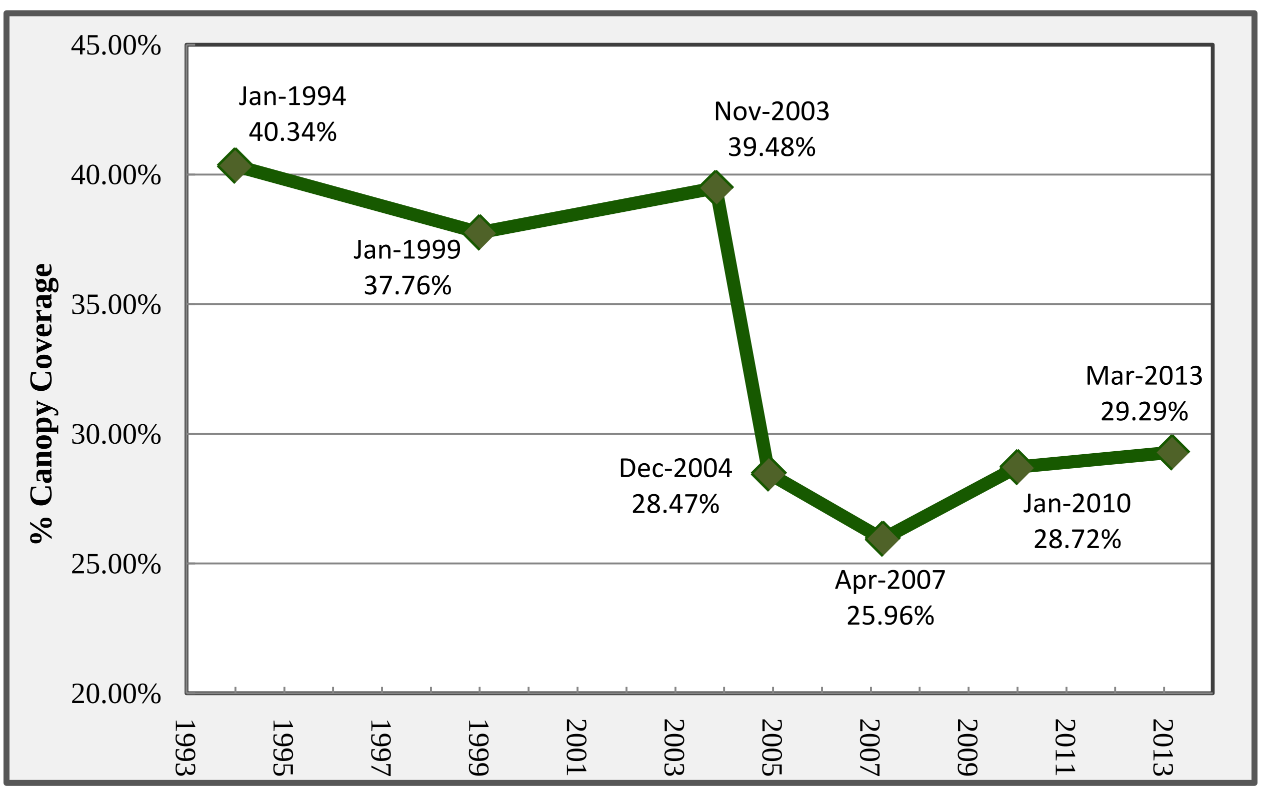
Overall canopy coverage during the period of interest ranged from 25.96% to 40.34% with the highest percent coverage observed at the beginning of the period in January 1994, and the lowest percent coverage observed in April 2007. Intervals showing decline in overall canopy coverage include January

1994 – January 1999, November 2003 – December 2004, and December 2004 – April 2007. All three periods correspond with one or more landfalling hurricanes (Erin, Opal, Ivan, Dennis), including at least one major hurricane (>95 kts) during each interval. Two other tropical storms (Alberto, Arlene) also made landfall during these periods.

The greatest loss of canopy was observed following Hurricane Ivan where an estimated 27.89% of the entire canopy within City of Pensacola was lost due to the storm and associated factors. Losses following Hurricane Dennis are estimated at 8.82% of the remaining canopy. This loss reflects considerably fewer trees considering the almost 9% loss was of the already reduced canopy coverage following Ivan. Limited availability of quality aerial imagery in the mid 1990s prevents the individual evaluation of Hurricanes Erin and Opal. Data collected for this study suggests only a 6.40% loss due to both storms, but actual losses could have been closer to 10% if a recovery typical of the recovery rate discussed below is assumed during the following three growing seasons before January 1999.

Figure 14 below visualizes changes in canopy cover from November 2003 – December 2004. Canopy loss and gain is shown as a color gradient between purple and green. Colors trending toward green reflect gains; colors trending toward purple reflect losses. Areas reflecting the highest percentage of canopy loss appear to correlate with the vegetative edge along Bayou Texar and the eastern shoreline of Pensacola Bay.

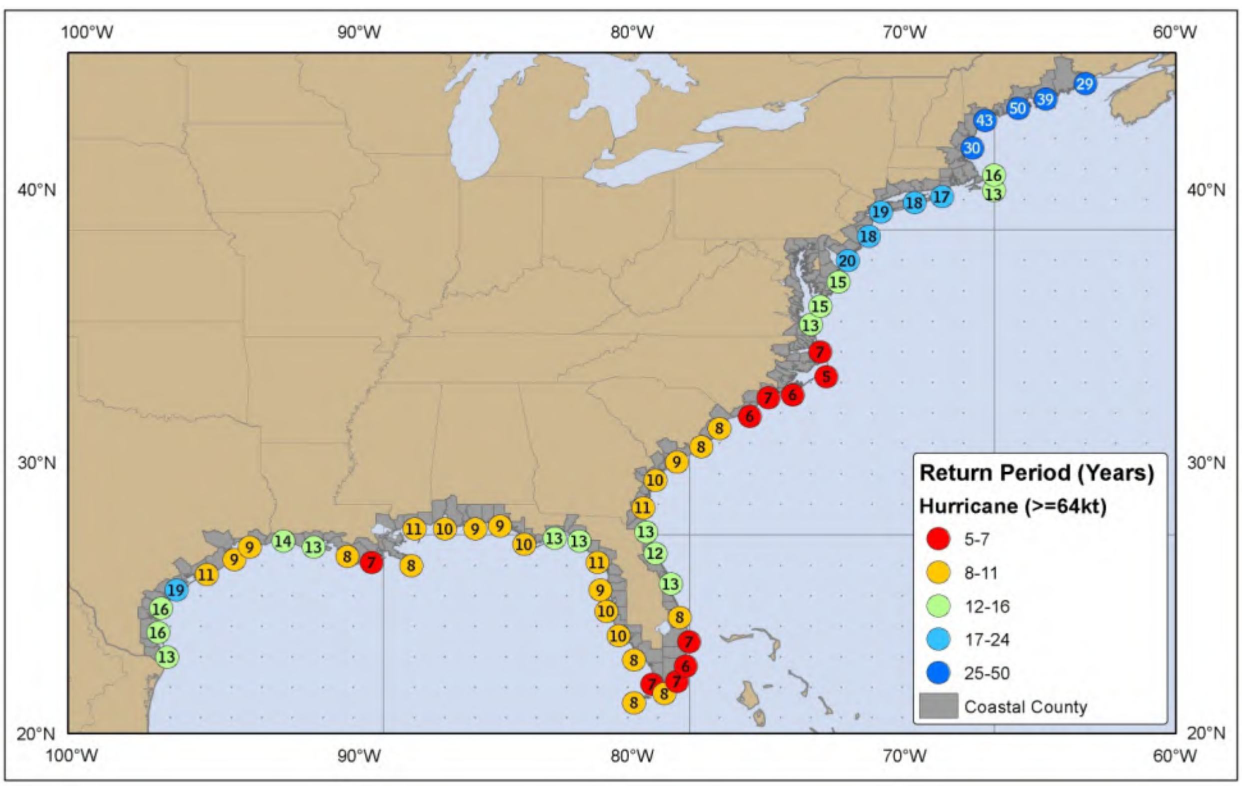
Figure 14: Estimated Canopy Coverage per Year



April 2007 – January 2010, and January 2010 – March 2013 are periods showing gains in canopy coverage generally do not include significant landfalling storms. Danny in 1997 is the only hurricane (minimal category 1 hurricane) to make landfall within 50 nautical miles of Pensacola during any of these periods of increase. Two other tropical storms (Helene, Claudette) also made landfall during these periods. No loss of canopy was able to be attributed to these storms. Decline, if any, attributed to these and other tropical storms was likely less than the relative margin of error (±1%) for the study.

The relationship between canopy loss and maximum sustained winds is not linear (Duryea et al. 2007). While localized impacts are possible, tropical storms generally do not appear to produce measurable canopy losses. Impacts from hurricanes, specifically major hurricanes, appear to be the largest single factor affecting the overall canopy trends for the City of Pensacola observed during the period evaluated for this study.

Figure 15: Average Return Periods between Landfalling Hurricanes

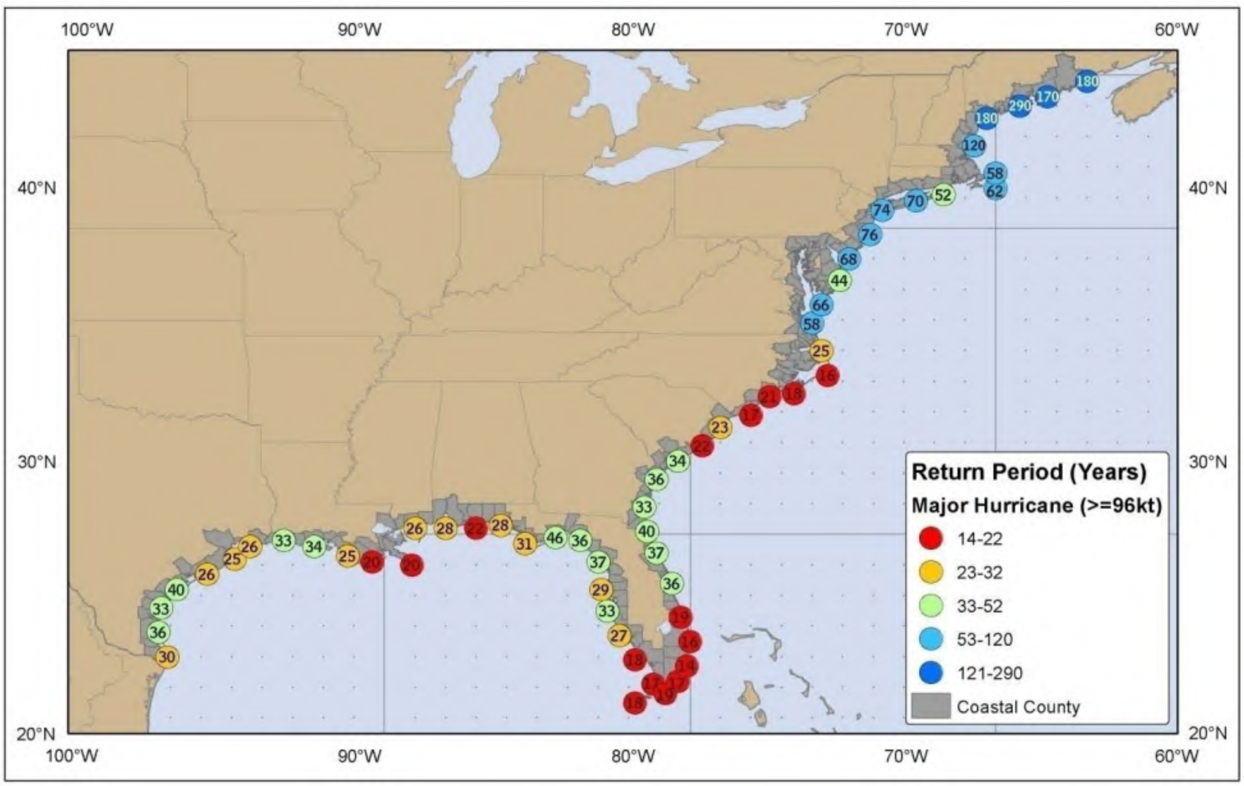


Map Source: National Oceanic and Atmospheric Administration (NOAA) - National Hurricane Center

Impacts from future tropical storms and hurricanes are inevitable. A canopy recovery strategy for the City of Pensacola should therefore consider the likely probability and severity of these impacts. The

National Oceanic and Atmospheric Administration (NOAA) has produced statistical probabilities of likely return periods (years between strikes) for the Atlantic Ocean and Gulf of Mexico using long-term historical data. The expected return period of a hurricane (64 – 95 kts) passing within 50 nautical miles of Pensacola is estimated at every nine years, or an 11.1% chance any given year. Data for estimated return periods for hurricanes is depicted in Figure15 above. The expected return period of a major hurricane (>95 kts) passing within 50 nautical miles of Pensacola is estimated at every 22 years, or a 4.5% chance any given year. Data for estimated return periods for major hurricanes is depicted in Figure 16 below. As of the date of this report, a hurricane, or major hurricane, has not made landfall within 50 nautical miles of Pensacola in nine years (Dennis 2005).

Figure 16: Average Return Periods between Landfalling Major Hurricanes



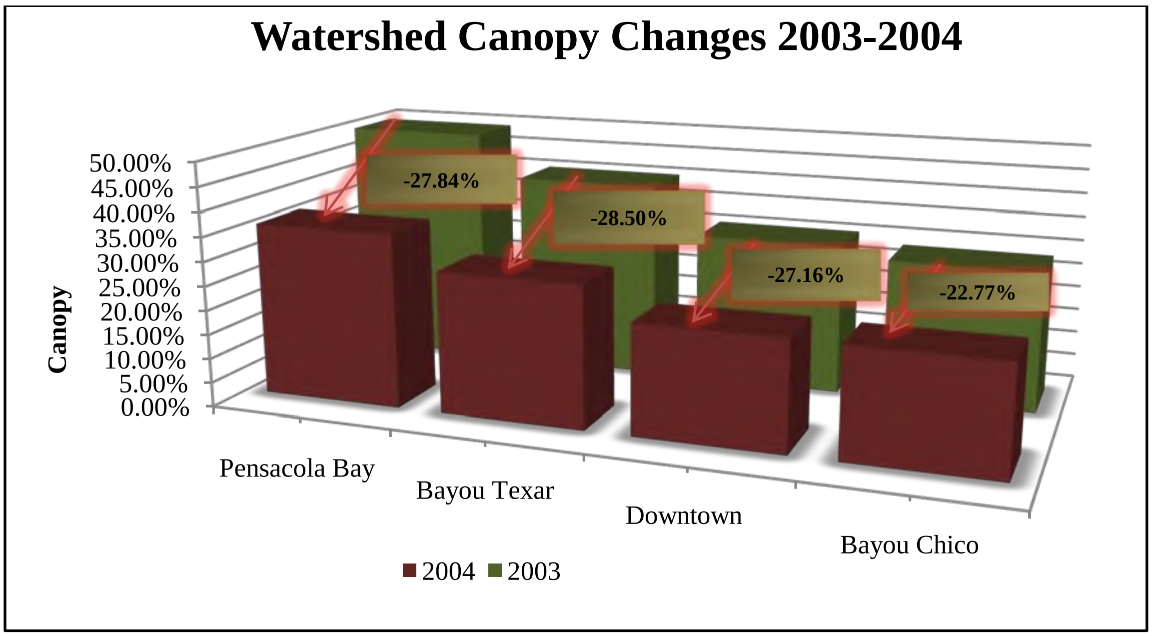
Map Source: National Oceanic and Atmospheric Administration (NOAA) - National Hurricane Center

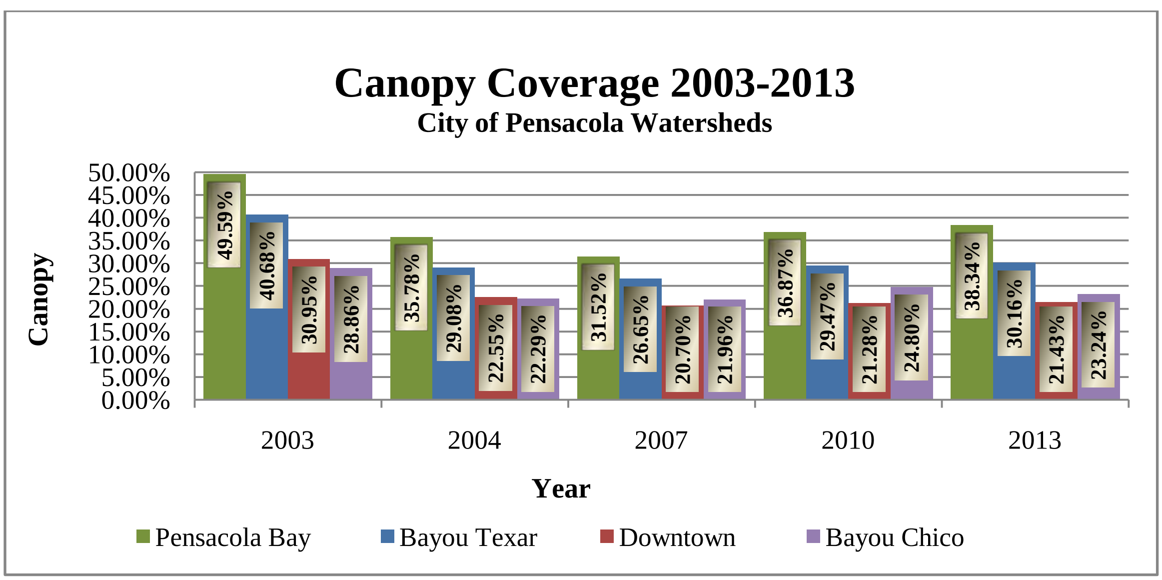
6.3 Canopy Trends Relating to Watersheds

Watershed based urban forestry incorporates urban tree canopy into water quality planning and resource management. This comprehensive strategy focuses on managing tree resources as a unit rather than on a site by site basis. USDA Forest Service studies have correlated canopy coverage greater than 45% with good and excellent water quality. (Urban Forestry Watershed Manual, 2005) Current recommendations from the USDA Forestry Service suggest a minimum canopy goal of 25% to 40% in suburban areas (greater than 25% impervious surface).

The study area was divided into 4 watershed areas-Bayou Chico (757 acres), Pensacola Bay (3,023 acres), Downtown (3,726 acres) and Bayou Texar (6,956). In 2013, average canopy coverage by watershed is 21.7%, 37.8%, 19.4% and 31.6% respectively. Both Bayou Chico and the Downtown watershed canopy coverage are less than 25%, below the minimum recommendation. For all watersheds, the greatest period of canopy change is associated with Hurricane Ivan. Bayou Texar experienced the greatest canopy loss during this time. (Figure 17) None of the watersheds have recovered to the pre-Ivan base line. The explanation for canopy not returning to base line was not addressed in the scope of this project.

Figure 17: Canopy Coverage Changes in each Watershed Over a 10 Year Period





6.4 Existing Canopy Cover 2013

Using 2013 high resolution imagery, three cover values (canopy, impervious and open space) were classified and evaluated. These values were used to analyze the City of Pensacola's existing tree cover and maximum attainable cover by land use or ownership. The urban tree canopy (UTC) analysis found the City has 4,228 acres of existing tree canopy. This corresponds to 29% of the City of Pensacola's land area. An additional 5,056 acres or 35% of Pensacola's land area is covered with grasses or other small vegetation. These areas could conceivably be covered by urban tree canopy. While it would not be desirable to cover all vegetated or open areas with tree canopy, these results indicate significant opportunities to increase Pensacola's tree canopy.

Figure 18: 2013 Pensacola's Primary Urban Cover Values. Cover values show Pensacola with 29.2% existing canopy, 30.7% impervious surfaces and 35% open space.

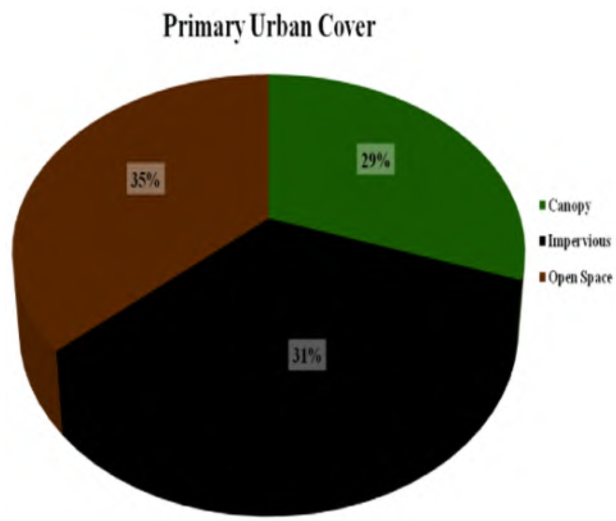
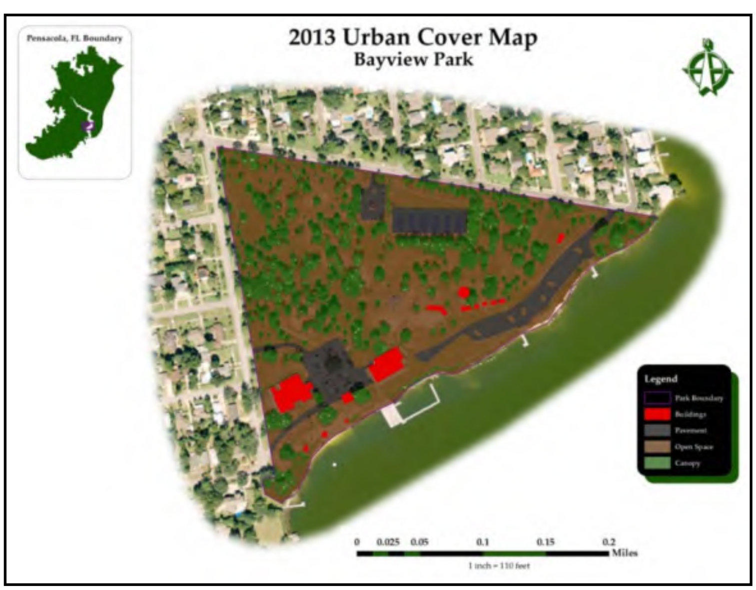
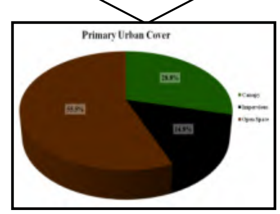


Figure 19: Example of GIS Analysis for an Individual Parcel: Analysis can be done on desired scale. Data and all support materials for analysis provided to City of Pensacola for future analysis.



Attribute	Value
Owner	City of Pensacola
Land use	Park
Acres	16
Tree Canopy	28.8%
Impervious	14.8%
Open Space	55.5%



Additional evaluations were then preformed based on objectives determined by the Environmental Advisory Board and City Staff. Evaluations included the gateway corridors (Figure 12) for potential improvement to shade and aesthetics. Additional evaluations include watersheds (Figure 17), riparian corridors and aquatic buffers (table 6) lacking adequate canopy coverage for water quality improvement and wildlife habitat utilization.

The lowest percent canopy coverage was found in the Downtown & Bayou Chico Watershed with 19.4% and 21.7% respectively. Downtown Watershed at 3,700 acres has a large commercial corridor with an overall average of 39% impervious areas with over 1,000 acres of open space. This area has the lowest tree density value with the highest impervious cover percentage for all four watersheds The City has 121 acres of open space. However, many of these areas have been recently planted. Additional planting areas may become available with retrofit or stormwater improvement projects. Bayou Chico is a 303.(d) listed impaired waterbody and represents the smallest watershed within the study area. Bayou Chico has 279 acres of open space, but only 7 acres are in City ownership.

Bayou Texar Watershed, the largest of the 4 watersheds experienced the greatest percentage of tree loss post Hurricane Ivan. The watershed has an average of 29% impervious with 32% tree canopy coverage. Analyzing a 100 foot aquatic buffer, the canopy percentage was 42.3% with over 54 acres of open space. Adequate planting spaces are afforded in this watershed. However, with over 2,000 acres of potential planting area in this watershed, only 206 acres are on City owned property. Planting in the commercial corridor of 9th Avenue and Bayou Boulevard should be considered. This area has a high percentage of impervious cover with a low percent canopy cover. Increasing the canopy and reducing impervious cover space in this high use area would not only increase aesthetic appeal but directly benefit citizens walking or waiting for a bus by reducing ambient air temperatures and providing shade during the summer.

At the request of the Environmental Advisory Board, an analysis was performed on the aquatic buffers for Maggie's Ditch, Carpenter's Creek, Graveyard Branch, Pensacola Bay, Bayou Texar and Bayou Chico. Analysis included a 100 foot buffer and a 200 foot buffer. Pensacola Bay had the least percent canopy coverage with 11.5% within the 100 foot buffer followed by Bayou Chico at 18.4% and Bayou Texar at 42.3%. The City owned property on Pensacola Bay Bluff shows opportunities to plant native vegetation in open spaces. Maintaining the appropriate native vegetative is an important component in natural areas management to reduce storm damage and prevent infiltration of exotic plants and trees.

Shading of streets has been shown to have several benefits including extending the life span of pavement, slowing traffic, reducing heat island effect, and aiding in an overall sense of well being (McPherson et al. 2005). At the request of City Staff, a comprehensive land cover value analysis was performed on Gateway Corridors within the City of Pensacola. The gateway corridor streets with less than 2% canopy coverage include East & West Cervantes Street, North & South Pace Blvd, North Palafox Street, South 9th Avenue and West Main Street. Estimated tree canopy in City owned right-of-way (ROW) is 17.9%, with an additional 10.8% in State owned ROW. With over 800 acres of ROW in City ownership, increasing canopy coverage in these areas would contribute to the overall tree canopy. The comprehensive GIS mapping and metric data has been provided to City GIS staff.

6.5 Forest Canopy Goals

Many communities measure their canopy success by setting a numerical target for their urban tree canopy percentage. A popular standard set by American Forest in is 40% with 50% of total coverage on residential property. Many communities exceed this number while other communities do not have the available planting space to reach this goal. The estimated average in the United States is 27% in urban areas and 33% in metropolitan areas. (Dwyer et al. 2000).

Table F-1. USDA, Urban Watershed Forestry Watershed Manuel, July 2005

Table F-1. Forest Canopy Goals for Metropolitan Areas	
Source	Forest Canopy Goal (% cover)
American Forests (2003)	40*
Nowak and O'Connor (2001)	30
USDA Forest Service (1993)	50

As of 2013, the City of Pensacola has an overall tree canopy of 29%. The City has significant areas of open space to substantially increase canopy percentages in right-of-ways and on City owned properties (over 1,000 acres potential planting space). As discussed, not all open or potential planting space should be planted. Significant aesthetic and environmental increases can come from properly planting the right tree in the right space and allowing enough space for each tree to reach maturity.
Planting in Pensacola is especially important, with over 50 % of Pensacola's existing tree canopy comprised of short lived and exotic trees including laurel oak, water oak, popcorn and cherry laurel trees. (Escobedo et al. 2009

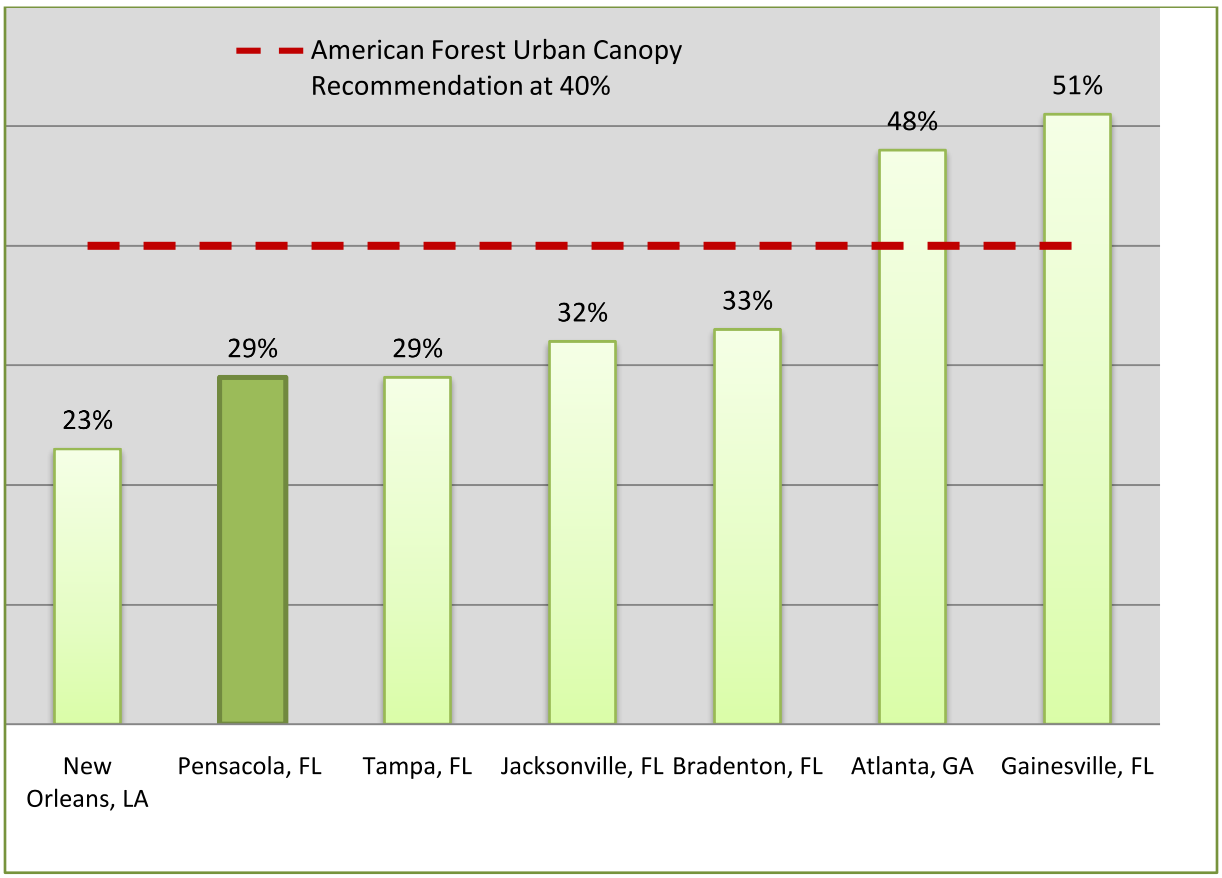
Figure 20: City of Pensacola Projected Tree Canopy

PLANTING 150 TREES/YEAR	CANOPY	TOTAL ACRES
2013	29.2%	4,228
2015	30.1%	4,290
2020	32.0%	4,634
2025	34.2%	4,940
2030	36.4%	5,267
2035	38.8%	5,474

The majority of canopy increase projected over the next 20 years will come from existing trees. Based on the geomean of trend canopy data collected, Pensacola's tree canopy has historically grown at a 1% rate annually. Projecting growth is highly subjective with many variables that cannot be accounted for including mortality, development, storm events, land use policy changes, and historic planting projects. Trees with a long life expectancy and high storm resiliency should be provided extra protection and maintenance. As an example, the southern live oak has an average life span of 350 years and represents only 5 percent of existing trees in Pensacola. However, this historically significant tree is almost 30% of the overall canopy. (Escobedo et al. 2009).

The urban tree canopy is a dynamic living resource. Maintaining this resource requires constant inputs including new plantings, maintenance and removal of dead and diseased material. A healthy urban tree canopy brings associated increases in urban tree canopy benefits (Galvin, 2006). These benefits include improving water quality, lowering ambient temperatures, saving energy, reducing noise and air pollution, increasing neighborhood desirability and quality of life, enhancing property values, providing wildlife habitat and providing aesthetic benefits.

Figure 21. Comparison of City of Pensacola Tree Canopy with Other Cities.



7.0 Recommendations

7.1. Optimizing Tree Canopy through Planting

1. **Establish measurement of success and set planting priorities**. All plantings should follow American National Standard-ANSI A300 Standard Practices for Tree Care Operations.

2. **Planting the easy areas first**. The easy areas are public owned spaces needing no or limited modifications to the site including adequate soil type and volume for minimum inputs after establishment. The easier locations have the greater chance of successful trees at a lower price. (Urban, J. 2008).

3. **Expand street tree planting by designing space for trees**. Incorporate tree species, soil properties, soil volume and drainage in initial design. Tree size is directly related to planting space, no matter the tree species. Share rooting space in continuous planting strips like in a road median. Connect tree pits to lawn area to share planting space in commercial landscape.

4. **Encourage planting on residential property** through education and street tree planting programs placing priority on neighborhoods willing to provide supplemental early tree care. Target and encourage "right tree right place" plantings in areas with lower canopy densities (Figure 7).

5. **Maintain natural areas with appropriate native specie**s though restoration plantings and removal of exotic invasive plants.

7.2 Optimizing Canopy through Maintenance and Species Diversity

6. **Conduct rotational tree assessments** addressing maintenance, planting and removal. All tree care maintenance should follow American National Standard ANSI A300 for tree care. Improving tree structure will increase wind resistance (Duryea et al. 2000) and reduce tree risk.

7. **Maintain a tree database** with tree inventory to promote tree structure improvements, mitigate risk and report maintenance concerns.

8. **Tree maintenance personnel** should have a reasonable understanding of indicators that determine risk factors affecting the health and structure of the trees.

9. **Selecting the right tree for space** and making the space right for the tree. Species should be selected by their ability to perform the desired functions and aesthetic contributions to the design. Long-term maintenance and resources for establishment period should be factored into design.

10. **Increase species diversity**, plant species that have longer average life spans and medium to high wind resistance. If possible work with local and regional nurseries to grow unique and desirable tree species not commercially available.

11. **Foster a tree education program** providing city residents with information about tree preservation policies, the benefits trees provide, and the importance of tree canopy.

7.3 Site Recommendations

Plant public owned spaces needing no or limited modifications first. The easier locations have the greater chance of successful tree establishment at a lower price. (Urban, J 2008). Listed parks have a low percent canopy with adequate space to support canopy trees with minimum maintenance after establishment. Recently planted parks including Maritime Park and Plaza De Luna have been excluded from the list. When scheduling planting projects consider removing and replacing over-mature and diseased trees (i.e. Mallory Height and Woodland Heights). The comprehensive Parks list with Urban Cover Values is in Appendix A.

Table 8: City of Pensacola Parks Listed by Watershed and Tree Coverage Value: Listed parks have less than 31% tree coverage. Recently planted parks have been excluded from the list.

DOWNTOWN WATERSHED			
PARK NAME	Percent Tree	Total Acres	Potential Planting Acres
LIONS PARK	0.40%	2.54	1.02
TERRY WAYNE EAST PARK	0.80%	2.1	0.44
MORRIS COURT PARK	1.50%	2.39	0.02
FRICKER RESOURCE CENTER	1.50%	2.39	0.02
E.S. COBB RESOURCE CENTER	4.5%	1.51	1.17
LEGION FIELD	4.60%	8.59	5.49
KIWANIS PARK	6.80%	2.34	1.2
ARMSTRONG PARK	8.30%	2.12	1.94
MALCOLM YONGE GYM	20.70%	1.37	0.85
CORINNE JONES PARK	25.1%	4.06	2.98
CORDOVA SQUARE	27.20%	2.43	1.76
BARTRAM PARK	30.20%	2.81	1.34

PENSACOLA BAY & BAYOU CHICO WATERSHED			
PARK NAME	Percent Tree	Total Acres	Open Acres
MAGEE FIELD	1.60	4.58	1.36
SCENIC HEIGHTS PARK	3.80	3.72	2.42
ALLEN PARK	7.4	1.92	1.77
BILL GREGORY PARK	17.90	7.85	3.79

Table 8: City of Pensacola Parks Listed by Watershed and Tree Coverage Value (cont.)

BAYOU TEXAR WATERSHED			
PARK NAME	Percent Tree Canopy	Total Acres	Open Acres
CATALONIA SQUARE	0.00%	2.45	1.01
PINTADO PARK	9.90%	3.72	2.59
H.K. MATTHEWS PARK	13.40%	2.52	2.14
OPERTO SQUARE	14.80%	2.44	2.06
SEMMES	15.20%	1.94	1.64
PARKER CIRCLE	15.80%	6.15	4.28
MALLORY HEIGHTS	18.00%	3.4	1.65
ZAMORA SQUARE	19.10%	2.37	1.48
MIRALLA PARK	23.50%	4.31	2.26
ANDALUSIA SQUARE	23.50%	2.45	1.86
ESTRAMADURA	23.70%	2.43	1.84
GRANADA SQUARE	25.00%	2.33	1.72
MIRAFLORES PARK	25.60%	2.54	1.83
SPRINGDALE PARK	26.90%	5	2.65
BAYVIEW PARK	28.80%	28.92	16.05
TOLEDO SQUARE	29.20%	2.37	1.65
MALLORY HEIGHTS	31.10%	5.99	1.53
WOODLAND HEIGHTS	31.20%	2.62	1.58

Expand Street Tree Planting

- Incorporate tree species, soil volume and drainage in the initial street design. Tree size is directly related to planting space, no matter the tree species.
- Target street tree planting projects in residential areas where residents agree to aide in establishing the tree. For easier establishment, plan planting project during winter months.

Planting Gateway Corridors

- Incorporate space for trees into initial design in new construction, redevelopment and retrofit projects.
- Project construction plans should show specific and enforceable requirements for vegetative plantings.

Table 9: Gateway Corridor Planting Areas Listed from Least to Highest Tree Canopy Percent

GATEWAY CORRIDOR PLANTING				
STREET NAME	Acres	Existing Canopy	Impervious Cover	Open Space
N Pace Blvd	6.20	0.3%	81.8%	18.1%
N Palafox St	9.16	0.6%	75.6%	24.1%
S Pace Blvd	8.16	0.7%	76.3%	20.5%
W Cervantes St	16.99	1.2%	85.6%	13.8%
S 9th Ave	7.73	1.8%	70.2%	28.9%
W Main St	16.09	2.0%	65.5%	17.8%
E Cervantes St	22.47	2.0%	76.7%	21.4%
E Fairfield Dr	39.03	3.6%	52.3%	44.3%
Barrancas Ave	25.16	3.8%	50.1%	25.5%
Bay Front Pkwy	26.13	4.6%	42.3%	49.4%
W Navy Blvd	23.16	5.3%	52.3%	39.5%
W Garden St	22.84	5.4%	68.3%	26.8%
E Garden St	5.88	6.4%	66.3%	27.6%
N 9th Ave	68.93	7.9%	62.8%	31.5%
S Palafox St	15.14	8.0%	62.7%	31.6%
Langley Ave	25.65	8.1%	53.8%	38.9%
Creighton Rd	20.26	13.1%	78.8%	40.3%
Summit Blvd	32.91	15.1%	49.5%	38.6%
N 12th Ave	48.20	16.1%	51.9%	34.3%
S 12th Ave	4.15	16.4%	44.0%	42.3%
S 17th Ave	6.18	20.6%	46.1%	32.3%
N 17th Ave	14.83	23.8%	42.7%	37.9%
Scenic Hwy	64.43	26.6%	37.6%	36.1%

Street Tree Planting Design

- Design should include plant quality, species, size, installation procedures, water requirements, any soil amendments, placement and type of mulch. Warranty period and maintenance (if applicable) should be clearly stated with specific criteria on tree replacement. There is direct ratio between mature tree size and available soil space.

- Planting distance from hardscape depends on species. Allow room for stabilizing trunk expansion. Use root barriers if necessary to protect hardscape.

- Provide adequate soil volume while matching species to the site. Tree size is directly related to planting space, no matter the tree species.

- When space is available, plant larger species. Larger species provide a significantly greater value to the community. (Appendix D)

Incorporate Tree Design to Aide in Mitigating Stormwater Runoff.

- Use structural soil and pavement structural support systems. Structural soils are highly porous and engineered aggregate mixes designed to support tree growth and serve as sub-base for pavement. Structural soils are typically composed of 70% to 80% angular gravel and 20% to 30% clay loam soil and a small amount of hydrogel (~3%) to prevent separation during mixing. Structural soils have 20% to 25% void space which supports root growth and accommodates stormwater runoff. These soils can be compacted to meet load bearing requirements for sidewalks or roadways while preserving porosity and permeability.

- Interconnecting stormwater storage systems can reduce peak flows and reduce overall volume of runoff. Consult engineers and landscape architects for design of connecting these contiguous areas with other green and grey infrastructure. Consult and municipal arborist for choosing tree species and other plantings that will perform well for the given system design.

- Bioswales can be used to retain stormwater over multiple sites rather than collecting runoff at one centralized location.

- Trees and structural soils combined can create a zero runoff site. (Day, S. D., and Dickinson (eds.) 2008). A stormwater engineer can determine the quantity of water that the system will need and whether to link systems and use overflow piping. Municipal Arborists, Urban Foresters and other qualified plant professionals should be consulted during the design process for choosing tree species and other plantings that will perform well for the given system design.

7.3 Tree Placement and Installation

The installation of plants in appropriate locations is essential to their long-term survival. Locations should match mature plant size to available soil volume and other conditions for growth. Provide appropriate separation from lights, signs, utilities and hardscapes including pavement, sidewalks and structures.

Minimum Tree Spacing

Each new tree should be planted allowing for expansion of trunk and stabilizing root plate. Planting should be at center of a minimum pervious rooting area clear of obstructions to allow growth to maturity. Unless root barriers or other site modifications are used, minimum recommended distances are as follows:

- Understory Tree: planted no closer than 4 feet from an existing hardscape or 8 feet from another understory tree.
- Canopy Tree: planted no closer than 8 feet from a hardscape or 15 feet from another canopy tree.
- Consider planting trees in groups with alternating centers. Group planting can improve the trees wind resistance, reduce competing vegetation through shading, and reduce mowing zones.

Installation

- Grade recommendation is Florida Grade#1 or better according to "Grades and Standards for Nursery Plants" by Florida Department of Agricultural and Consumer Services (Appendix B)
- For planting Ball & Burlap trees, remove all synthetic material and cut basket 6" below shoulder of root ball before back filling
- For future stability of the tree, avoid planting any trees that have circling roots.
- Backfill tree planting hole with appropriate native soil. Construction backfill or heavy clay soil should not be used.
- Thoroughly water tree immediately after planting. Apply water by hose directly to the root ball and the adjacent soil
- Water regime should be applied at rate to allow infiltration directly onto the root ball.
- Stake appropriately only if necessary. All staking materials should be removed no later than one year.
- No mulch should be placed next to trunk and only lightly over root ball until established.

Planting Detail: By Edward Gilman, Department of Horticulture University of Florida

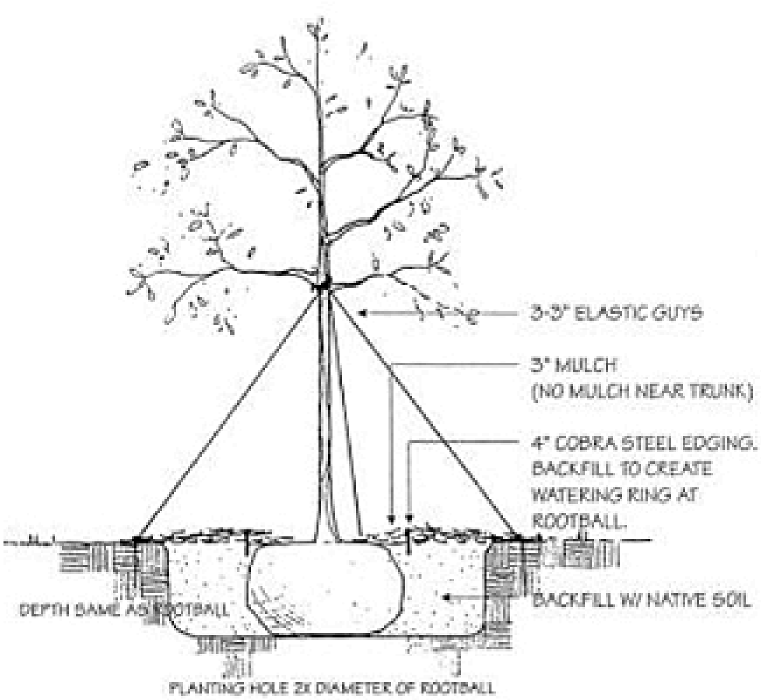
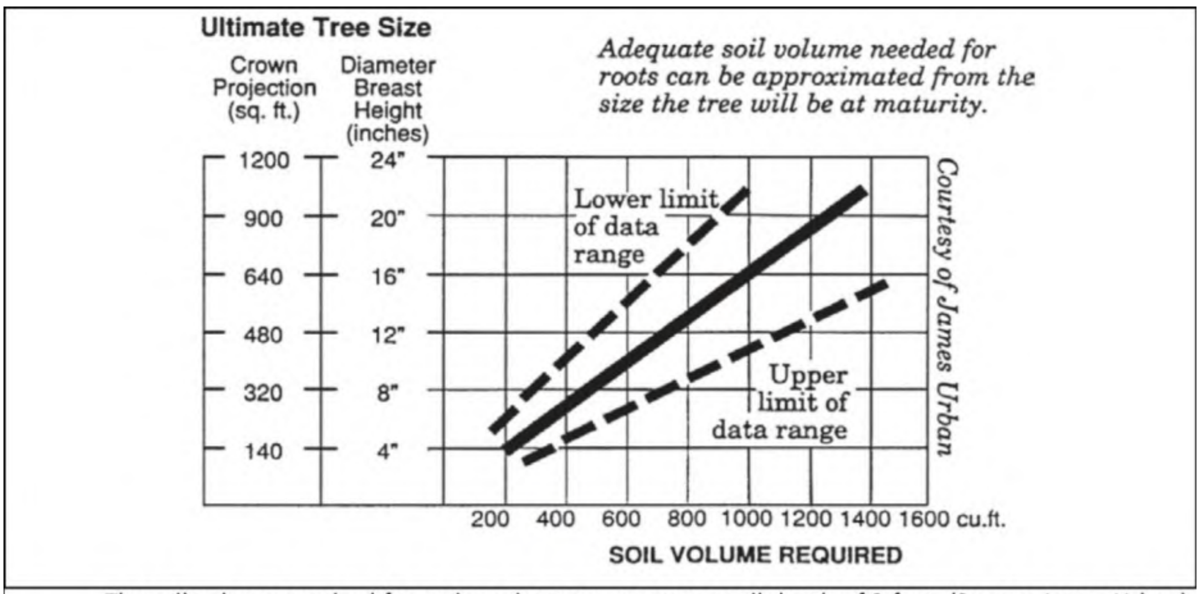


Figure 22: Recommended Irrigation Schedule, University of Florida

Irrigation Regimen for Tree Establishment		
Size of Nursery Stock	Irrigation for Vigor	Irrigation for Survival
< 2 inch caliper	Daily for 2 weeks; every other day for 2 months; weekly until established	Twice weekly for 2-3 months
2-4 inch caliper	Daily for 1 month; every other day for 3 months; weekly until established.	Twice weekly for 3-4 months
➢ **4 inch caliper**	Daily for 6 weeks; every other day for 5 months; weekly until established	Twice weekly for 4-5 months
Apply 2-3 gallons per inch trunk caliper over the root ball only.		

Soil Volume
Soil Volume should be appropriate for species to reach maturity. Trees will only grow as large as the space allows, no matter what the species.

Figure 23: Soil Volume to Tree Growth Calculations



The soil volume required for various size trees assumes a soil depth of 3 feet. (Source: James Urban)

Figure 24: Recommended Canopy Species for Parks

NATIVE CANOPY SPECIES APPROPRIATE FOR CITY PARKS PLANTING More than 25 feet at maturity		
Common Name **Scientific Name**	**Deciduous/ Evergreen**	**Use Considerations**
River birch ***Betula nigra***	deciduous	med drought tolerance, med-high wind resistance, low salt tolerance, suitable for wet sites
Green Ash ***Fraxinus pennsylvanica***	deciduous	Tolerates wet conditions, Good for shaded areas, med-low wind resistance
Eastern red cedar ***Juniperus virginiana***	evergreen	high drought tolerance susceptible to breakage, good for screening
Sweet gum ***Liquidambar styraciflua***	deciduous	med drought tolerance med-high wind resistance, 1-3" round fruit in fall, not for use close to hardscapes
Southern magnolia ***Magnolia grandiflora***	evergreen	med drought tolerance, high wind resistance high salt tolerance
Eastern hophornbean ***Ostrya virginiana***	evergreen	high drought tolerance, med-high wind resistance low-no salt tolerance
Sycamore ***Plantanus occidentalis***	deciduous	high drought tolerance med-low wind resistance urban tolerant
White oak ***Quercus alba***	deciduous	med-high drought tolerance, med-high wind resistance, high salt tolerance
Southern red oak ***Quercus falcata***	deciduous	high drought tolerance, low wind resistance med salt tolerance
Overcup oak ***Quercus lyrata***	deciduous	med drought tolerance, breakage resistant low-no salt tolerance
Nuttall oak ***Quercus nuttallii***	deciduous	med drought tolerance breakage resistant low-no salt tolerance, urban tolerant
Shumard oak ***Quercus shumardii***	deciduous	high drought tolerance breakage resistant med salt tolerance, urban tolerant
Live oak ***Quercus virginiana***	evergreen	high drought tolerance, high wind resistance high salt tolerance, urban tolerant
Pond cypress ***Taxodium ascendens***	deciduous	high drought tolerance, high wind resistance med salt tolerance, ideal for wet locations
Bald cypress ***Taxodium distichum***	deciduous	high drought tolerance, high wind resistance low-no med salt tolerance, urban tolerant
Winged elm ***Ulmus alata***	deciduous	high drought tolerance med-high wind resistance, med salt tolerance, urban tolerant
American elm ***Ulmus americana***	deciduous	high drought tolerance, med-low wind resistance, sensitive to pests/diseases urban tolerant

NATIVE UNDERSTORY TREES APPROPRIATE FOR CITY PARKS PLANTING Less than 25 feet at maturity		
Common name Scientific Name	**Deciduous/ Evergreen**	**Use Considerations**
Red buckeye *Aesculus pavia*	deciduous	med drought tolerance breakage resistant med salt tolerance, shade-part shade
American hornbeam *Carpinus caroliniana*	deciduous	med drought tolerance, med-high wind resistance, no salt tolerance
Eastern redbud *Cercis canadensis*	deciduous	high drought tolerance, med-high wind resistance, no salt tolerance
Fringe tree *Chionanthus virginicus*	deciduous	med drought tolerance, med-high wind resistance, no salt tolerance
Loquat *Eriobotrya japonica*	evergreen	med drought tolerance, med-low wind resistance, urban tolerant, fruit can be messy, wildlife value
Dahoon holly *Ilex cassine*	evergreen	med drought tolerance, high wind resistance med salt tolerance, urban tolerant, wildlife value
Yaupon holly *Ilex vomitoria*	evergreen	high drought tolerance, high wind resistance, high salt tolerance, urban tolerant, wildlife value
Star Anise *Illicium*	evergreen	med drought tolerance, low-no salt tolerance, tolerates wet or dry sites
Waxmyrtle *Myrica cerifera*	evergreen	native med drought tolerance, med-low wind resistance high salt tolerance
Sparkleberry *Vaccinium arboreum*	deciduous	high wind resistance, wildlife value

CITY PROPERTY WITHIN 100 FEET OF MEDIAN HIGH WATER				
Water Body	**Acres**	**Canopy**	**Impervious**	**Open Space**
Pensacola Bay	**156.37**	**21.2%**	**30.9%**	**39.2%**
Bayou Texar	**59.59**	**33.1%**	**13.2%**	**53.3%**
Bayou Chico	**.22**	**51.5%**	**0.0%**	**39.0%**
Carpenters Creek	**10.59**	**41.8%**	**1.1%**	**4.7%**
Other Streams	**8.22**	**67.5%**	**.4%**	**25.9%**
Graveyard Branch	**.33**	**48.5%**	**0.0%**	**5.1%**

8.0 References

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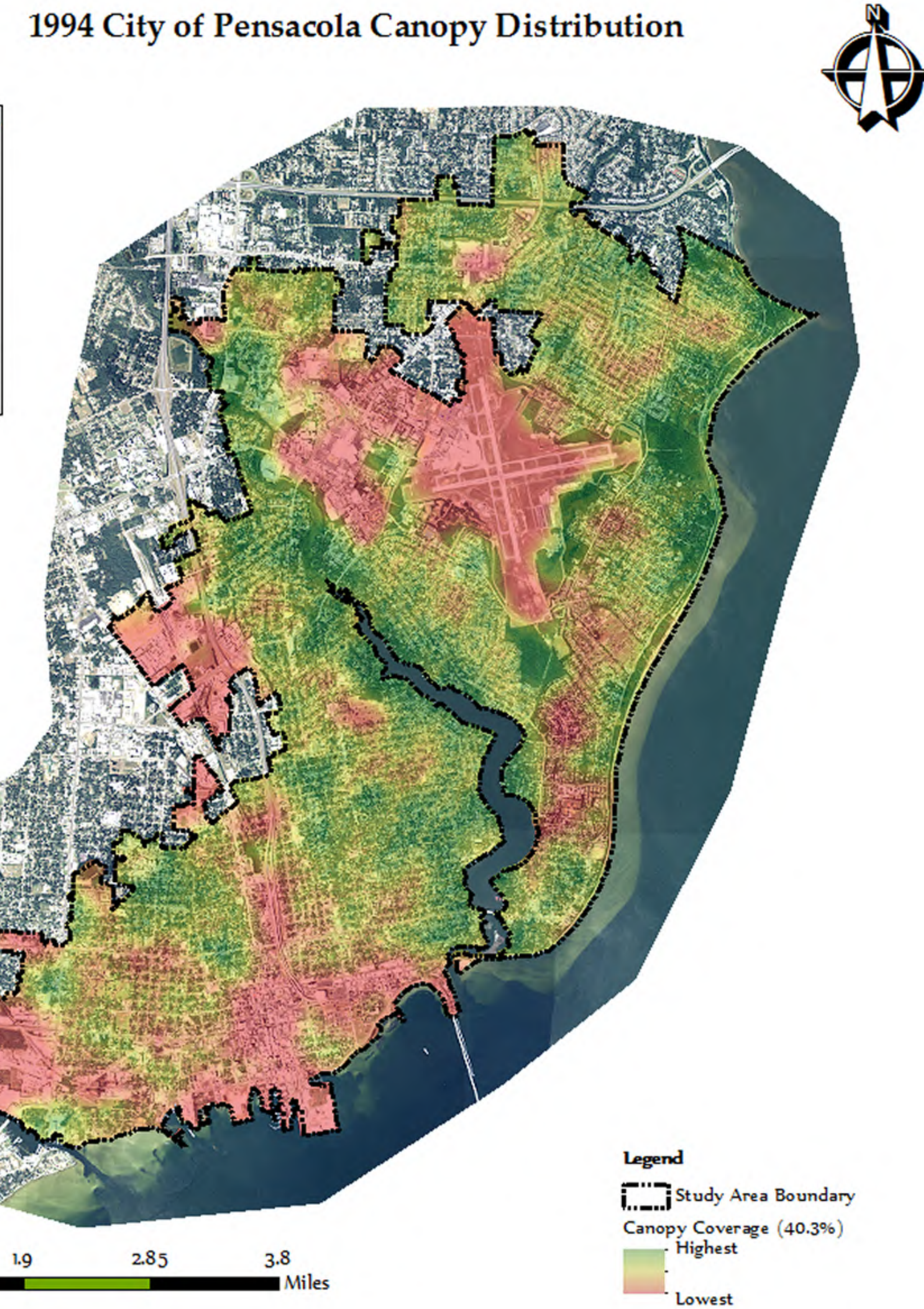
1994 City of Pensacola Canopy Distribution

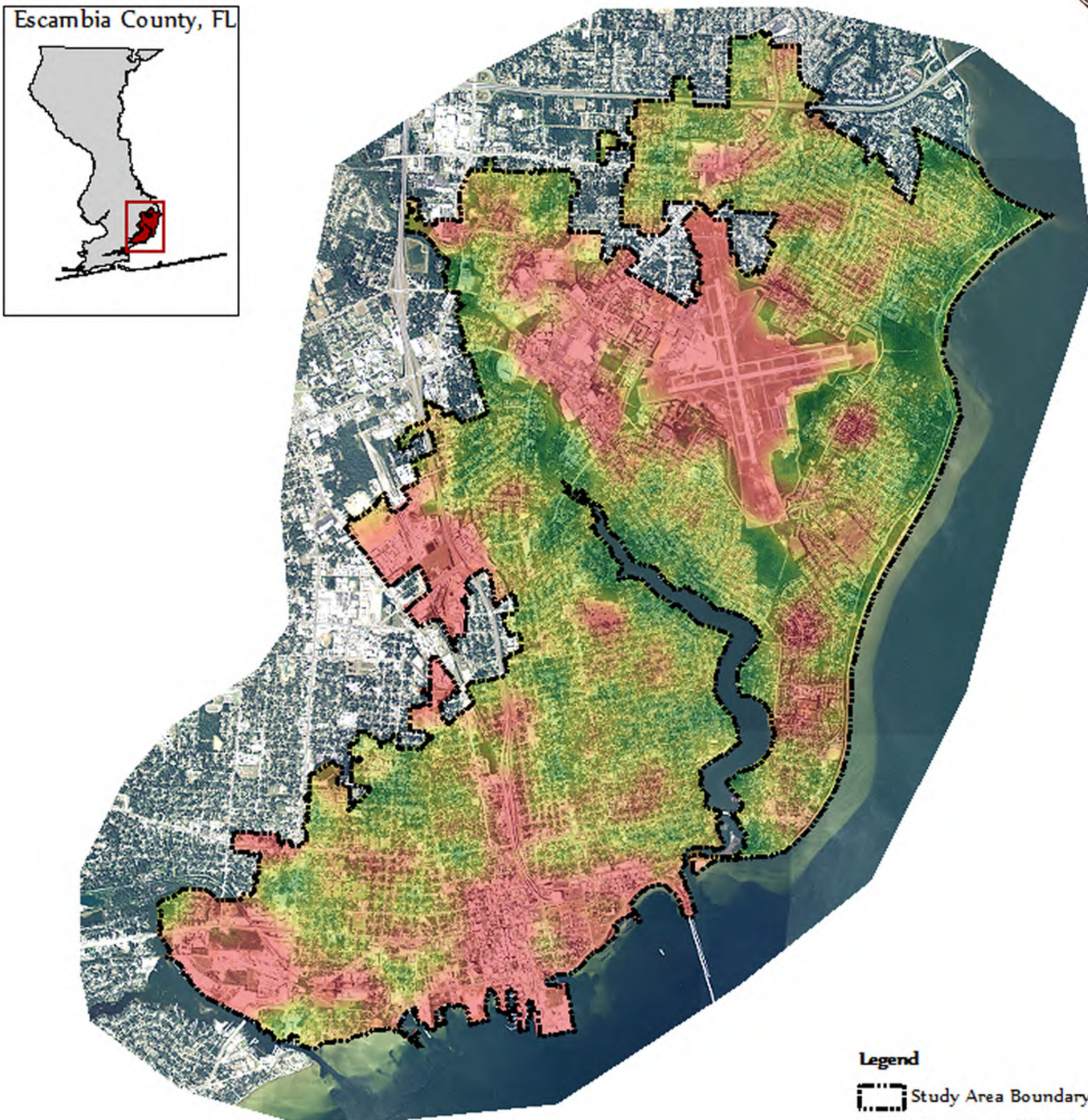


*Canopy coverage map generated through a kriging interpolation function of 6,515 random sample points visually classified with aerial orthophotos taken on 01/94.

Map created 1/16/2014

Data Sources: Escambia County, DOT, USDA, City of Pensacola

1999 City of Pensacola Canopy Distribution



0 0.475 0.95 1.9 2.85 3.8 Miles

Legend

Study Area Boundary

Canopy Coverage (37.7%)

Highest

Lowest

*Canopy coverage map generated through a kriging interpolation function of 6,515 random sample points visually classified with aerial orthophotos taken on 01/99.

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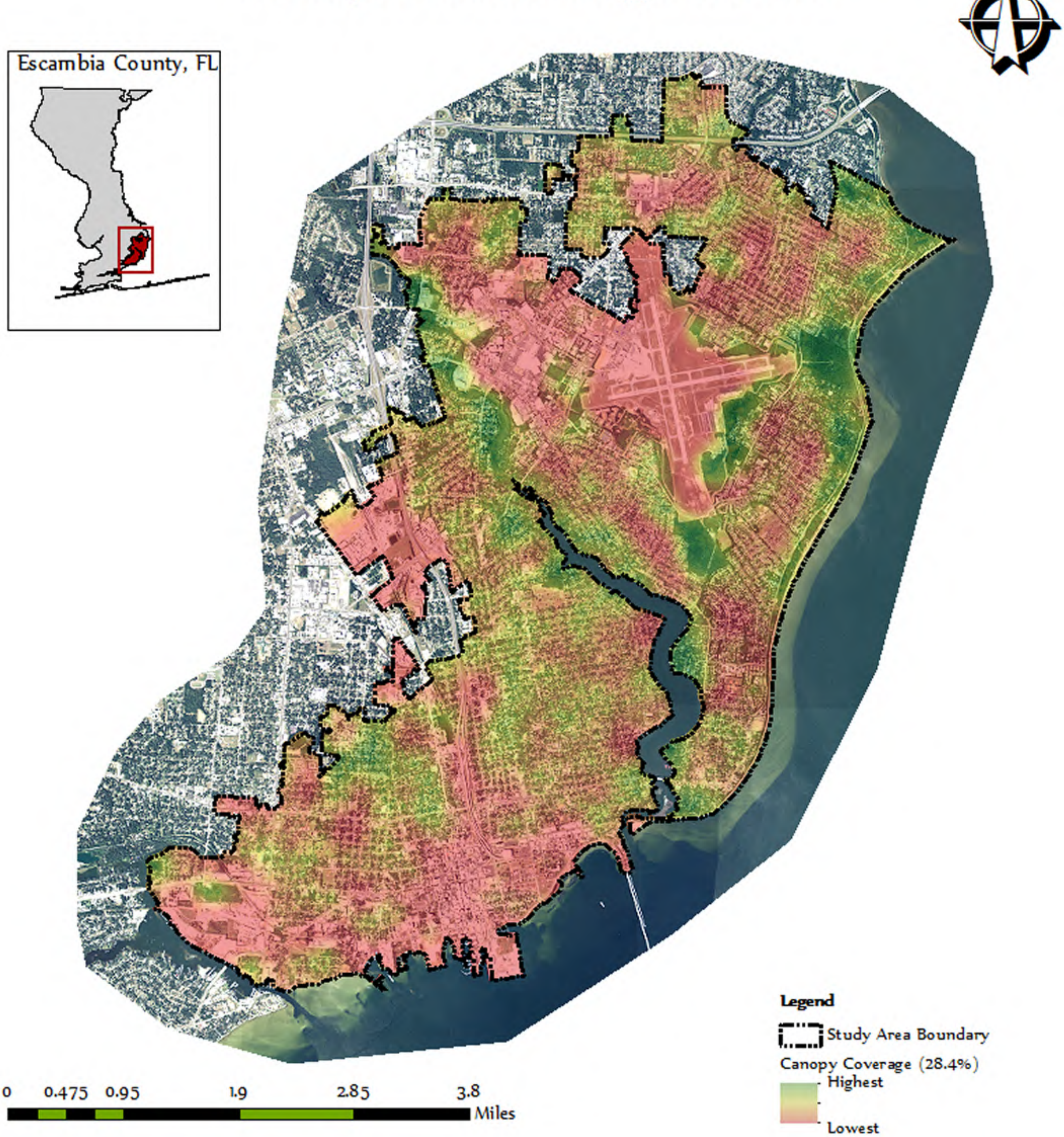
myescambia

Map created 1/16/2014

Data Sources: Escambia County, DOT, USDA, City of Pensacola

2004 City of Pensacola Canopy Distribution



*Canopy coverage map generated through a kriging interpolation function of 6,515 random sample points visually classified with aerial orthophotos taken on 12/04.

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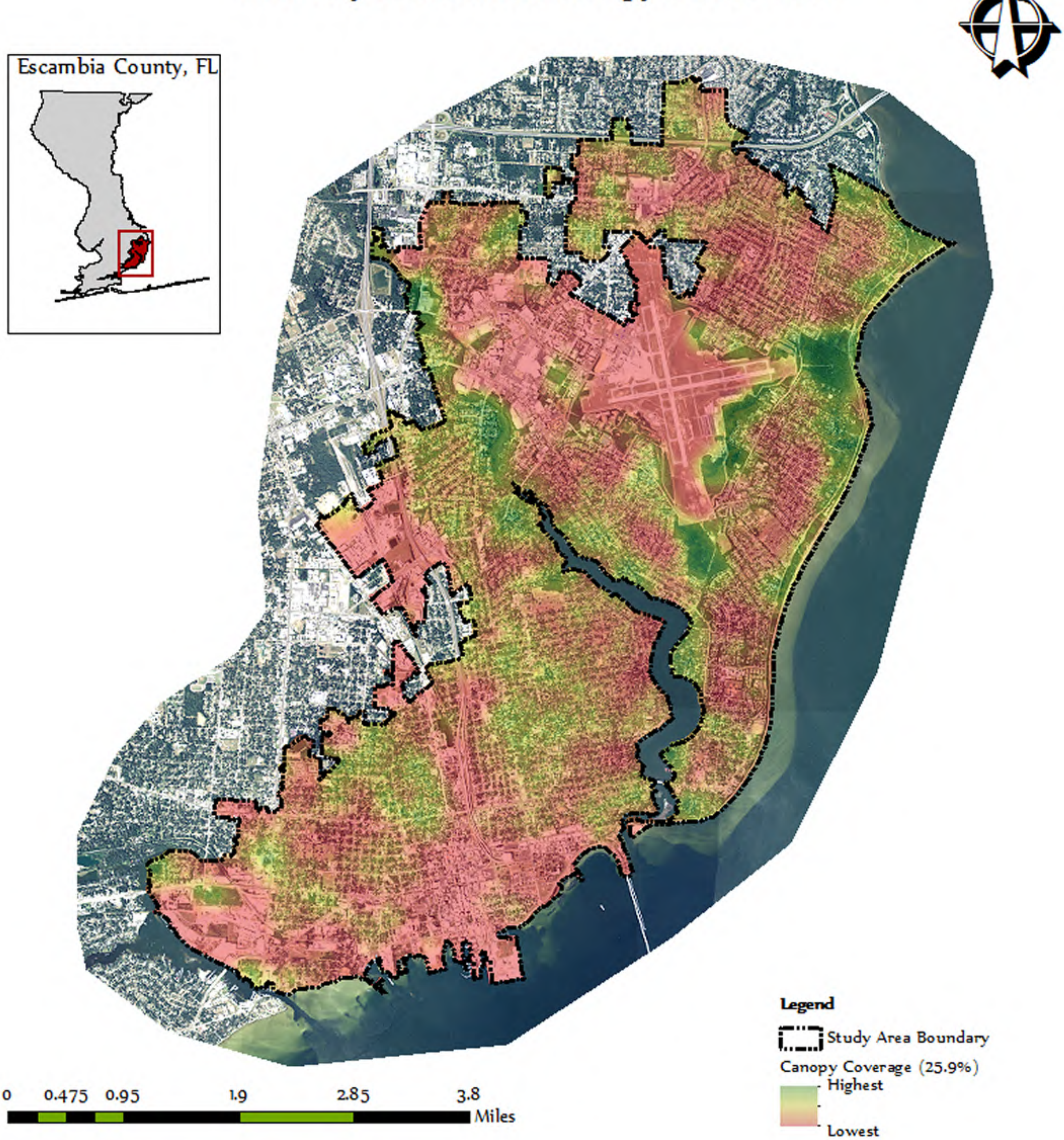
my escambia

Map created 1/16/2014

Data Sources: Escambia County, DOT, USDA, City of Pensacola

2007 City of Pensacola Canopy Distribution



*Canopy coverage map generated through a kriging interpolation function of 6,515 random sample points visually classified with aerial orthophotos taken on 04/07.

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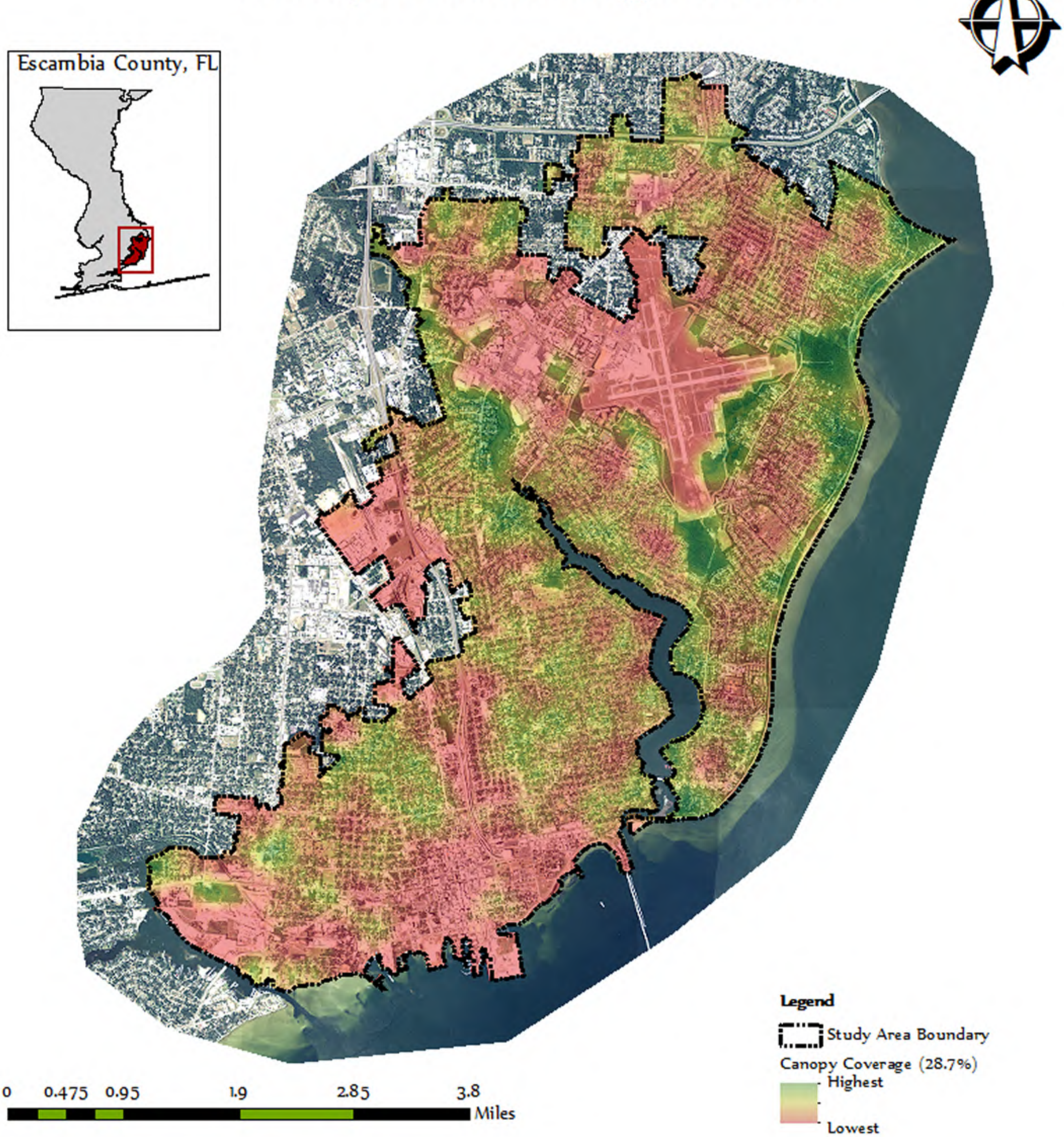
Map created 1/16/2014

Data Sources: Escambia County, DOT, USDA, City of Pensacola

2010 City of Pensacola Canopy Distribution



*Canopy coverage map generated through a kriging interpolation function of 6,515 random sample points visually classified with aerial orthophotos taken on 01/10.

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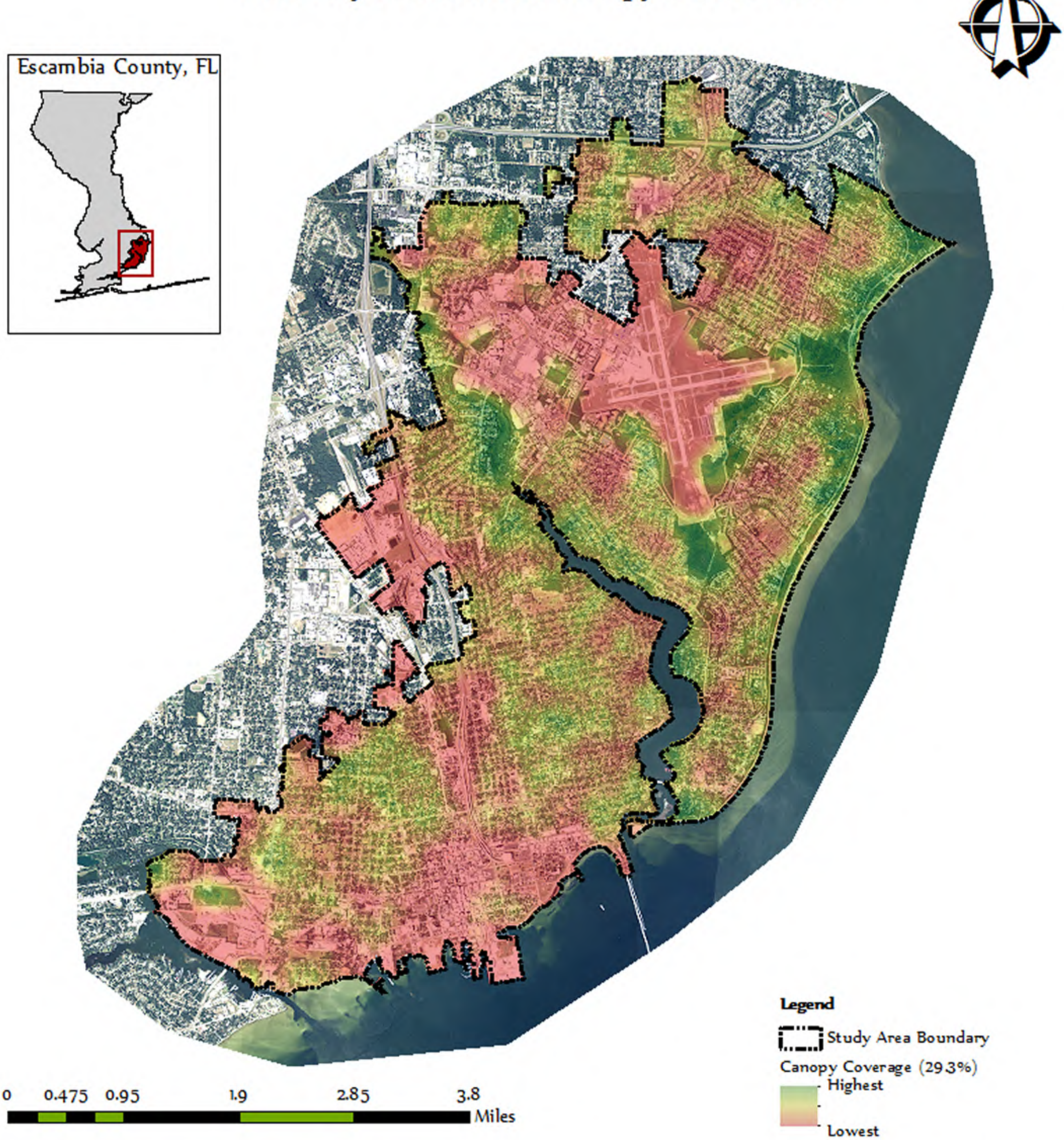
Map created 1/16/2014

Data Sources: Escambia County, DOT, USDA, City of Pensacola

2013 City of Pensacola Canopy Distribution



*Canopy coverage map generated through a kriging interpolation function of 6,515 random sample points visually classified with aerial orthophotos taken on 03/13.

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myescambia

Map created 1/16/2014

Data Sources: Escambia County, DOT, USDA, City of Pensacola

Area of Interest	Canopy	Impervious	Open Space	Total Acres	Canopy Acres	Impervious Acres	Open Acres
Study Area (City Limits)	29.2%	30.7%	35.0%	14462.21	4228.17	4444.31	5056.17
Pensacola Bay Watershed	37.8%	23.6%	34.4%	3022.84	1142.03	712.79	1039.06
Bayou Texar Watershed	31.6%	28.7%	32.5%	6955.66	2197.65	1994.42	2262.93
Downtown Watershed	19.4%	39.3%	39.6%	3726.47	722.96	1463.39	1475.43
Bayou Chico Watershed	21.7%	35.8%	36.8%	757.18	164.15	271.30	278.75
City Owned Pensacola Bay Watershed	49.2%	9.4%	18.0%	475.67	233.86	44.77	85.41
City Owned Bayou Texar Watershed	22.0%	22.3%	15.2%	1357.84	299.25	303.02	206.37
City Owned Downtown Watershed	10.7%	32.6%	44.5%	273.40	29.37	89.13	121.53
City Owned Bayou Chico Watershed	18.9%	12.4%	51.2%	12.81	2.42	1.59	6.56
South Delineation	18.6%	39.8%	39.2%	2711.49	503.62	1077.90	1061.82
Central Delineation	30.2%	30.6%	38.9%	4122.11	1243.71	1263.31	1604.55
North Delineation	32.4%	27.5%	31.2%	7634.93	2476.22	2099.19	2381.76
DOR Residential Land Use	42.2%	20.0%	38.6%	6095.54	2572.10	1216.42	2355.66
DOR Commercial Land Use	19.2%	47.7%	32.6%	1868.40	359.12	891.06	609.50
DOR Industrial Land Use	8.1%	60.2%	27.2%	291.90	23.69	175.71	79.39
DOR Institutional Land Use	21.1%	30.7%	47.9%	558.17	117.86	171.21	267.46
DOR Government Land Use	25.4%	21.6%	22.2%	2185.60	554.15	472.22	485.76
DOR Other Land Use	17.8%	26.4%	32.0%	424.73	75.65	112.24	136.09
City Owned Property	26.6%	20.7%	19.8%	2119.71	564.90	438.51	419.87
City Owned Property (excluding runway)	42.2%	16.7%	31.4%	1337.48	564.90	223.00	419.87
City Owned Parks	38.5%	3.0%	45.4%	273.35	105.33	8.31	124.05
City Owned Schools	10.2%	35.1%	56.9%	0.18	0.02	0.06	0.10
Non-City Govt. Owned Property	14.5%	34.9%	43.6%	664.79	96.71	232.06	289.70
Non-City Govt. Owned Parks	45.3%	2.2%	37.0%	37.34	16.90	0.84	13.83
Non-City Govt. Owned Schools	10.2%	40.2%	41.9%	351.14	35.80	141.12	147.25
Public Property (City & Non-City Govt.)	23.8%	24.1%	25.5%	2784.51	661.61	670.56	709.57
Private Commercial Property	19.0%	49.7%	31.0%	1653.81	315.01	822.25	513.03
Private Residential Property	42.3%	20.1%	38.5%	6004.23	2542.38	1205.27	2310.09
Maggie's Ditch 50ft. Aquatic Buffer	56.5%	3.6%	25.1%	3.84	2.17	0.14	0.96
Capenters Creek 50ft. Aquatic Buffer	79.8%	3.1%	10.7%	68.18	54.40	2.12	7.33
Other Streams 50ft. Aquatic Buffer	80.6%	2.8%	8.1%	3.59	2.90	0.10	0.29

Graveyard Branch 50ft. Aquatic Buffer	74.7%	0.2%	4.9%	4.89	3.65	0.01	0.24
Maggie's Ditch 100ft. Aquatic Buffer	42.6%	8.0%	31.8%	7.95	3.39	0.64	2.53
Capenters Creek 100ft. Aquatic Buffer	74.2%	5.4%	13.3%	112.09	83.15	6.11	14.88
Other Streams 100ft. Aquatic Buffer	80.6%	4.0%	8.7%	7.34	5.92	0.29	0.64
Graveyard Branch 100ft. Aquatic Buffer	70.8%	5.3%	11.0%	10.23	7.24	0.54	1.12
Pensacola Bay 100ft. Aquatic Buffer	11.5%	16.8%	44.1%	167.02	19.22	28.05	73.64
Bayou Texar 100ft. Aquatic Buffer	42.3%	6.0%	46.9%	115.74	48.99	6.98	54.30
Bayou Chico 100ft. Aquatic Buffer	18.4%	38.6%	38.6%	30.79	5.65	11.90	11.88
Maggie's Ditch 200ft. Aquatic Buffer	33.6%	15.2%	36.2%	16.94	5.69	2.57	6.14
Capenters Creek 200ft. Aquatic Buffer	63.4%	12.4%	17.6%	192.47	121.97	23.93	33.90
Other Streams 200ft. Aquatic Buffer	75.4%	5.1%	12.8%	15.35	11.57	0.79	1.97
Graveyard Branch 200ft. Aquatic Buffer	59.2%	13.0%	20.9%	21.69	12.85	2.81	4.54
State Right of Way	10.8%	56.7%	33.0%	556.83	60.00	315.98	183.58
City Right of Way	17.9%	46.6%	38.9%	2274.57	407.21	1060.79	884.81
Gateway Right of Way	10.4%	56.5%	33.6%	522.15	54.07	295.18	175.46
Barrancas Ave Gateway Right of Way	3.8%	50.1%	25.5%	25.16	0.94	12.61	6.41
Bay Front Pkwy Gateway Right of Way	4.6%	42.3%	49.4%	26.13	1.20	11.07	12.91
Creighton Rd Gateway Right of Way	13.1%	78.8%	40.3%	20.26	2.64	15.96	8.16
E Cervantes St Gateway Right of Way	2.0%	76.7%	21.4%	22.47	0.46	17.24	4.81
E Fairfield Dr Gateway Right of Way	3.6%	52.3%	44.3%	39.03	1.41	20.43	17.30
E Garden St Gateway Right of Way	6.4%	66.3%	27.6%	5.88	0.38	3.90	1.62
Langley Ave Gateway Right of Way	8.1%	53.8%	38.9%	25.65	2.09	13.81	9.98
N 12th Ave Gateway Right of Way	16.1%	51.9%	34.3%	48.20	7.74	25.00	16.51
N 17th Ave Gateway Right of Way	23.8%	42.7%	37.9%	14.83	3.53	6.33	5.62
N 9th Ave Gateway Right of Way	7.9%	62.8%	31.5%	68.93	5.45	43.30	21.73
N Pace Blvd Gateway Right of Way	0.3%	81.8%	18.1%	6.20	0.02	5.08	1.13
N Palafox St Gateway Right of Way	0.6%	75.6%	24.1%	9.16	0.05	6.92	2.21
S 12th Ave Gateway Right of Way	16.4%	44.0%	42.3%	4.15	0.68	1.83	1.76
S 17th Ave Gateway Right of Way	20.6%	46.1%	32.3%	6.18	1.27	2.85	1.99
S 9th Ave Gateway Right of Way	1.8%	70.2%	28.9%	7.73	0.14	5.43	2.23
S Pace Blvd Gateway Right of Way	0.7%	76.3%	20.5%	8.16	0.06	6.23	1.67
S Palafox St Gateway Right of Way	8.0%	62.7%	31.6%	15.14	1.21	9.50	4.78
Scenic Hwy Gateway Right of Way	26.6%	37.6%	36.1%	64.43	17.14	24.25	23.29

Summit Blvd Gateway Right of Way	15.1%	49.5%	38.6%	32.91	4.98	16.29	12.71
W Cervantes St Gateway Right of Way	1.2%	85.6%	13.8%	16.99	0.20	14.54	2.34
W Garden St Gateway Right of Way	5.4%	68.3%	26.8%	22.84	1.23	15.60	6.12
W Main St Gateway Right of Way	2.0%	65.5%	17.8%	16.09	0.32	10.54	2.87
W Navy Blvd Gateway Right of Way	5.3%	52.3%	39.5%	23.16	1.23	12.11	9.15
50ft. City Property Barrancas Ave	0.0%	0.0%	100.0%	0.06	0.00	0.00	0.06
50ft. City Property Bay Front Pkwy	11.9%	19.6%	60.4%	3.83	0.45	0.75	2.31
50ft. City Property Creighton Rd	26.2%	40.3%	36.8%	0.37	0.10	0.15	0.14
50ft. City Property E Cervantes St	34.8%	9.2%	58.7%	2.00	0.70	0.18	1.17
50ft. City Property E Garden St	2.5%	71.5%	27.4%	0.18	0.00	0.13	0.05
50ft. City Property Langley Ave	14.2%	8.4%	56.5%	5.83	0.83	0.49	3.29
50ft. City Property N 12th Ave	37.2%	9.1%	44.1%	8.35	3.10	0.76	3.68
50ft. City Property N 17th Ave	20.8%	0.0%	78.3%	0.61	0.13	0.00	0.48
50ft. City Property N 9th Ave	34.0%	16.0%	54.7%	0.73	0.25	0.12	0.40
50ft. City Property N Pace Blvd	0.0%	35.6%	64.4%	0.17	0.00	0.06	0.11
50ft. City Property N Palafox St	42.5%	0.2%	55.7%	0.69	0.29	0.00	0.38
50ft. City Property S 12th Ave	0.1%	12.9%	67.3%	0.32	0.00	0.04	0.21
50ft. City Property S 17th Ave	16.0%	16.6%	63.4%	1.37	0.22	0.23	0.87
50ft. City Property S 9th Ave	3.3%	17.4%	79.6%	1.49	0.05	0.26	1.19
50ft. City Property S Palafox St	38.0%	39.3%	23.8%	3.23	1.23	1.27	0.77
50ft. City Property Scenic Hwy	65.0%	4.6%	28.5%	13.02	8.46	0.60	3.71
50ft. City Property Summit Blvd	34.9%	5.1%	59.3%	9.06	3.16	0.46	5.37
50ft. City Property W Garden St	8.7%	57.3%	36.3%	0.22	0.02	0.13	0.08
50ft. City Property W Main St	5.5%	35.5%	56.2%	3.60	0.20	1.28	2.02
50ft. City Property W Navy Blvd	8.5%	48.7%	34.6%	0.83	0.07	0.40	0.29
Maggie's Ditch 100ft. City Property	N/A	N/A	N/A	0.00	0.00	0.00	0.00
Capenters Creek 100ft. City Property	41.8%	1.1%	4.7%	10.59	4.43	0.11	0.50
Other Streams 100ft. City Property	67.5%	0.4%	25.9%	8.22	5.55	0.03	2.13
Graveyard Branch 100ft. City Property	48.5%	0.0%	5.1%	0.33	0.16	0.00	0.02
Pensacola Bay 100ft. City Property	21.2%	30.9%	39.2%	156.37	33.10	48.36	61.31
Bayou Texar 100ft. City Property	33.1%	13.2%	53.3%	59.59	19.70	7.88	31.74
Bayou Chico 100ft. City Property	51.5%	0.0%	39.0%	0.22	0.11	0.00	0.09

Land Use	Acres	Canopy	Impervious	Open Space
Residential	6095.54	42.2%	20.0%	38.6%
Commercial	1868.40	19.2%	47.7%	32.6%
Industrial	291.90	8.1%	60.2%	27.2%
Institutional	558.17	21.1%	30.7%	47.9%
Government	2185.60	25.4%	21.6%	22.2%
Other	424.73	17.8%	26.4%	32.0%

Table 1: Current (2013) urban cover metrics for Department of Revenue land use types within the City of Pensacola.

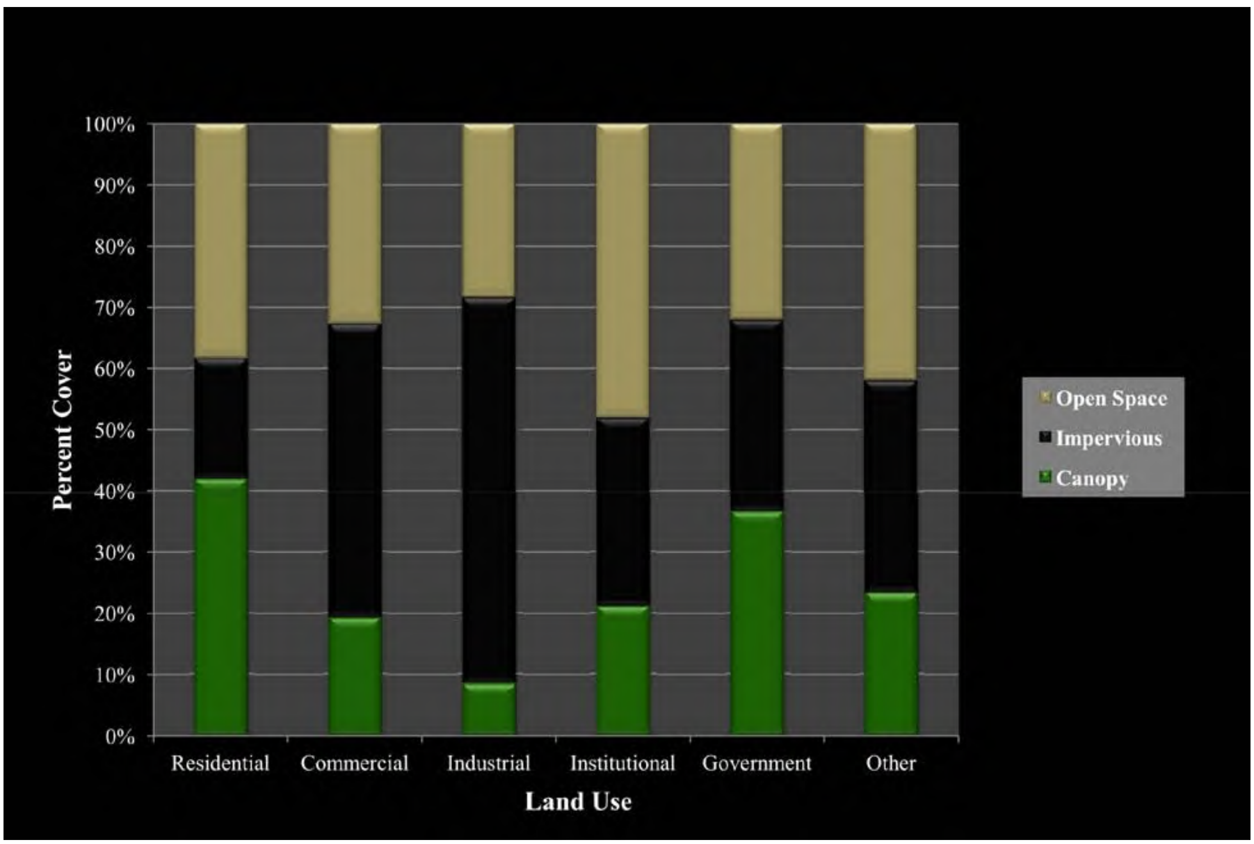


Figure 3: Visualizing Table 1 data, primary urban cover values are compared within each of the City of Pensacola's six land use types.

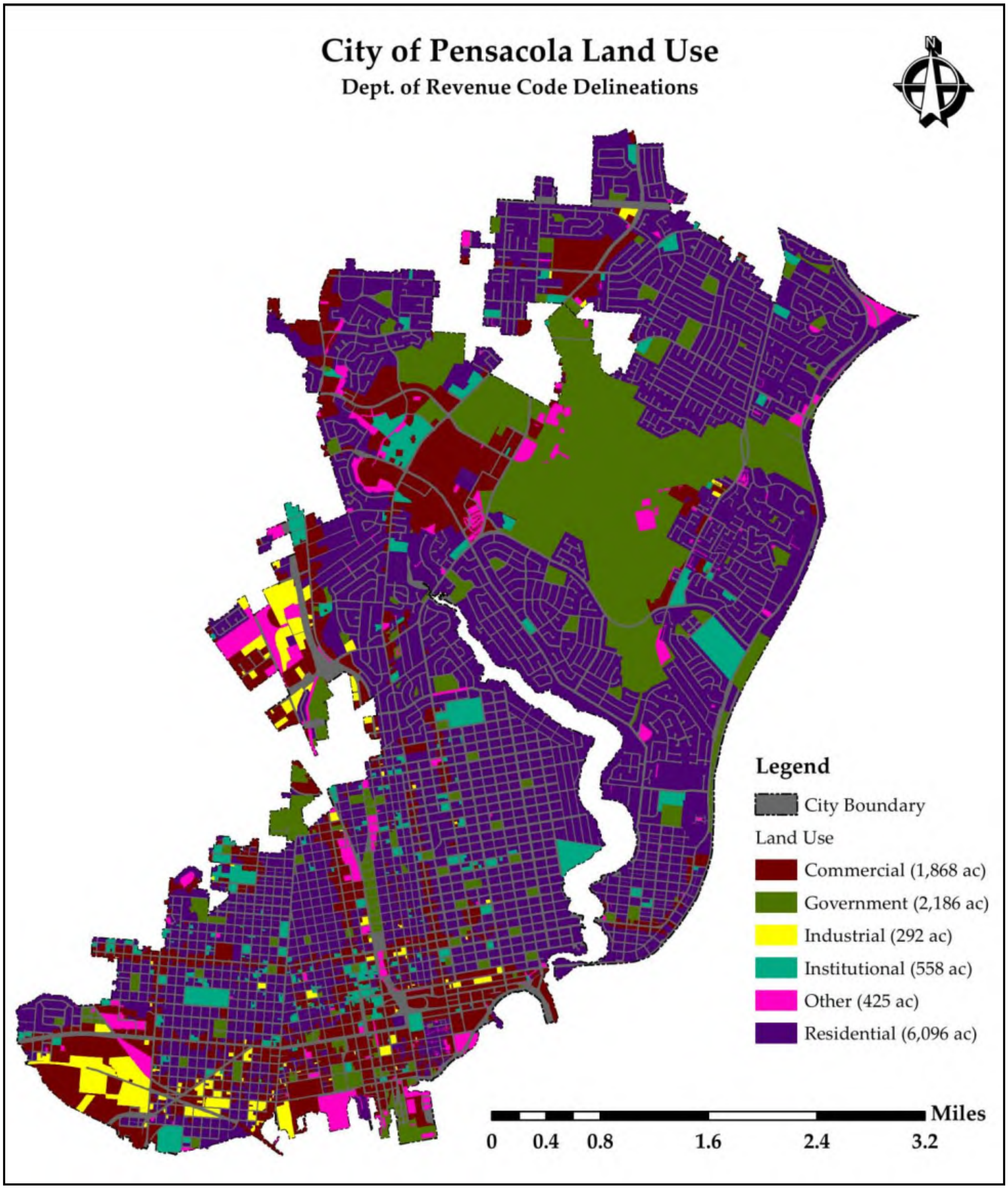


Figure 4: Map showing locations of the Department of Revenue's six land use type groupings within the City of Pensacola ("Misc." and "Non-Ag. Acreage" grouped together as "Other").

2013 City of Pensacola Parks

Primary Urban Cover Values

FRICKER RESOURCE CENTER	1.7%	36.9%	38.8%	2.08	0.03	0.77	0.81
GEORGIA SQUARE	34.1%	13.5%	56.4%	0.84	0.29	0.11	0.47
GRANADA SQUARE	25.0%	0.0%	73.9%	2.33	0.58	0.00	1.72
GRANADA SUBDIVISION PARK	42.8%	0.2%	54.8%	1.18	0.50	0.00	0.65
GREENWOOD PARK	55.2%	13.7%	30.8%	2.20	1.21	0.30	0.68
H.K. MATTHEWS PARK	13.4%	1.0%	85.2%	2.52	0.34	0.03	2.14
HENRY T. WYER PARK	41.7%	1.1%	55.1%	0.67	0.28	0.01	0.37
HIGHLAND TERRACE	33.3%	0.0%	65.1%	2.69	0.90	0.00	1.75
HITZMAN-OPTIMIST PARK	52.7%	6.8%	36.5%	11.95	6.30	0.81	4.36
HOLLICE T. WILLIAMS PARK	6.0%	41.5%	52.1%	25.38	1.51	10.52	13.23
KIWANIS PARK	6.8%	0.0%	51.2%	2.34	0.16	0.00	1.20
LAMANCHA SQUARE	36.8%	0.0%	62.3%	2.39	0.88	0.00	1.49
LAVALLET PARK	63.2%	0.0%	34.5%	3.78	2.39	0.00	1.30
LEE SQUARE	53.1%	13.9%	37.1%	1.77	0.94	0.24	0.66
LEGION FIELD	4.6%	2.7%	63.9%	8.59	0.40	0.23	5.49
LIONS PARK	0.4%	1.6%	40.3%	2.54	0.01	0.04	1.02
LONG HOLLOW PARK	28.7%	2.1%	68.4%	0.81	0.23	0.02	0.55
MAGEE FIELD	1.6%	13.7%	29.7%	4.58	0.07	0.62	1.36
MALAGA SQUARE	36.6%	0.0%	62.4%	2.39	0.87	0.00	1.49
MALCOLM YONGE GYM	20.7%	17.0%	61.6%	1.37	0.28	0.23	0.85
MALLORY HEIGHTS PARK #1	18.0%	0.0%	48.5%	3.40	0.61	0.00	1.65
MALLORY HEIGHTS PARK #2	31.1%	0.0%	25.6%	5.99	1.86	0.00	1.53
MALLORY HEIGHTS PARK #3	68.5%	0.0%	18.3%	16.96	11.62	0.00	3.10
MARITIME PARK	0.4%	36.5%	31.9%	40.87	0.17	14.91	13.02
MIRAFLORES PARK	25.6%	1.8%	72.0%	2.54	0.65	0.05	1.83
MIRALLA PARK	23.5%	0.1%	52.5%	4.31	1.01	0.00	2.26
MIRANDA SQUARE	41.3%	14.9%	44.4%	0.84	0.35	0.13	0.38
MORRIS COURT PARK	1.5%	4.4%	0.7%	2.39	0.03	0.11	0.02
OPERTO SQUARE	14.8%	0.0%	84.7%	2.44	0.36	0.00	2.06
PARKER CIRCLE NEIGHBORHOOD PARK	15.8%	0.0%	69.5%	6.15	0.97	0.00	4.28
PINEGLADES PARK	47.9%	6.9%	44.4%	1.49	0.72	0.10	0.66
PINTADO PARK	9.9%	0.0%	69.5%	3.72	0.37	0.00	2.59
PLAZA DE LUNA	0.6%	85.5%	13.9%	2.34	0.01	2.00	0.32
PLAZA FERDINAND VII	52.2%	0.0%	45.1%	1.63	0.85	0.00	0.74
ROGER SCOTT ATHLETIC COMPLEX	29.8%	16.9%	35.4%	46.99	13.98	7.95	16.64
SANDERS BEACH PARK	9.4%	39.2%	48.0%	5.28	0.50	2.07	2.53
SCENIC HEIGHTS PARK	3.8%	0.0%	65.1%	3.72	0.14	0.00	2.42
SEMMES	15.2%	0.0%	84.3%	1.94	0.30	0.00	1.64
SEVILLE SQUARE	49.9%	0.0%	46.5%	1.73	0.87	0.00	0.81
SPRINGDALE PARK	26.9%	0.0%	53.1%	5.00	1.35	0.00	2.65
TERRY WAYNE EAST PARK	0.8%	0.8%	21.2%	2.10	0.02	0.02	0.44
TIERRA VERDE PARK	36.6%	0.0%	62.2%	1.17	0.43	0.00	0.73

2013 City of Pensacola Parks
Primary Urban Cover Values

TIPPIN PARK	38.9%	0.0%	38.5%	2.98	1.16	0.00	1.15
TOLEDO SQUARE	29.2%	0.0%	69.8%	2.37	0.69	0.00	1.65
VICTORY PARK 1	15.2%	0.0%	82.9%	0.15	0.02	0.00	0.12
VICTORY PARK 2	18.6%	6.9%	74.1%	0.24	0.04	0.02	0.17
WAYSIDE PARK EAST	7.2%	13.1%	29.5%	18.14	1.30	2.37	5.34
WAYSIDE PARK WEST	8.9%	0.0%	90.9%	3.20	0.28	0.00	2.91
WOODCLIFF PARK	45.0%	0.1%	50.5%	4.63	2.08	0.00	2.34
WOODLAND HEIGHTS PARK (W. E. MCNEALY SR.)	31.2%	7.9%	60.5%	2.62	0.82	0.21	1.58
ZAMORA SQUARE	19.1%	0.0%	62.6%	2.37	0.45	0.00	1.48

Data Type	Acres	Canopy	Impervious	Open Space	Total Acres
City Property	2119.71	26.6%	20.7%	19.8%	2119.71
City Parks	273.35	38.5%	3.0%	45.4%	273.35
City Schools	0.18	10.2%	35.1%	56.9%	0.18
Other Govt. Property	664.79	14.5%	34.9%	43.6%	664.79
Other Govt. Parks	37.34	45.3%	2.2%	37.0%	37.34
Other Govt. Schools	351.14	10.2%	40.2%	41.9%	351.14

Table 3: Current (2013) urban cover metrics for city and other government owned land within the City of Pensacola.

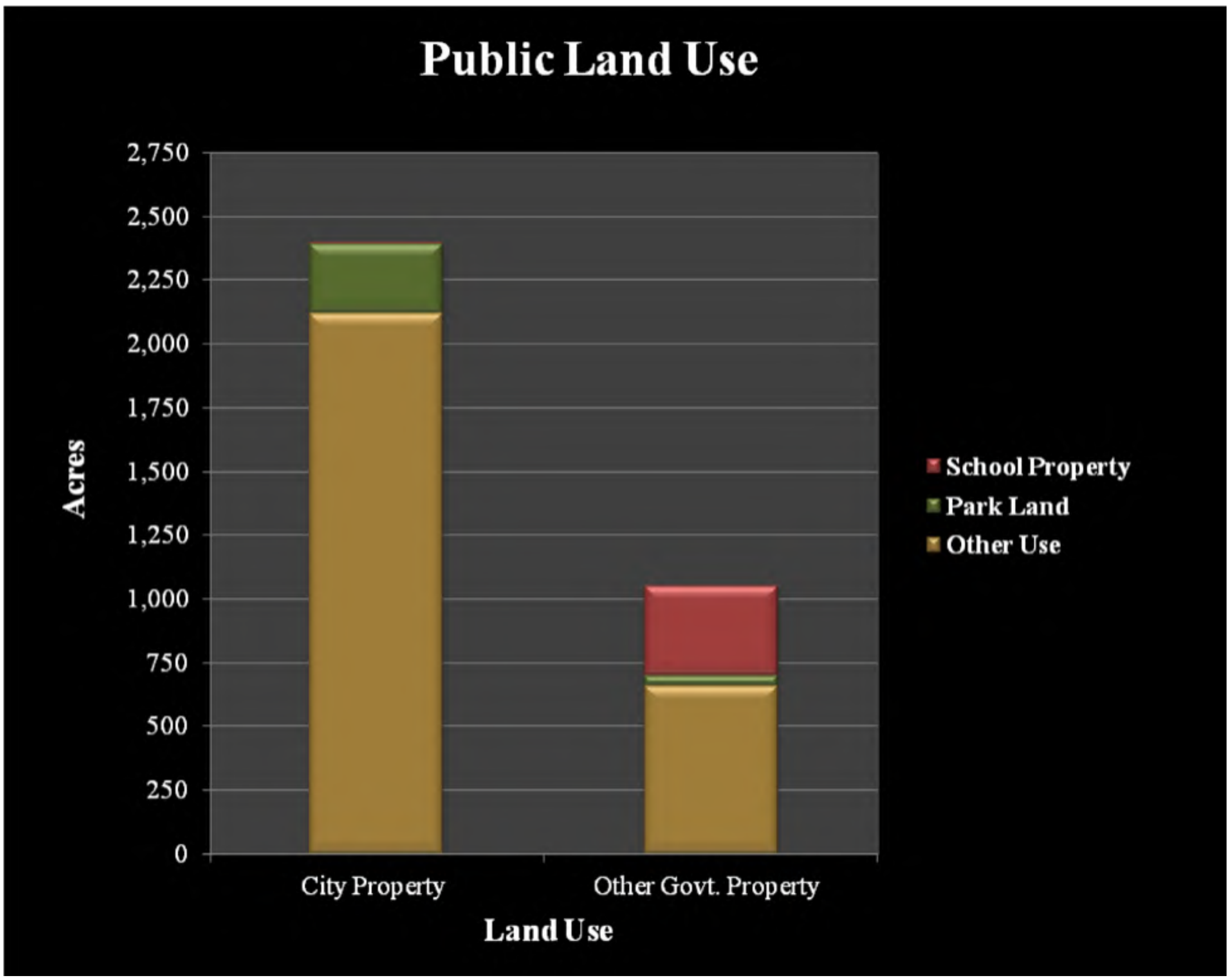


Figure 6: Comparison of acres/owner and primary use types between city and other government owned land.

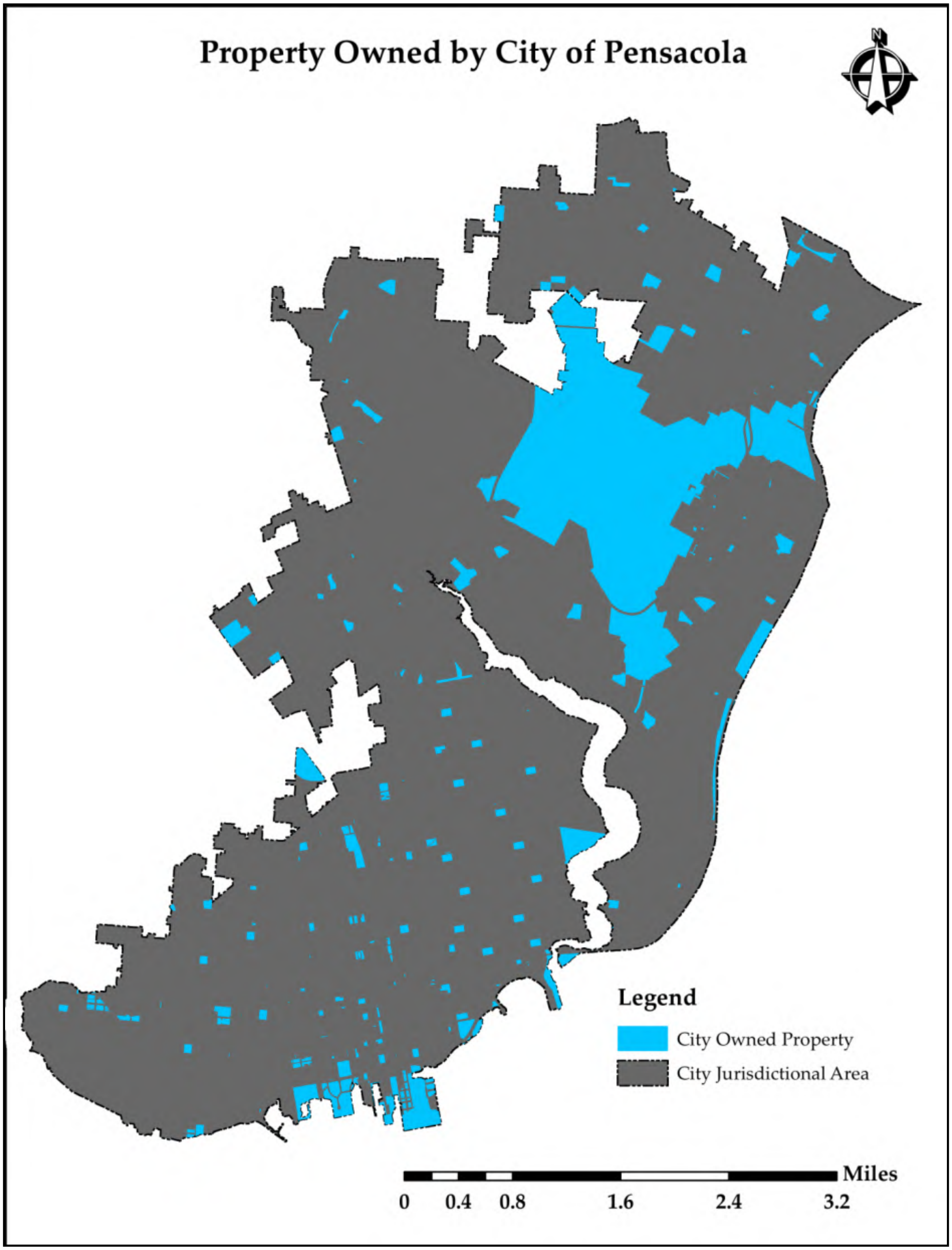
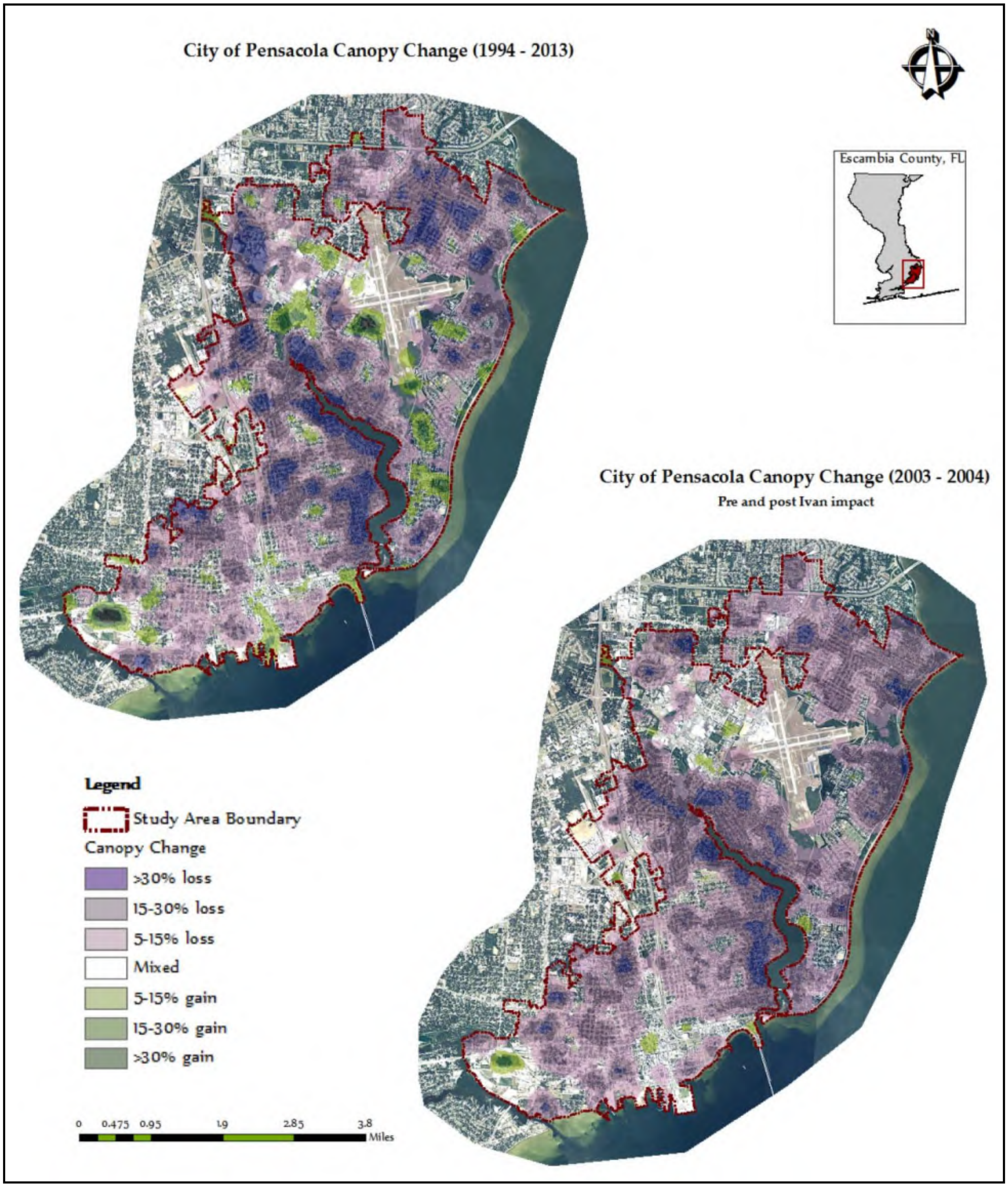


Figure 7: Location of city owned property within city jurisdictional area.



Hurricane Ivan related (2003-2004) canopy impacts. Relative changes in canopy coverage are visualized and can be quantified within general areas of interest such as Bayou Texar where extreme losses are apparent as a direct result from Hurricane Ivan.

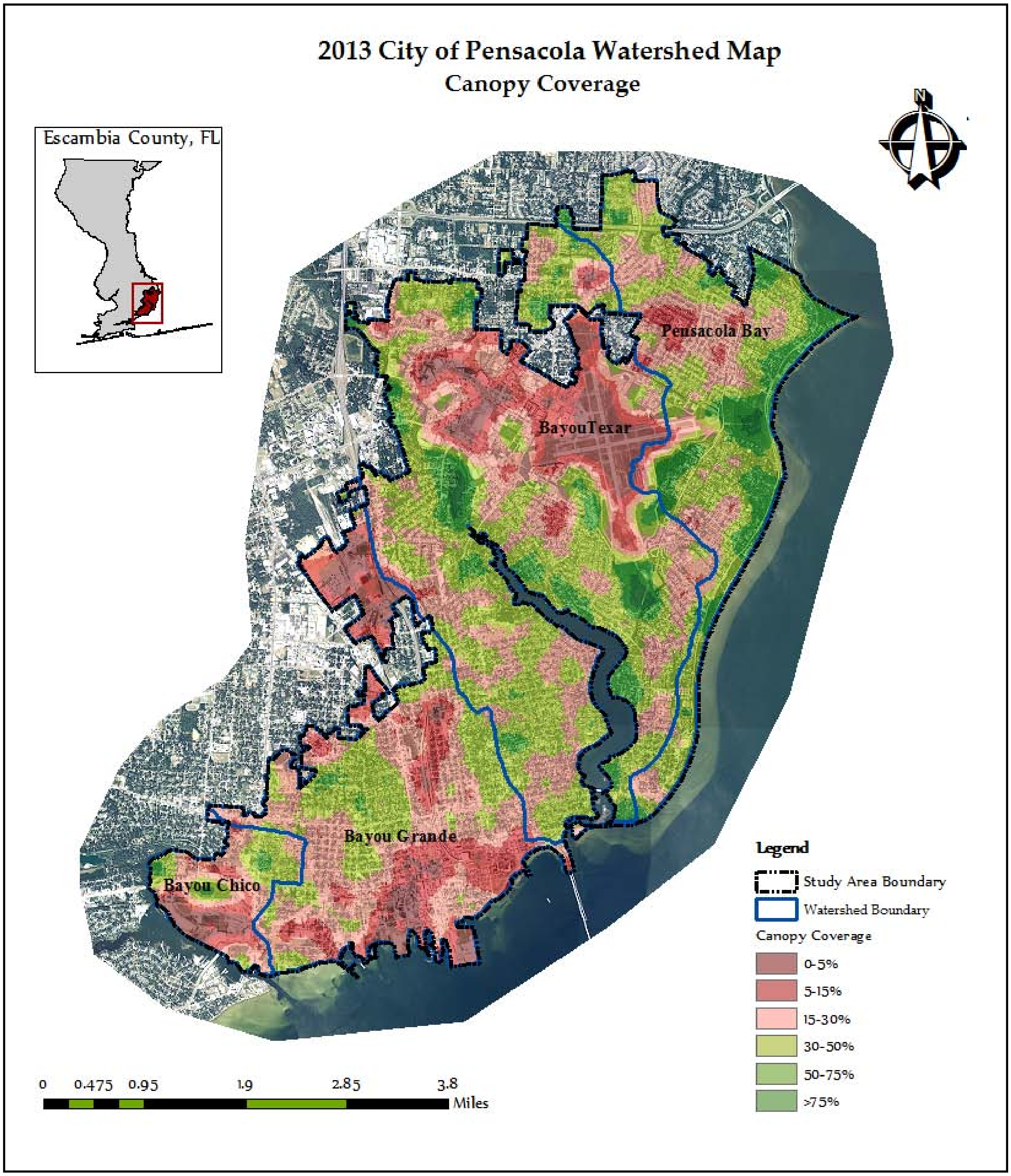


Figure 10: Overall 2013 canopy coverage map overlaid onto the City of Pensacola's four watershed delineations. Primary areas of canopy be seen along aquatic buffers, in airport noise buffers and in certain residential and park areas such as the East Hill Neighborhood and Bayview Park.

Property Type	Watershed	Acres	Canopy	Impervious	Open Space
All	Pensacola Bay	3022.84	37.8%	23.6%	34.4%
All	Bayou Texar	6955.66	31.6%	28.7%	32.5%
All	Downtown	3726.47	19.4%	39.3%	39.6%
All	Bayou Chico	757.18	21.7%	35.8%	36.8%

***Table 4*: ** Current (2013) urban cover metrics for the City of Pensacola's four watershed delineations.

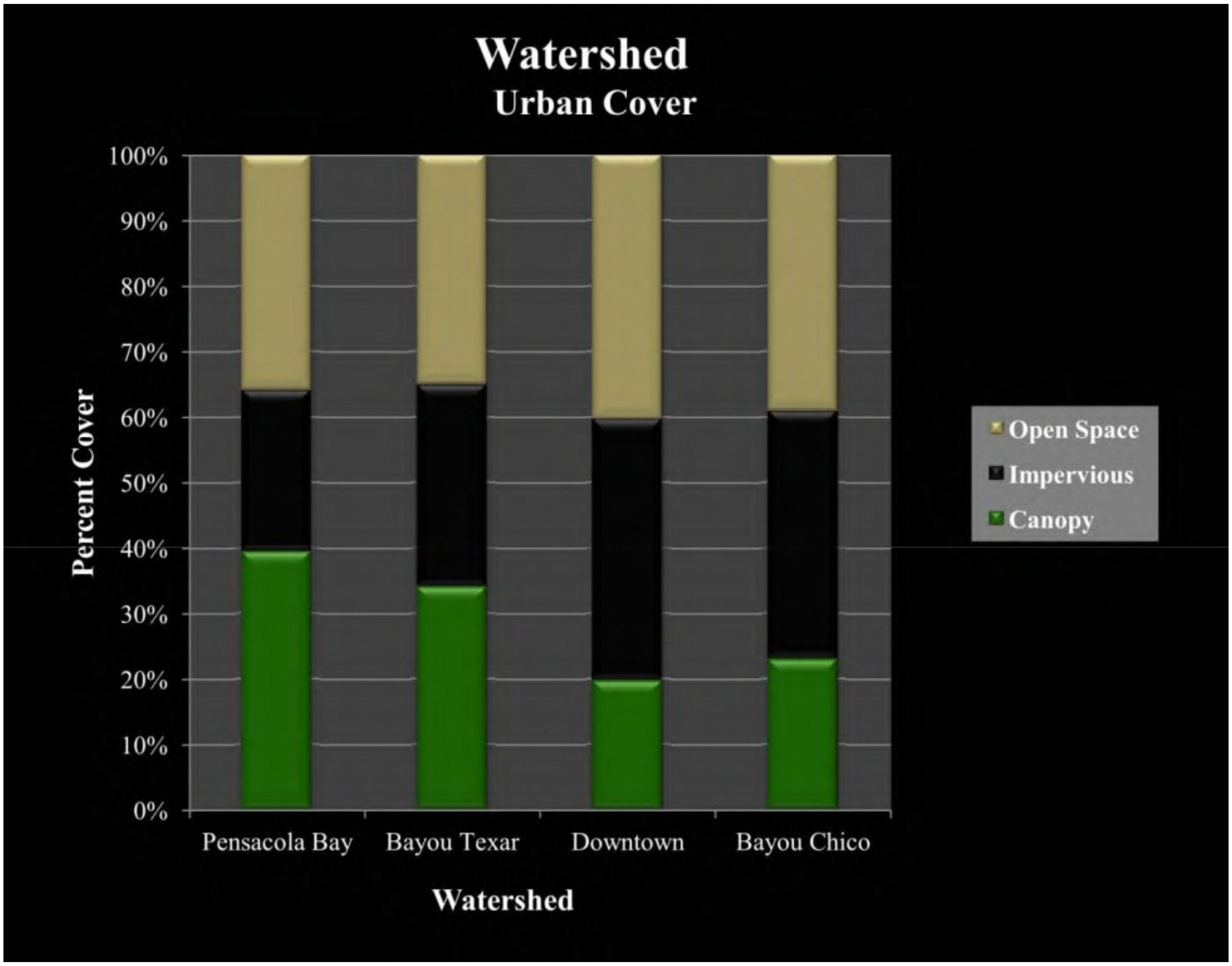


Figure 11: Visualizing Table 4 data, primary urban cover values are compared within each of the City of Pensacola's four watershed basins.

Property Type	Watershed	Acres	Canopy	Impervious	Open Space
City	Pensacola Bay	475.67	49.2%	9.4%	18.0%
City	Bayou Texar	1357.84	22.0%	22.3%	15.2%
City	Downtown	273.40	10.7%	32.6%	44.5%
City	Bayou Chico	12.81	18.9%	12.4%	51.2%

Table 5: Current (2013) urban cover metrics for city owned property (grouped) within each of the City of Pensacola's four watershed delineations.

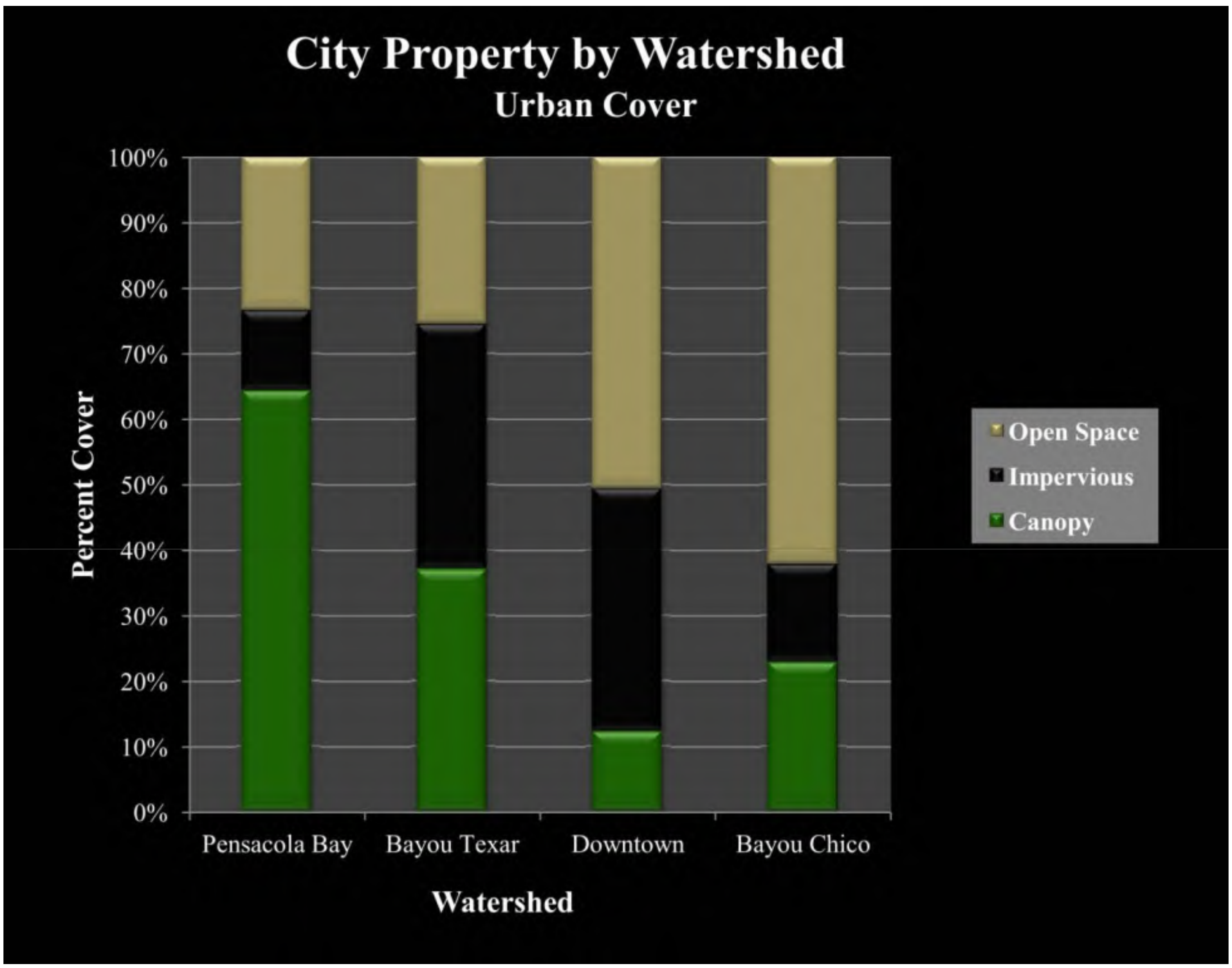


Figure 12: Visualizing Table 5 data, primary urban cover values of city owned properties (grouped) are compared within each of the City of Pensacola's four watershed basins.

Property Type	100 ft. Aquatic Buffer	Acres	Canopy	Impervious	Open Space
All	Pensacola Bay	167.02	11.5%	16.8%	44.1%
All	Bayou Texar	115.74	42.3%	6.0%	46.9%
All	Bayou Chico	30.79	18.4%	38.6%	38.6%
All	Maggie's Ditch	7.95	42.6%	8.0%	31.8%
All	Carpenters Creek	112.09	74.2%	5.4%	13.3%
All	Other Streams	7.34	80.6%	4.0%	8.7%
All	Graveyard Branch	10.23	70.8%	5.3%	11.0%

Table 6: Current (2013) urban cover metrics for the City of Pensacola's 100 ft. aquatic buffers.

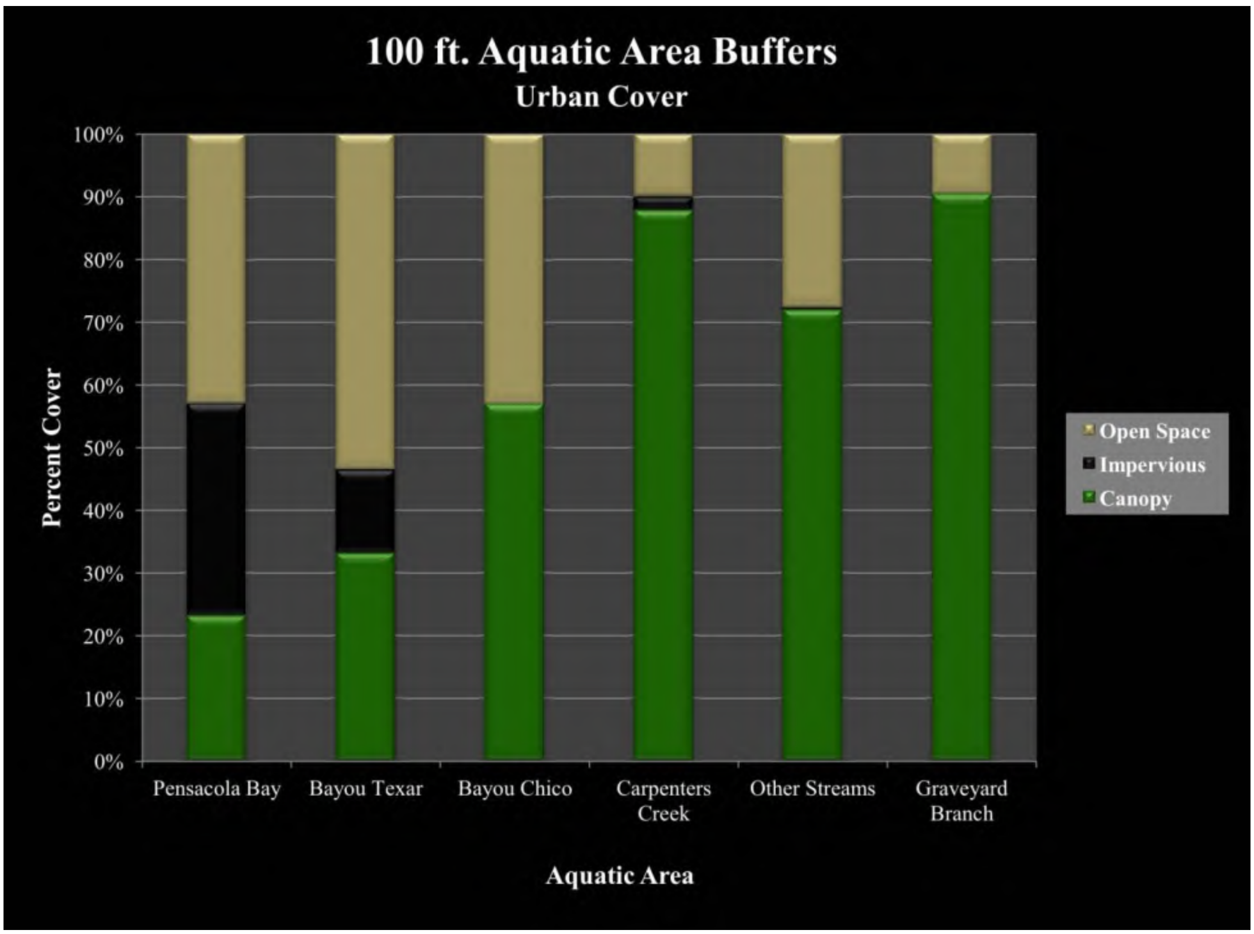


Figure 13: Visualizing Table 6 data, primary urban cover values are compared within each of the City of Pensacola's 100 ft. aquatic buffers.

Property Type	100 ft. Aquatic Buffer	Acres	Canopy	Impervious	Open Space
City (intersecting)	Pensacola Bay	156.37	21.2%	30.9%	39.2%
City (intersecting)	Bayou Texar	59.59	33.1%	13.2%	53.3%
City (intersecting)	Bayou Chico	0.22	51.5%	0.0%	39.0%
City (intersecting)	Carpenters Creek	10.59	41.8%	1.1%	4.7%
City (intersecting)	Other Streams	8.22	67.5%	0.4%	25.9%
City (intersecting)	Graveyard Branch	0.33	48.5%	0.0%	5.1%

Table 7: Current (2013) urban cover metrics for city owned property (grouped) falling at least partially within each of the City of Pensacola's 100 ft. aquatic buffers.

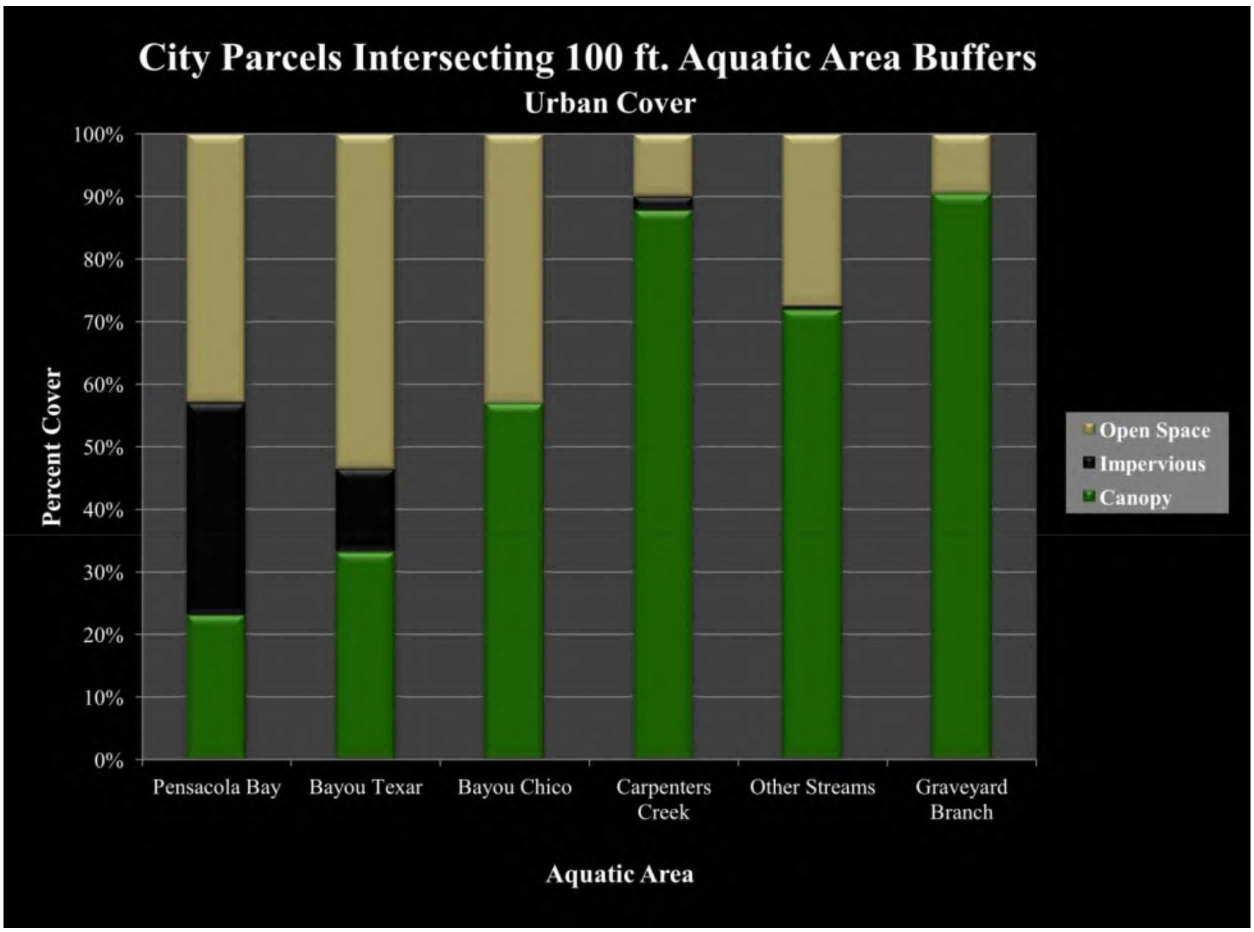


Figure 14: Visualizing Table 7 data, primary urban cover values are compared for city owned property (grouped) falling at least partially within each of the City of Pensacola's 100 ft. aquatic buffers.

Property Type	Gateway Area	Acres	Canopy	Impervious	Open Space
All	All Gateways	522.15	10.4%	56.5%	33.6%
All	Barrancas Ave	25.16	3.8%	50.1%	25.5%
All	Bay Front Pkwy	26.13	4.6%	42.3%	49.4%
All	Creighton Rd	20.26	13.1%	78.8%	40.3%
All	E Cervantes St	22.47	2.0%	76.7%	21.4%
All	E Fairfield Dr	39.03	3.6%	52.3%	44.3%
All	E Garden St	5.88	6.4%	66.3%	27.6%
All	Langley Ave	25.65	8.1%	53.8%	38.9%
All	N 12th Ave	48.20	16.1%	51.9%	34.3%
All	N 17th Ave	14.83	23.8%	42.7%	37.9%
All	N 9th Ave	68.93	7.9%	62.8%	31.5%
All	N Pace Blvd	6.20	0.3%	81.8%	18.1%
All	N Palafox St	9.16	0.6%	75.6%	24.1%
All	S 12th Ave	4.15	16.4%	44.0%	42.3%
All	S 17th Ave	6.18	20.6%	46.1%	32.3%
All	S 9th Ave	7.73	1.8%	70.2%	28.9%
All	S Pace Blvd	8.16	0.7%	76.3%	20.5%
All	S Palafox St	15.14	8.0%	62.7%	31.6%
All	Scenic Hwy	64.43	26.6%	37.6%	36.1%
All	Summit Blvd	32.91	15.1%	49.5%	38.6%
All	W Cervantes St	16.99	1.2%	85.6%	13.8%
All	W Garden St	22.84	5.4%	68.3%	26.8%
All	W Main St	16.09	2.0%	65.5%	17.8%
All	W Navy Blvd	23.16	5.3%	52.3%	39.5%

Table 8: Current (2013) urban cover metrics within gateway right-of-way areas

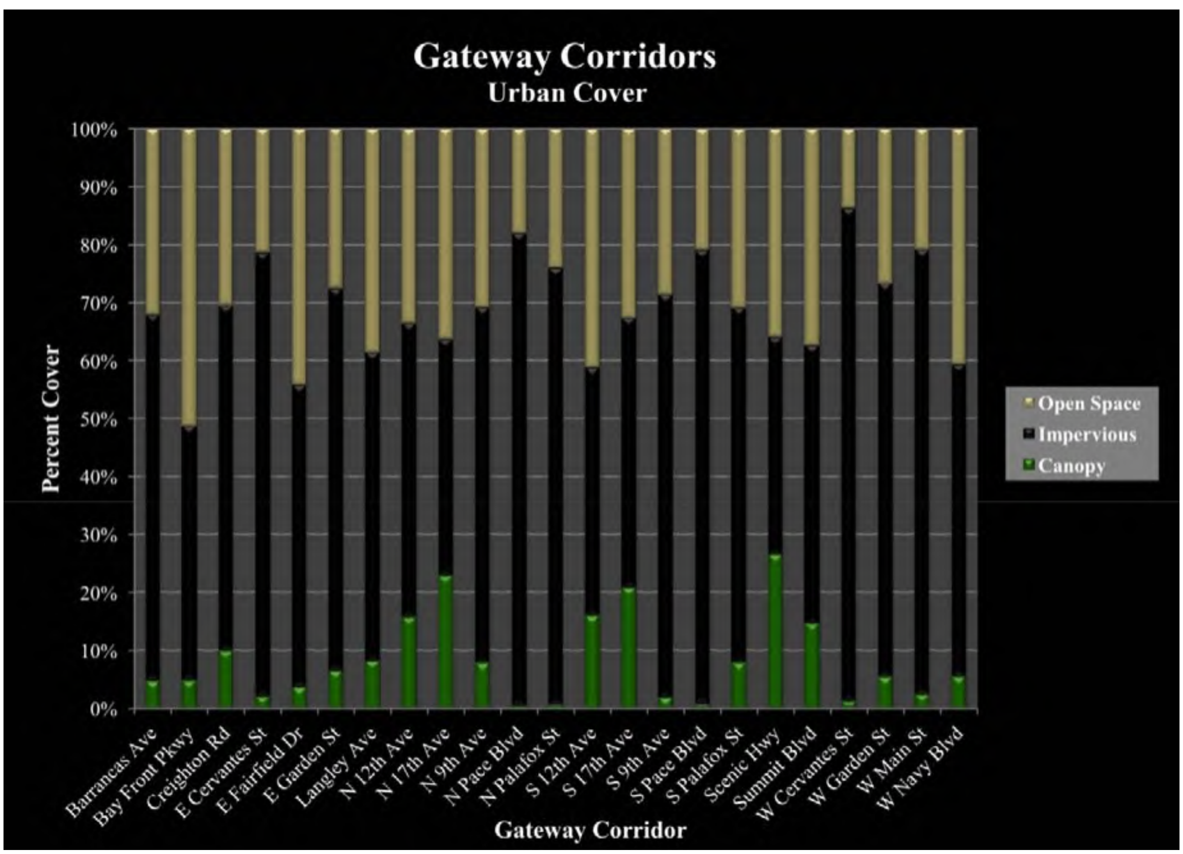


Figure 15: Visualizing Table 8 data, primary urban cover values are compared between gateway right-of-way areas.

Property Type	Gateway Area	Acres	Canopy	Impervious	Open Space
City (within 50ft)	Barrancas Ave	0.06	0.0%	0.0%	100.0%
City (within 50ft)	Bay Front Pkwy	3.83	11.9%	19.6%	60.4%
City (within 50ft)	Creighton Rd	0.37	26.2%	40.3%	36.8%
City (within 50ft)	E Cervantes St	2.00	34.8%	9.2%	58.7%
City (within 50ft)	E Garden St	0.18	2.5%	71.5%	27.4%
City (within 50ft)	Langley Ave	5.83	14.2%	8.4%	56.5%
City (within 50ft)	N 12th Ave	8.35	37.2%	9.1%	44.1%
City (within 50ft)	N 17th Ave	0.61	20.8%	0.0%	78.3%
City (within 50ft)	N 9th Ave	0.73	34.0%	16.0%	54.7%
City (within 50ft)	N Pace Blvd	0.17	0.0%	35.6%	64.4%
City (within 50ft)	N Palafox St	0.69	42.5%	0.2%	55.7%
City (within 50ft)	S 12th Ave	0.32	0.1%	12.9%	67.3%
City (within 50ft)	S 17th Ave	1.37	16.0%	16.6%	63.4%
City (within 50ft)	S 9th Ave	1.49	3.3%	17.4%	79.6%
City (within 50ft)	S Palafox St	3.23	38.0%	39.3%	23.8%
City (within 50ft)	Scenic Hwy	13.02	65.0%	4.6%	28.5%
City (within 50ft)	Summit Blvd	9.06	34.9%	5.1%	59.3%
City (within 50ft)	W Garden St	0.22	8.7%	57.3%	36.3%
City (within 50ft)	W Main St	3.60	5.5%	35.5%	56.2%
City (within 50ft)	W Navy Blvd	0.83	8.5%	48.7%	34.6%

Table 9: Current (2013) urban cover metrics for city owned property (grouped) falling within 50 feet of a gateway right-of-way area.

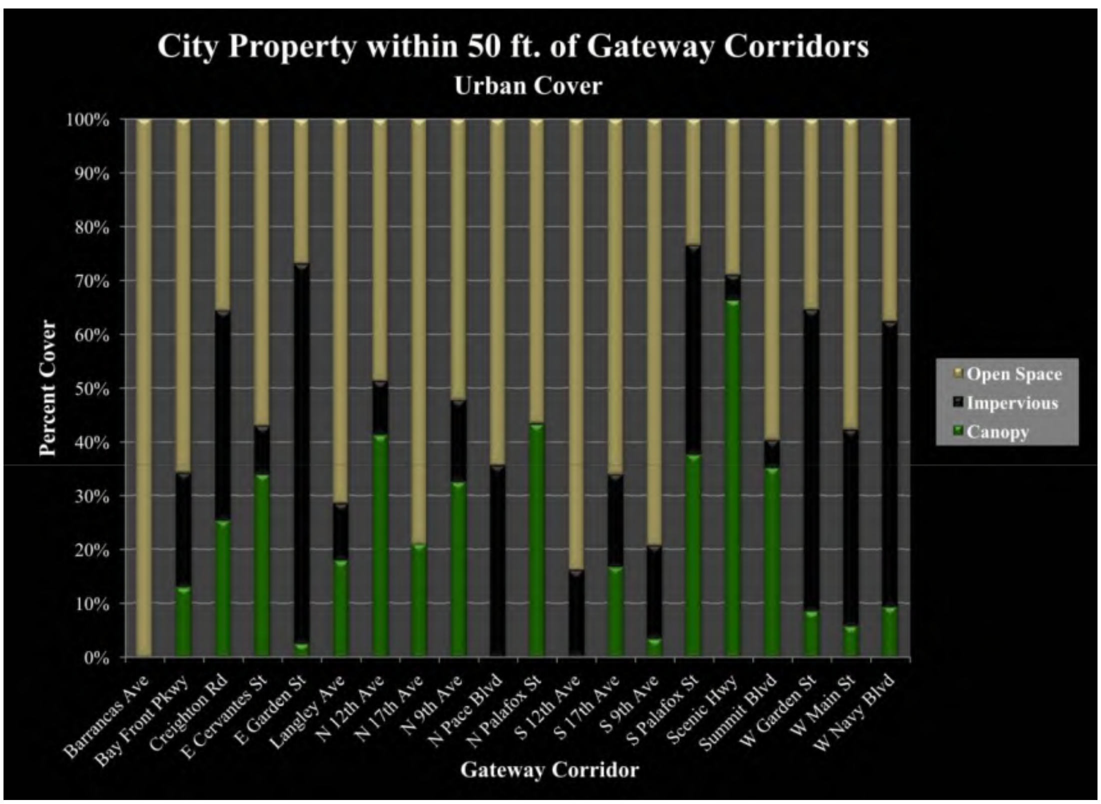


Figure 16: Visualizing Table 9 data, primary urban cover values are compared between city properties (grouped) within 50 feet of each gateway right-of-way area.

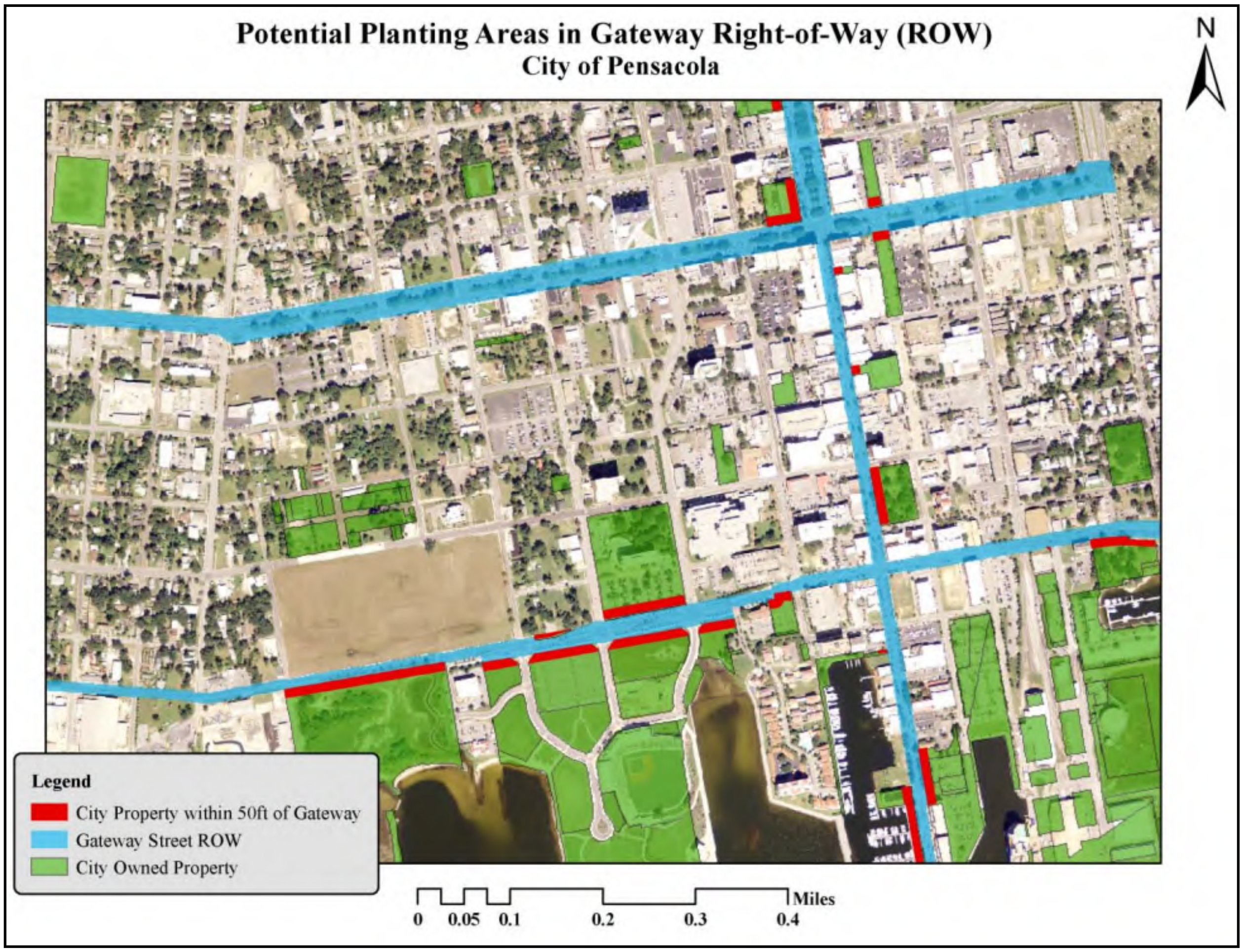


Figure 17: Example of city property within 50 feet of gateway right-of-way areas (red areas in map).

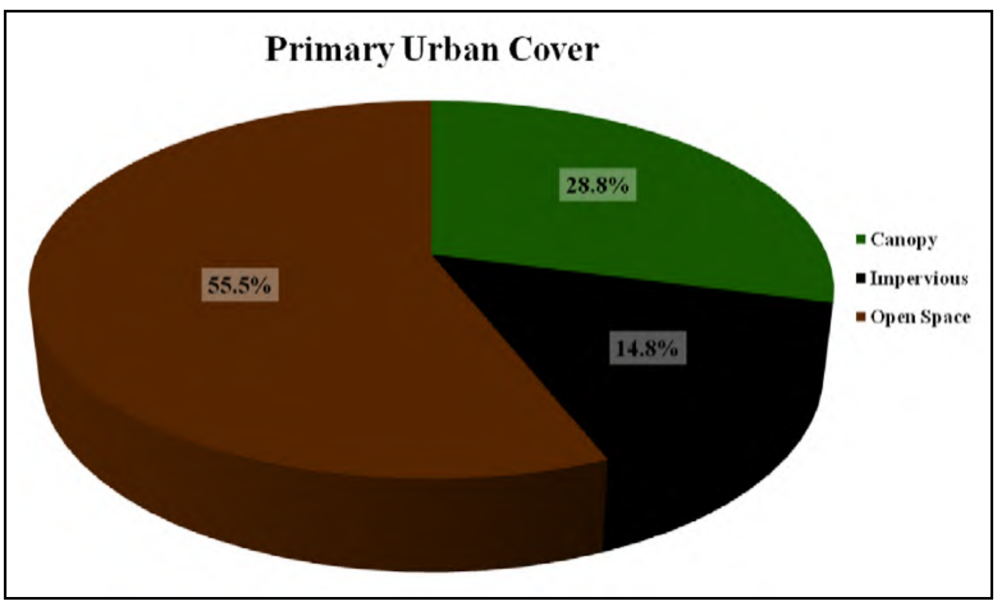


Figure 18: Current (2013) urban cover metrics for Bayview Park

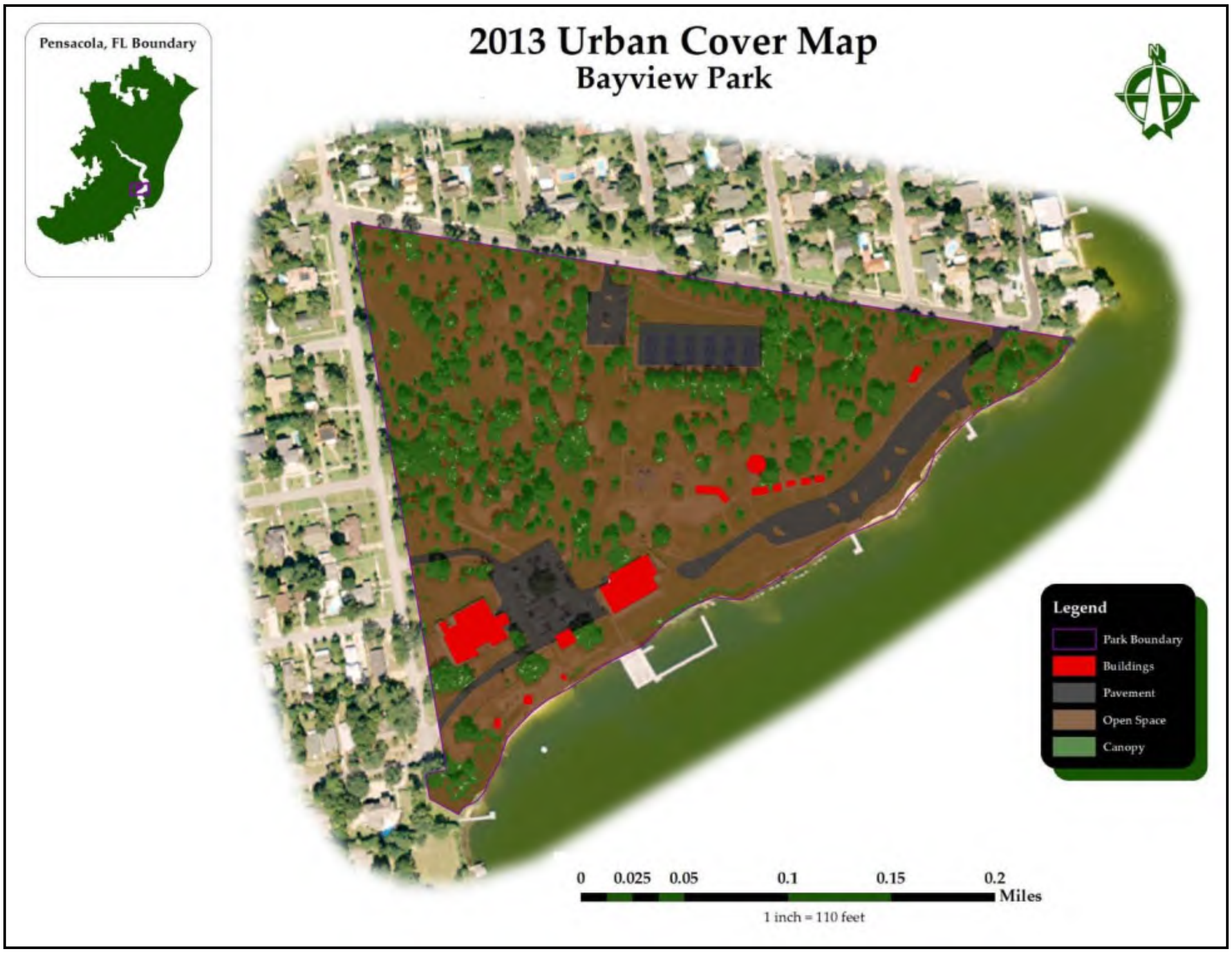


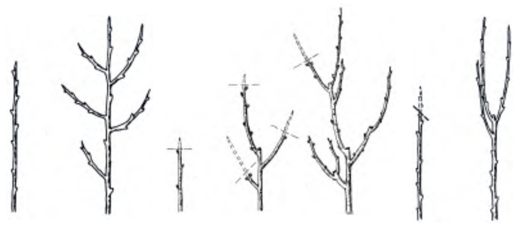
Figure: Example of urban cover mapping within Bayview Park.

Appendix B

Tree Quality Cue Card

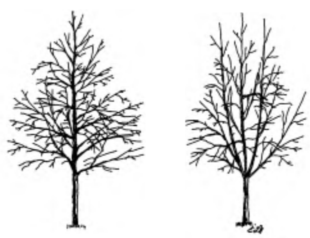
Shade trees that grow to be large should have one relatively straight central leader. Heading the tree is acceptable provided the central leader is retrained.

Desirable | Desirable | Not desirable



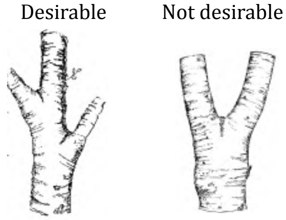
Main branches should be well distributed along the central leader, not clustered together. They should form a balanced crown appropriate for the cultivar or species.

Desirable | Not desirable



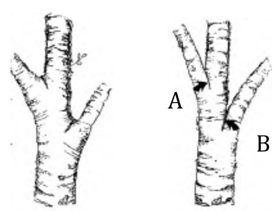
The diameter of branches that grow from the central leader, or trunk, should be no larger than two-thirds (one-half is preferred) the diameter of the trunk measured just above the branch.

Desirable | Not desirable



The largest branches should be free of bark that extends into the branch union, known as included bark (see A and B).

Desirable | Not desirable



Temporary branches particularly on trees less than 1 inch caliper should be present along the lower trunk below the lowest main branch. These branches should be no larger than 3/8 inch in diameter.

Desirable | Not desirable

The trunk should be free of wounds, sunburned areas, conks (fungal fruiting bodies), wood cracks, bleeding areas, signs of boring insects, cankers, or lesions. Properly made recent pruning cuts are acceptable.

The trunk caliper (thickness) and taper should be sufficient so that the tree remains vertical without a stake.

Desirable | Not desirable

The root collar (the uppermost roots) should be within the upper 2 inches of the soil media (substrate). The root collar and the inside portion of the root ball should be free of defects, including circling, kinked, and stem girdling roots. You may need to remove soil near the root collar to inspect for root defects.

Desirable | Not desirable

The tree should be well rooted in the soil media. Roots should be uniformly distributed throughout the container. The tree's structure and growth should be appropriate for the species or cultivar. When the container is removed, the root ball should remain intact. When the trunk is lifted, both the trunk and root system should move as one.

The root ball should be moist throughout at the time of inspection and delivery. The roots should show no signs of excess soil moisture as indicated by poor root growth, root discoloration, distortion, death, or foul odor. The crown should show no signs of moisture stress as indicated by wilted, shriveled, or dead leaves or branch dieback.

Urban Tree Foundation | CAL FIRE | California ReLEAF | Western Chapter International Society of Arboriculture

Using CU-Structural Soil™ in the Urban Environment

Cornell University

Urban Horticulture Institute
Cornell University
Department of Horticulture
134A Plant Science Building
Ithaca, NY 14853
www.hort.cornell.edu/UHI

Founded in 1980 with the explicit mission of improving the quality of urban life by enhancing the functions of plants within the urban ecosystem, the Urban Horticulture Institute program integrates plant stress physiology, horticultural science, plant ecology and soil science and applies them to three broad areas of inquiry.

They are:

- The selection, evaluation and propagation of superior plants with improved tolerance of biotic and abiotic stresses, and enhanced functional uses in the disturbed landscape.

- Developing improved technologies for assessing and ameliorating site limitations to improve plant growth and development.

- Developing improved transplant technologies to insure the successful establishment of plants in the urban environment.

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N. Bassuk, B. Kalter, & P. Trowbridge

Cover Photo:
Elm trees planted in CU-Structural Soil™ in Union Square Park, NYC.

The Case for CU-Structural Soil™:
Why do we need it, what is it, and how is it used?

Urban trees experience a litany of environmental insults: soil and air pollution, heat loads, deicing salts, and impacts from utilities, vehicles, and buildings. The most significant problem that urban trees face, however, is the lack of useable soil volume for root growth, since trees are often an afterthought in city planning and streescape design. (Fig. 1.1)

Fig. 1.1 Tree root ball prior to being planted in a 4' x 5' tree pit in NYC.

Fig. 1.2 Compaction is necessary to create a load-bearing surface on which to lay pavement.

Soil Compaction

Ongoing construction, including sidewalk and road repair, disturbs and compacts soil (Fig. 1.2), crushing macropores (Fig. 1.3). Loss of macropores has three negative consequences: restricted aeration, diminished water drainage, and creating a dense soil that is difficult for roots to penetrate. These effects limit useable rooting space.

Macropores

- the relatively large spaces between soil aggregates
- water drains quickly through macropores
- air diffuses through macropores

Macropores are the spaces between the soil aggregates

Fig. 1.3 Macropores are spaces between soil aggregates that allow water, air and subsequently root growth.

Fig. 1.4 Surface rooting of trees growing in compacted soils

What happens when roots encounter dense, compacted soil?

When roots encounter dense soil, they change direction, stop growing, (Fig 1.5) or adapt by remaining abnormally close to the surface (Fig. 1.4) This superficial rooting makes urban trees more vulnerable to drought and can cause pavement heaving. However, if a dense soil is waterlogged, tree roots can also rot from lack of oxygen.

Fig. 1.5 Tree roots which are typically superficial can become 'containerized' by compacted soil under and around trees.

Fig.1.6 This photograph shows the effect of soil volume on tree growth. Both rows of willow oaks were planted at the same time on Pennsylvania Avenue, Washington, D.C. The trees on the right are in tree pits, and those on the left are in an open grassed area.

The role of soil volume on tree growth

The soil in urban tree lawns or parks can be improved by amendment or soil replacement. Where soil volume is limited by pavement, tree roots suffer (Fig 1.6). The highly compacted soils required for constructing pavements do not allow root penetration, resulting in declining trees which are all too common in cities. Yet it is precisely these paved areas such as parking lots and streets that most need the mitigating effects of shade trees.

Healthy trees need a large volume of non-compacted soil with adequate drainage and aeration and reasonable fertility. CU-Structural Soil™ meets these needs while also fulfilling engineers' load-bearing requirements for base courses under pavement.

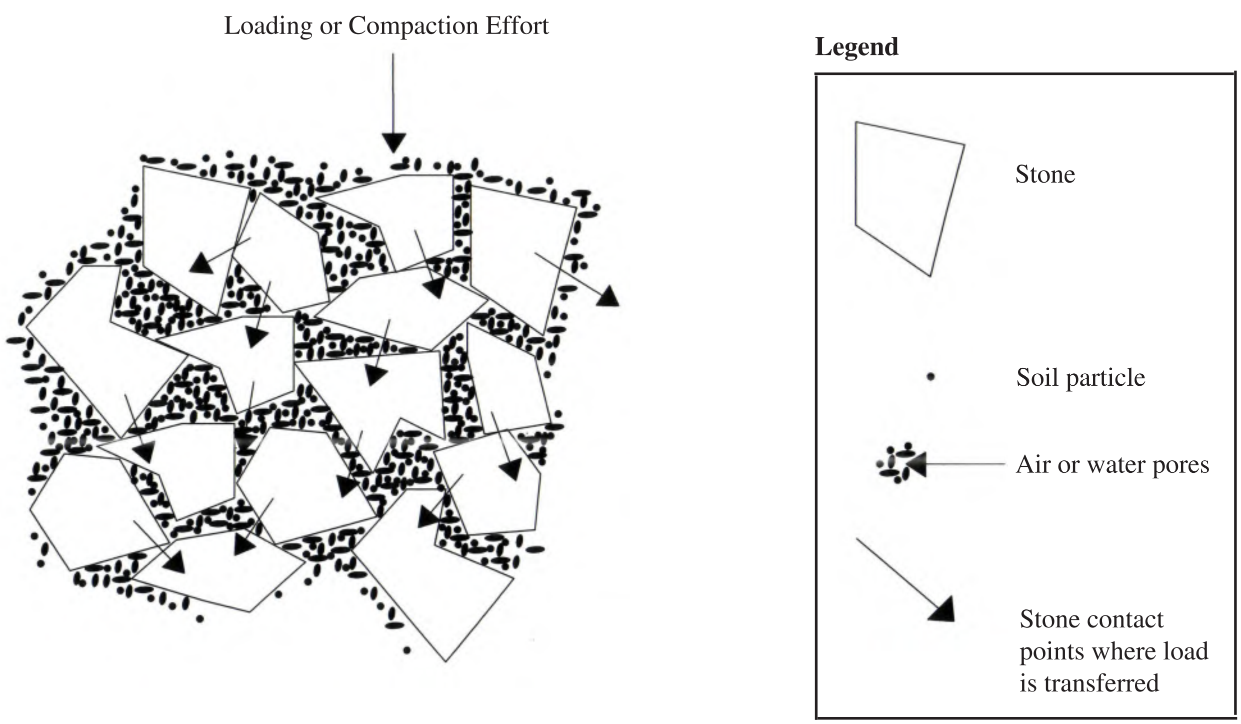


Fig.1.7 Conceptual diagram of CU-Structural Soil™ including stone-on-stone compaction and soil in interstitial spaces used as a base course for pavements.

CU-Structural Soil™ Basics

CU-Structural Soil™ (U.S. Patent # 5,849,069) is a two-part system comprised of a rigid stone “lattice” to meet engineering requirements for a load-bearing soil, and a quantity of soil, to meet tree requirements for root growth. The lattice of load-bearing stones provides stability as well as interconnected voids for root penetration, air and water movement (Fig. 1.7). The uniformly graded 3/4”-1 1/2” angular crushed stone specified for CU-Structural Soil™ is designed to ensure the greatest porosity. Crushed or angular stone provides more compaction and structural interface of stone-to-stone than round stone. Because stone is the load-bearing component of structural soil, the aggregates used should meet regional or state department of transportation standards for pavement base courses.

Since among soil textures, clay has the most water and nutrient-holding capacity, a heavy clay loam or loam, with a minimum of 20% clay, is selected for the CU-Structural Soil™ system. CU-Structural Soil™ should also have organic matter content ranging from 2%-5% to ensure nutrient and water holding while encouraging beneficial microbial activity. A minimum of 20% clay is also essential for an adequate cation exchange capacity.

With carefully chosen uniformly-graded stone and the proper stone to soil ratio, a medium for healthy root growth is created that also can be compacted to meet engineers’ load-bearing specifications (Fig. 1.8). The intention is to “suspend” the clay soil between the stones without over-filling the voids, which would compromise aeration and bearing capacity. CU-Structural Soil™ utilizes Gelscape® hydrogel as a non-toxic, non-phytotoxic tackifier, in addition to stone and soil components.

Fig. 1.8 From upper left, clockwise: uniformly-graded crushed stone of 3/4” - 1 1/2” diameter, pile and close-up; CU-Structural Soil™ after mixing; clay loam.

Using CU-Structural Soil™ for Street Trees

CU-Structural Soil™ is intended for paved sites to provide adequate soil volumes for tree roots under pavements (Fig. 1.9). It can and should be used under pedestrian mall paving, sidewalks, parking lots, and low-use access roads. The Urban Horticulture Institute is currently conducting trials of its use under turf and porous asphalt to provide more porous parking areas. Research at Cornell has shown that tree roots in CU-Structural Soil™ profiles grow deep into the base course material, away from the fluctuating temperatures at the pavement surface. One benefit of this is that roots are less likely to heave and crack pavement than with conventional paving systems (Fig. 1.10).

Planting a tree into CU-Structural Soil™ is much like conventional planting. If possible, the pavement opening should be expandable (via removable pavers or using a mulched area) for the sake of the anticipated buttress roots of maturing trees (Fig. 1.11). CU-Structural Soil™ should be used at a depth of at least 24" but preferably 36" (Fig.1.12). CU-Structural Soil™ can be used right up to the surface grade where there is a pavement opening that is large enough to allow for tree installation.

Fig.1.9 Installing CU-Structural Soil™ in Ithaca, NY in 1997

Fig. 1.10 Sidewalk heaving caused by superficial tree root growth, Ithaca, NY

Fig. 1.11 Lindens in CU-Structural Soil™ in Boston, 2002

Fig. 1.12a Example of street tree planting using CU-Structural Soil™ under conventional concrete sidewalk in Brooklyn, NY

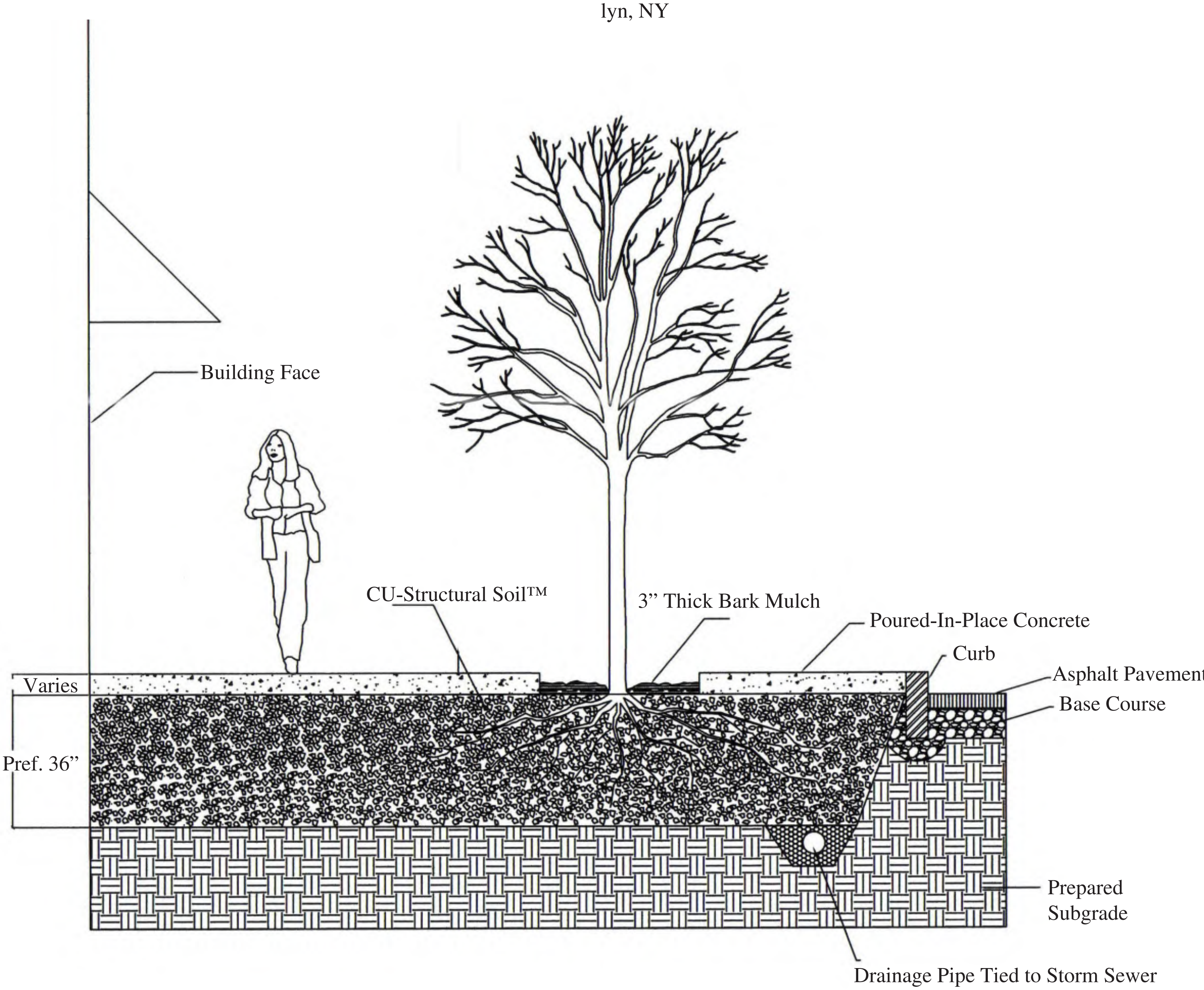


Fig. 1.12 Typical street tree planting using CU-Structural Soil™ under a sidewalk

Trees in Parking Lots and Plazas:

CU-Structural Soil™ may also be used to enlarge a ‘tree island’ within a parking lot. With a large tree planting area, good, well draining topsoil can be used in the island and CU-Structural Soil™ added as an unseen rooting medium under the asphalt (Figs. 1.13 - 1.15).

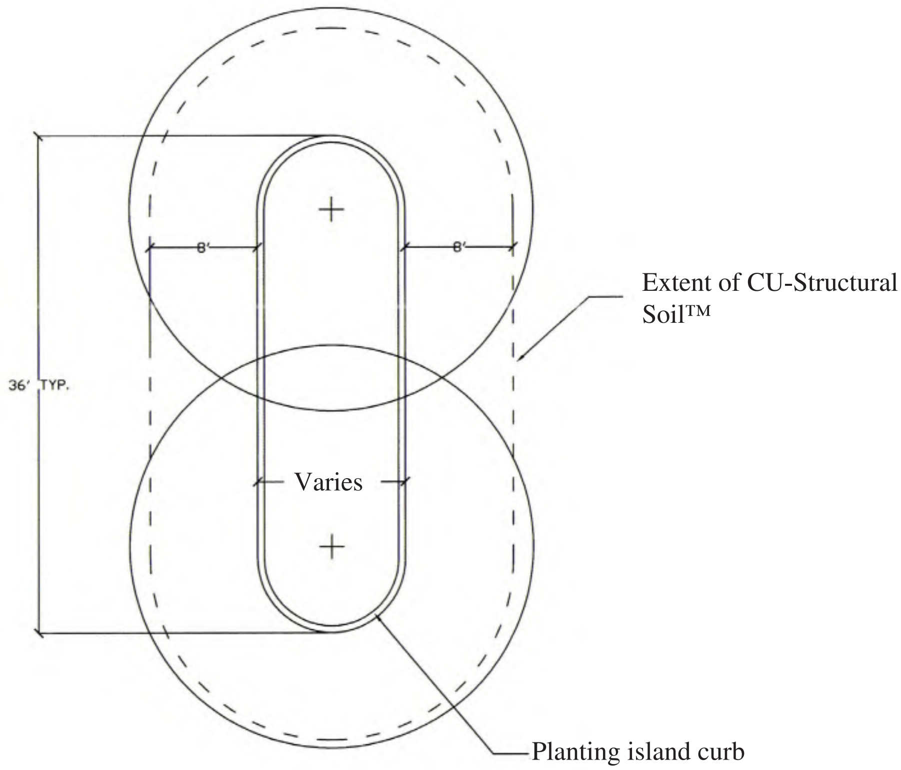


Fig. 1.13 Plan view of planting island

Fig. 1.14 Potential use of CU-Structural Soil™ to enlarge planting islands in parking lots without taking up parking space

Trees in parking lots, as well as paved plazas, benefit from the use of CU-Structural Soil™ (Fig.1.16 - 1.17). Whether there is a curb or not, good, well-drained topsoil may be used around the tree where the opening is at least 5’ x 5’. If the opening is smaller, CU-Structural Soil™ may be used right up to the tree ball. Although it is not necessary to use an additional base course on top of CU-Structural Soil™, some engineers may want to do this, immediately under the pavement.

Given the large volume of CU-Structural Soil™ for tree roots to explore, irrigation may not be necessary after tree establishment—the decision depends on the region of the country and on site management. While there is less moisture in CU-Structural Soil™ on a per-volume basis than in conventional soil, the root system in structural soil has more room for expansion, allowing for increased water absorption. Supplemental water should be provided during the first growing season as would be expected for any newly planted tree. In regions where irrigation is necessary to grow trees, low-volume, under-pavement irrigation systems have been used successfully. Fertilizer can be dissolved into the irrigation water if necessary, although to date, nutrient deficiencies have not been noted, probably due to the large volume of rooting media.

Fig. 1.15 In this parking lot, there is only a 2 foot opening for tree planting. Here CU-Structural Soil™ was installed parallel to railroad tracks, 12’ wide and 36” deep. With such a narrow opening, there is no reason to use a planting mix other than CU-Structural Soil™ around the tree ball.

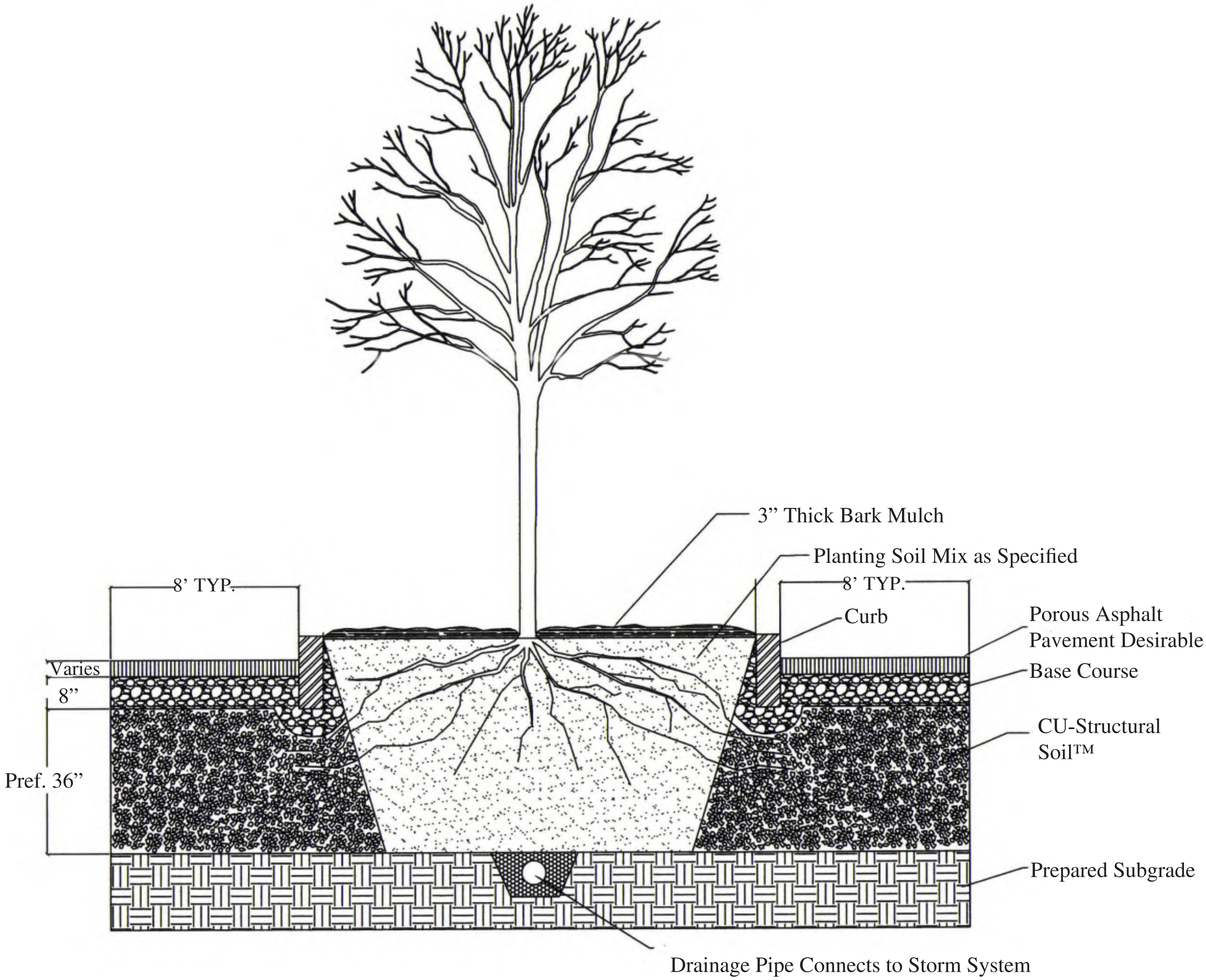


Fig. 1.16 Bare root tree in typical parking lot island or plaza

Fig. 1.17 English oaks planted in a plaza at Battery Park City, NYC

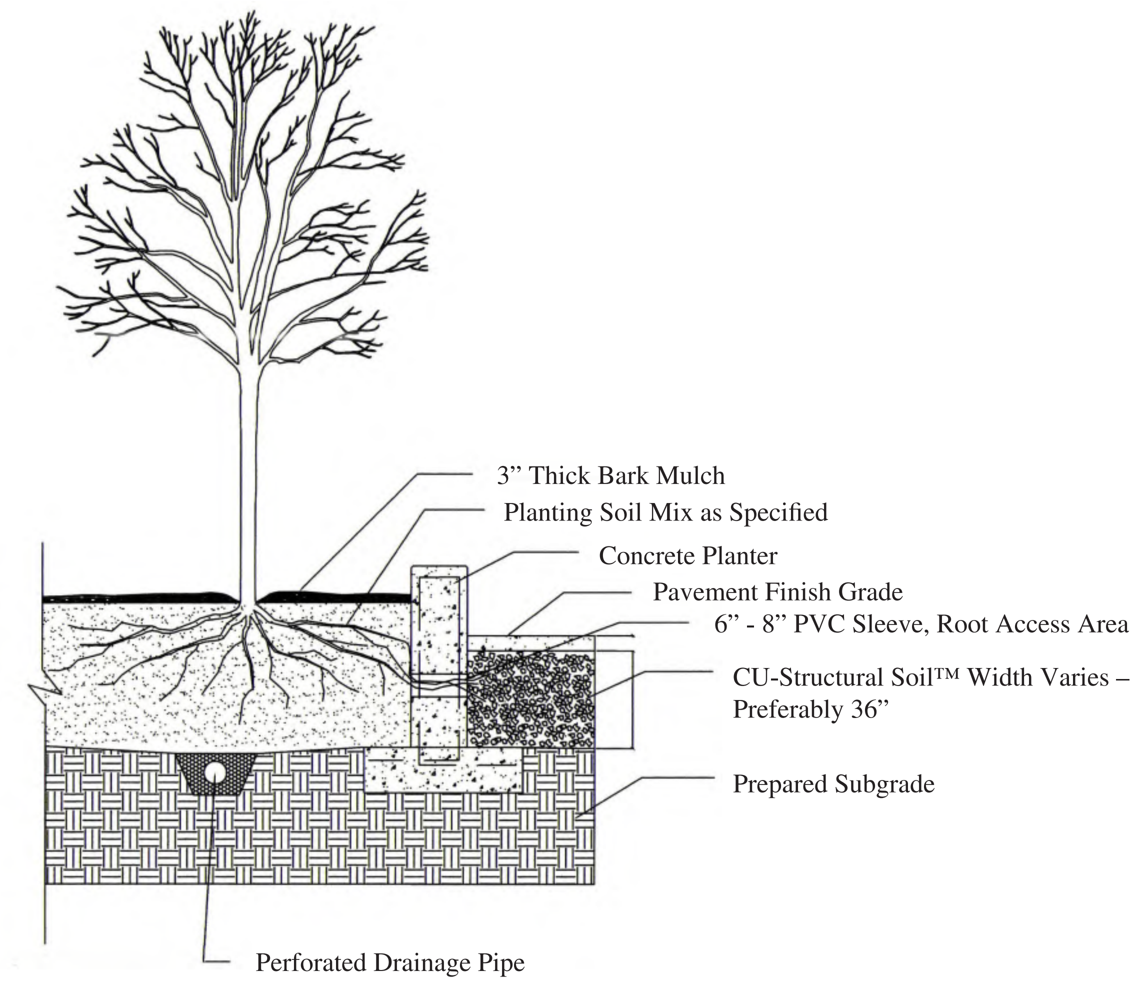


Fig. 1.18 Limited soil volume planter with root access into CU-Structural Soil™ under plaza pavement

Positive drainage below the root system is necessary in this system, since the sub-grade below the CU-Structural Soil™ may be compacted and impermeable. A perforated and wrapped drain, connected to storm drainage, should be placed between the CU-Structural Soil™ and the compacted sub-grade (Fig.1.18).

Where the curb footer goes to greater depth for a planter, a 6”- 8” PVC sleeve filled with uncompacted soil should be used to give tree roots access to the CU-Structural Soil™ beyond the planter wall (Figs 1.18-1.19).

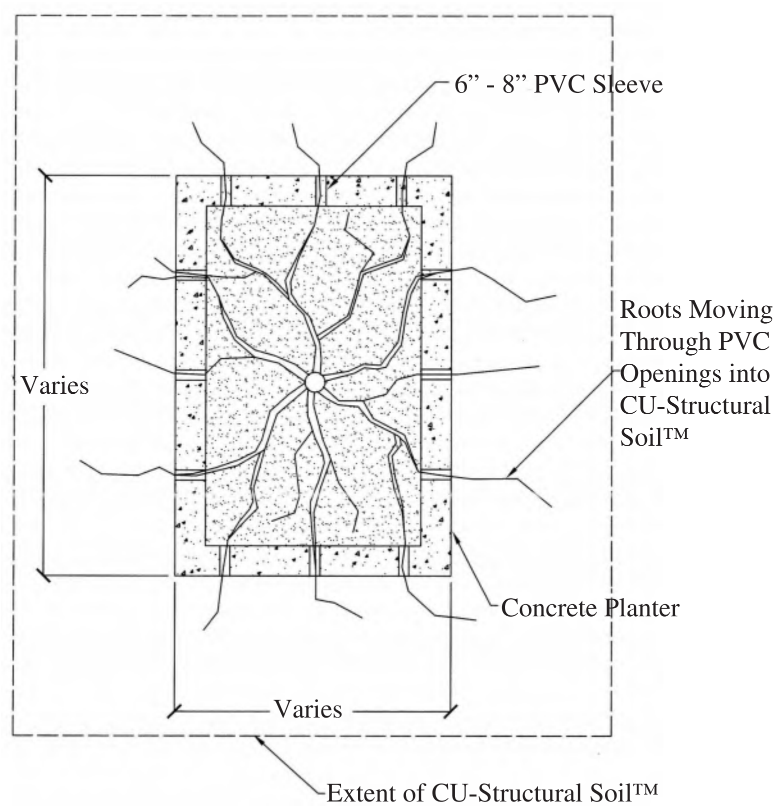


Fig. 1.19 Plan view of limited soil volume planter

Creating break-out zones for trees in narrow tree lawns

Where there is an adjacent green space, whether a park or front lawn, CU-Structural Soil™ may be used as a channel for roots to safely grow under pavement into this green space (Figs. 1.20 - 1.23). Generally two 5' concrete flags are removed, then the area is excavated to 24"- 36" and CU-Structural Soil™ is backfilled into them. Paving slabs are then replaced in a conventional manner.

Fig. 1.20 Break-out zone with CU-Structural Soil™ under a sidewalk between a narrow tree lawn and adjacent landscape area

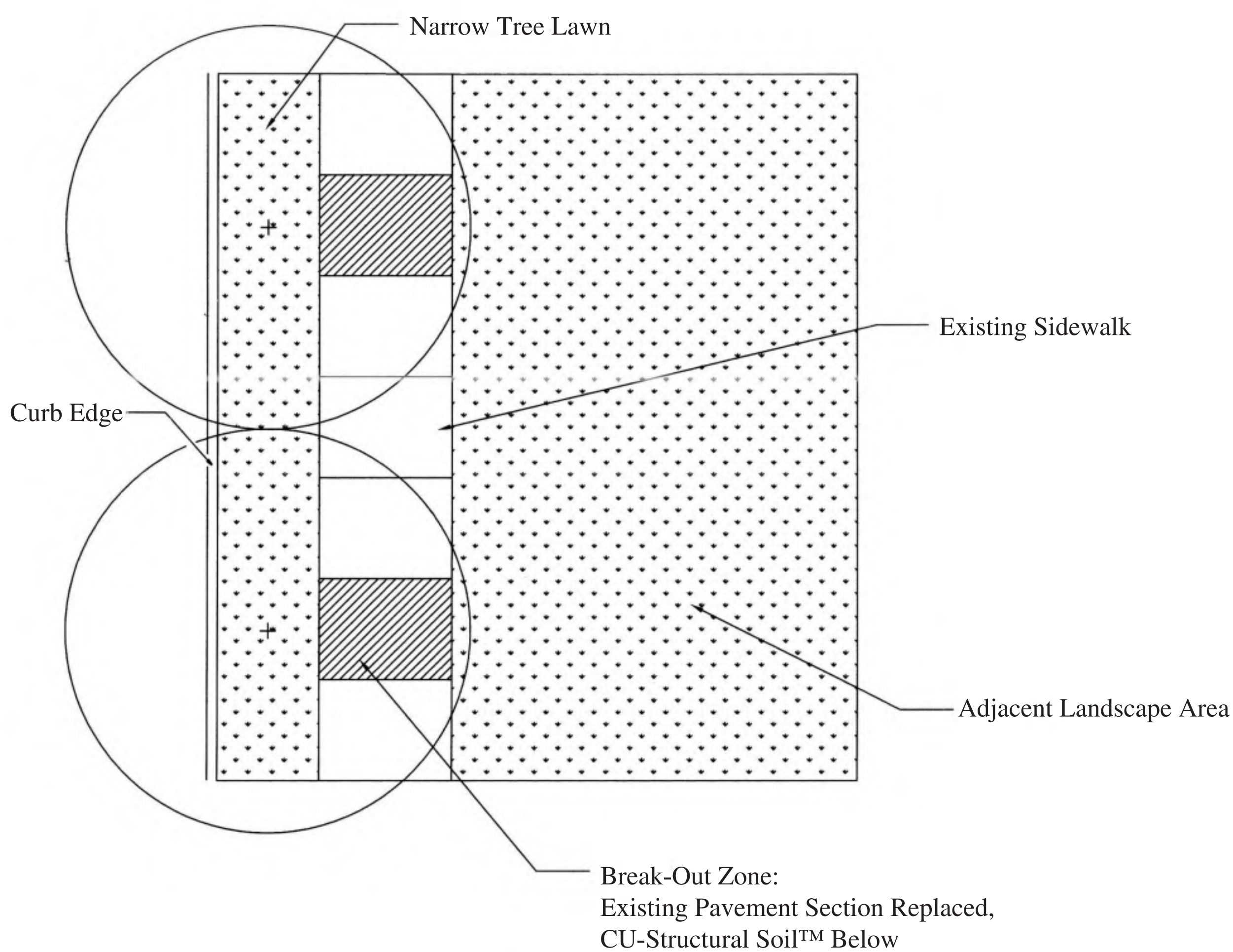


Fig. 1.21 Plan view of retrofitted CU-Structural Soil™ break-out zone

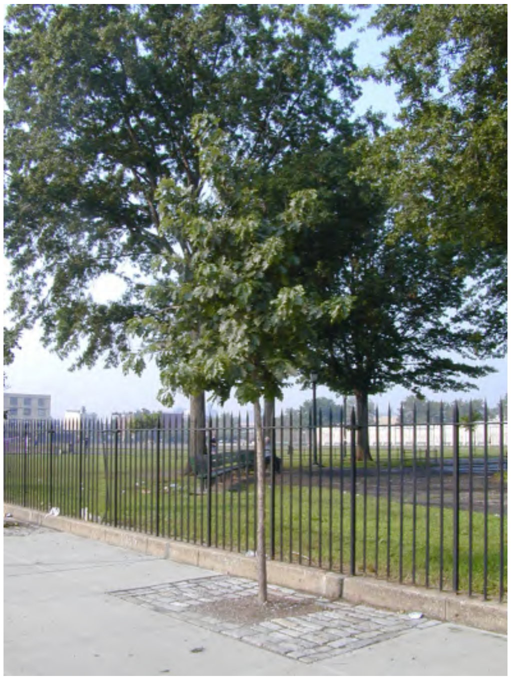


Fig. 1.22 Trees planted in Brooklyn, NY in 1997 where CU-Structural Soil™ was installed in a continuous trench 7' wide adjacent to the park fence.

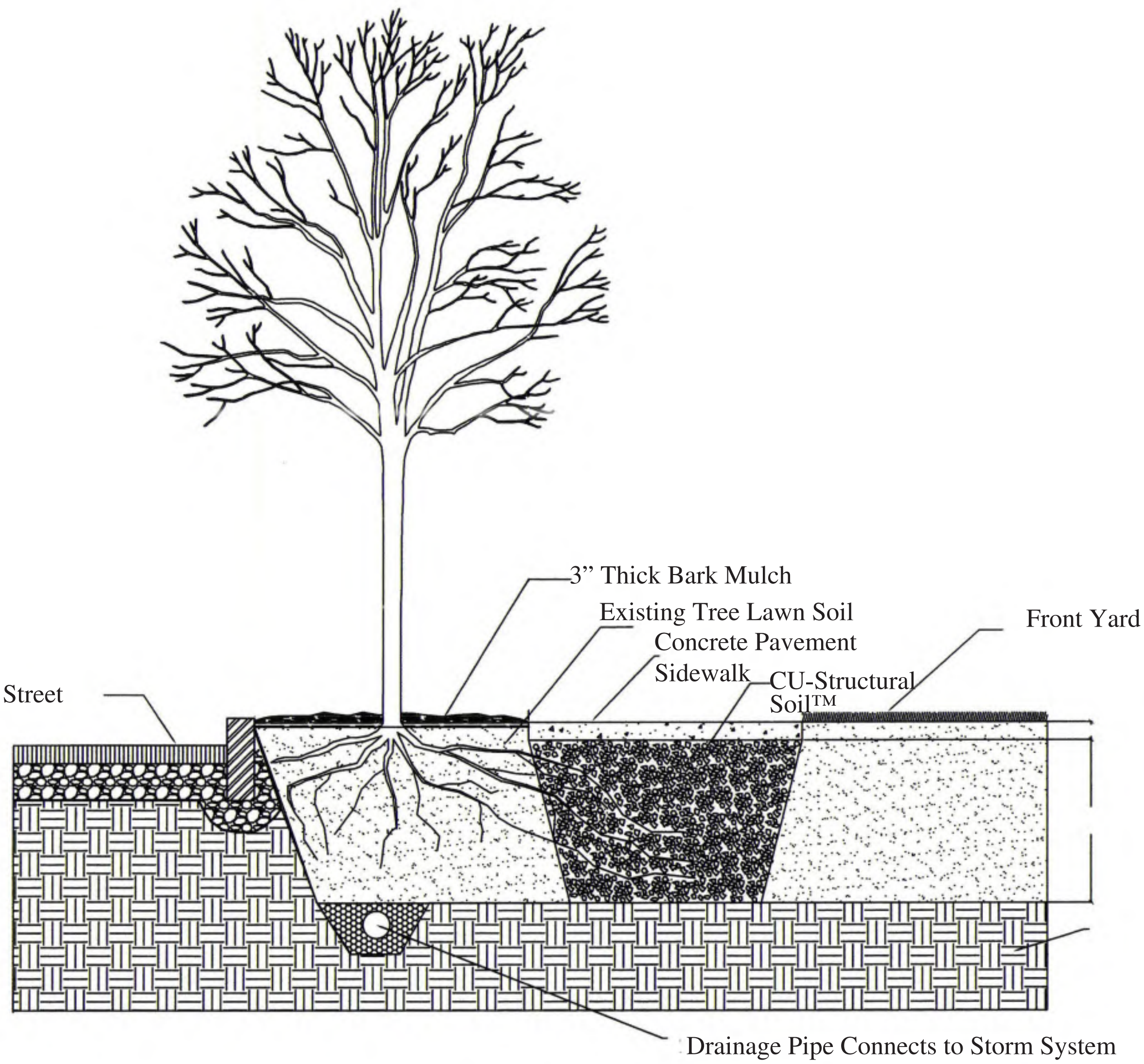


Fig. 1.23 CU-Structural Soil™ break-out zone from narrow tree lawn to adjacent landscape area

CU-Structural Soil ™ use with permeable pavers

If non-mortared pavers are used, a setting bed of uniformly-graded coarse sand should be used, to a depth specified by paver manufacturer specifications. To discourage rooting in this layer, a geo-textile—one that does not restrict water movement—can be used between this material and the CU-Structural Soil™ (Figs. 1.24 - 1.25).

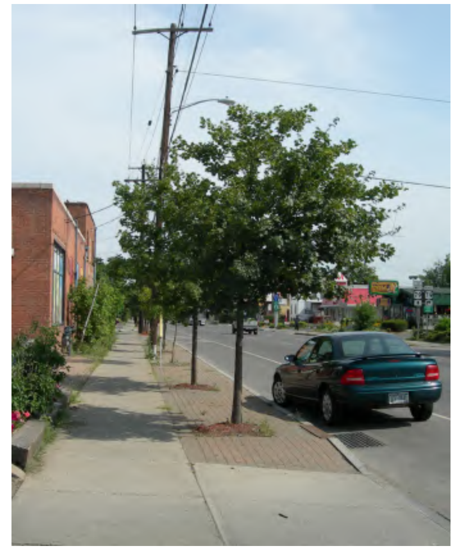


Fig. 1.24 Concrete unit pavers on a coarse sand setting bed on top of a continuous trench of CU-Structural Soil™ in Ithaca, NY

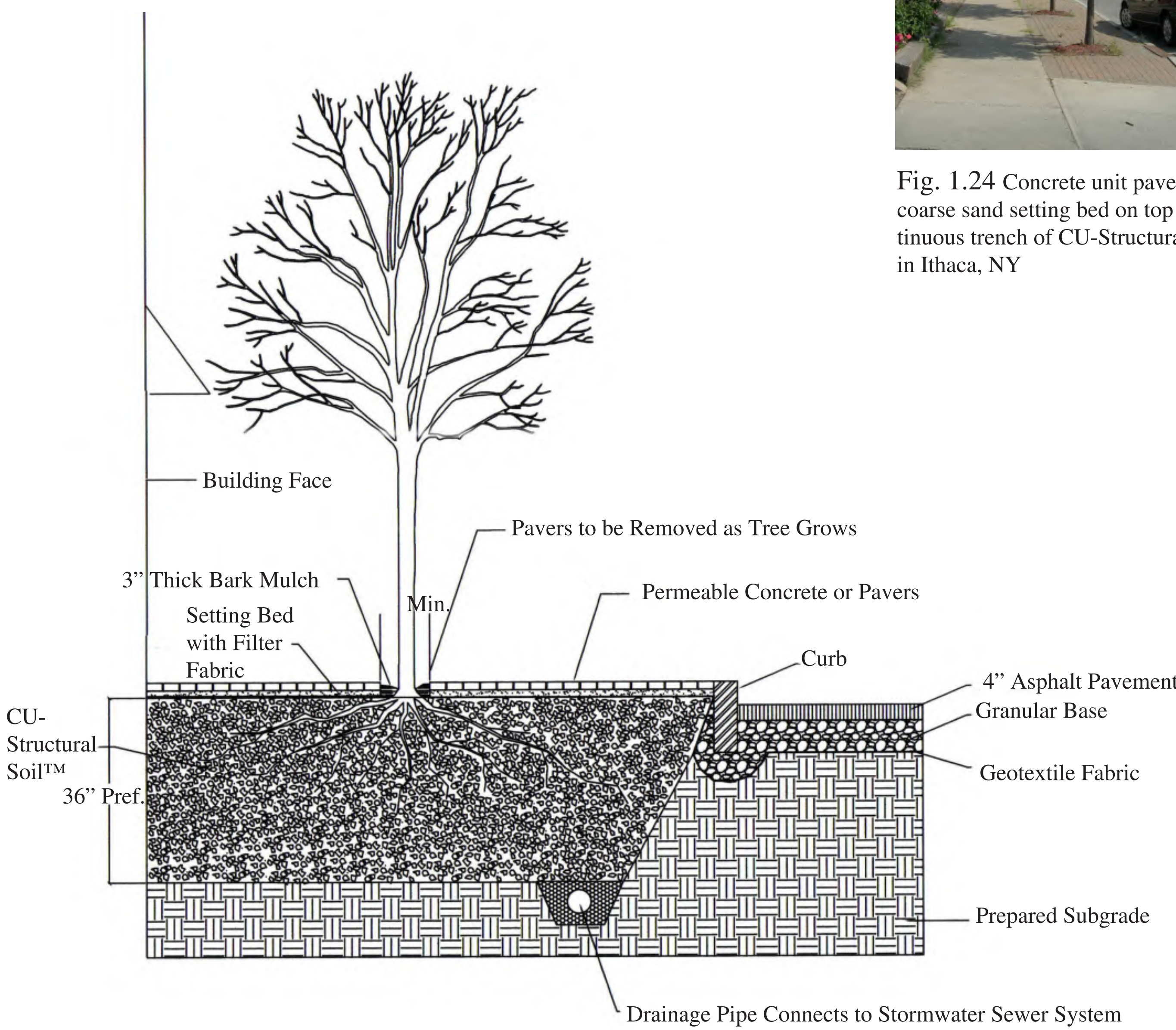


Fig. 1.25 Street tree detail with permeable pavers

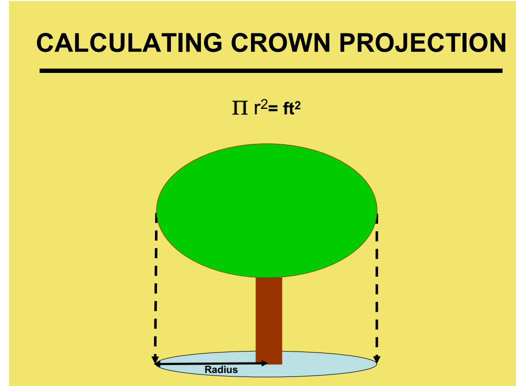
Some Street Trees Appropriate for use in CU-Structural Soil™

(Guiding selection criteria: moderate to highly drought tolerant and alkaline soil tolerant trees)

Botanic Name	**Common Name**
Acer campestre	Hedge Maple
Acer miyabei	Miyabei Maple
Acer nigrum	Black Maple
Acer platanoides	Norway Maple
Acer pseudoplatanus	Sycamore Maple
Acer truncatum	Painted Maple
Carpinus betulus	European Hornbeam
Catalpa speciosa	Northern Catalpa
Celtis occidentalis	Hackberry
Cercis canadensis	Redbud
Cornus mas	Cornelian Cherry
Cornus foemina (Cornus racemosa)	Gray Dogwood
Corylus colurna	Turkish Hazelnut
Crataegus crus-galli	Cockspur Hawthorn
Crataegus phaenopyrum	Washington Hawthorn
Crataegus punctata	Thicket Hawthorn
Crateagus viridis	Green Hawthorn
Eucommia ulmoides	Hardy Rubber Tree
Fraxinus americana	White Ash
Fraxinus excelsior	European Ash
Fraxinus pennsylvanica	Green Ash
Ginkgo biloba	Ginkgo
Gleditsia triacanthos	Honey Locust
Gymnocladus dioicus	Kentucky Coffee Tree
Koelreuteria paniculata	Goldenrain Tree
Maclura pomifera	Osage Orange
Malus spp.	Crabapple
Parrotia persica	Ironwood
Phellodendron amurense	Amur Cork Tree
Platanus x *acerifolia*	London Plane
Populus alba	White Poplar
Populus deltoides	Northern Cottonwood
Populus tremuloides	Quaking Aspen
Pyrus calleryana	Callery Pear
Pyrus ussuriensis	Ussurian Pear
Quercus macrocarpa	Mossy-Cup Oak
Quercus muehlenbergii	Chinkapin Oak
Quercus robur	English Oak
Robinia pseudoacacia	Black Locust
Styphnolobium japonicum (Sophora japonica)	Japanese Pagoda Tree
Sorbus alnifolia	Korean Mountain Ash
Sorbus thuringiaca	Oak-Leafed Mountain Ash
Syringa reticulata	Japanese Tree Lilac
Tilia americana	Basswood
Tilia cordata	Littleleaf Linden
Tilia tomentosa	Silver Linden
Tilia x *euchlora*	Crimean Linden
Ulmus americana	American Elm
Ulmus carpinifolia	Smooth-Leaf Elm
Ulmus parvifolia	Lace Bark Elm
Ulmus spp.	Elm Hybrids
Zelkova serrata	Japanese Zelkova

(names in parentheses are older botanic names)

Frequently Asked Questions



What volume of CU-Structural Soil™ is needed for a given tree?
The Urban Horticulture Institute at Cornell has found that, with the exception of the desert southwest, two cubic feet of soil is needed for every square foot of crown projection (the anticipated area under the drip line of the tree at expected maturity). Trees growing in CU-Structural Soil™ in areas that normally use irrigation to grow trees should also provide low volume drip irrigation in CU-Structural Soil™ installations.

What is the recommended depth for CU-Structural Soil™?
We suggest a minimum of 24" but 36" is preferred. A base course of gravel is not needed on top of CU-Structural Soil™ because it was designed to be as strong as a base course. Properly compacted to 95-100% Proctor Density or Modified Proctor Density, it has a CBR of 50 or greater.

What is the recommended length and width for CU-Structural Soil™ installation?
There is no established minimum. However, CU-Structural Soil™ was designed to go under the entire pavement area. This homogeneity would ensure uniform engineering characteristics below the pavement, particularly in regard to frost heaving and drainage. Ideally, the installation should focus on a whole sidewalk section from building face to curb, potentially for a whole block. If it is impossible to use the entire sidewalk area, using CU-Structural Soil™, it can be placed in a 5'- 8' wide trench parallel to the curb.

Won't the soil migrate down through a CU-Structural Soil™ profile after installation?
The excavation of a seven-year-old installation did not show any aggregate migration. The pores between stones in CU-Structural Soil™ are mostly filled with soil so there are few empty spaces for soil to migrate to.

Does hydrogel break down over time?
Over a long period of time, the soluble salts from which the hydrogel was produced, i.e. potassium (from potassium hydroxide) and ammoniacal nitrogen (from acrylamide) is released. The inert hydrogel becomes a minimum part of the soil system. Beyond that, we believe that colonizing roots and other organisms will, over time, replace the spatial and tackifying roles of the hydrogel. Research on this subject is on-going.

What happens when roots expand in CU-Structural Soil™?
There will come a time when the roots will likely displace the stone, but if the roots are, as we have observed, deep down in the profile, the pressure they generate during expansion would be spread over a larger surface area. We have seen roots move around the stone and actually surround some stones in older installations, rather than displace the stones.

Is CU-Structural Soil™ susceptible to frost heave?
This topic has not been rigorously tested, but we have not observed frost heave damage in the Ithaca, NY installations. Based on drainage testing and swell data on this extremely porous system, CU-Structural Soil™ appears quite stable.

Can you add normal soil in the tree pit and CU-Structural Soil™ under the pavement?
It would be desirable to use CU-Structural Soil™ under the tree ball to prevent the root ball from sinking. Planting trees directly in CU-Structural Soil™ provides a firmer base for unit pavers close to the root ball than does conventional soil. If the tree pit is sufficiently large, greater than 5' x 5', a conventional soil could be used in the open tree pit surrounding the root ball with CU-Structural Soil™ extending under the pavement.

Can you use balled-and-burlapped, bare root, or containerized trees in CU-Structural Soil™?
Trees from any production system can and have been used. It is important to water the newly planted tree as would be expected in any soil.

Should CU-Structural Soil™ be used in urban areas without pavement over the root zone?
CU-Structural Soil™ was designed to be used where soil compaction is required, such as under sidewalks, parking lots, medians, plazas, and low-access roads. Where soils are not required to be compacted, a good, well-draining soil should be used.

Can you store large quantities of CU-Structural Soil™?
CU-Structural Soil™ is produced by licensed producers and is preferably not stockpiled. It is mixed as necessary and should be delivered and installed in a timely manner. If any stockpiling is required, protection from rain and contamination should be provided.

Can CU-Structural Soil™ be utilized under existing trees?
There are several instances where CU-Structural Soil™ was utilized under and adjacent to existing trees. It appears that if few tree roots are damaged during the installation, the trees continue to grow well. Research is currently under way to investigate this issue.

What are the oldest installations of CU-Structural Soil™, and where are they?
The two oldest installations date to 1994; the first is a honeylocust planting at the Staten Island Esplanade Project in NYC, the second is a London plane tree planting on Ho Plaza on the Cornell campus, Ithaca, NY. There are now numerous installations of various sizes across the United States and Canada. For more information about installations, visit www.structuralsoil.com or contact Brian Kalter at Amereq, Inc. (see below).

Obtaining CU-Structural Soil™

CU-Structural Soil™ has been patented and licensed to qualified producers to ensure quality control; its trademarked names are CU-Structural Soil™ or CU-Soil™. By specifying this material, the contractor is guaranteed to have the material mixed and tested to meet research-based specifications. There are licensed producers throughout the US and in Canada. To find the one in your region or to become a licensee, contact Brian Kalter (bkalter@amereq.com) or Fernando Erazo (FE@amereq.com) at Amereq Inc., 19 Squadron Blvd. New City, New York 10956. (800) 832-8788

Further Information

See the Urban Horticulture Institute website:
www.hort.cornell.edu/uhi and go to Outreach > Structural Soil

A DVD showing videos of the mixing, installation and tree growth in CU-Structural Soil™ is available at:
www.hort.cornell.edu/uhi/outreach/csc/index.html

Or contact Dr. Nina Bassuk (nlb2@cornell.edu), (607) 255-4586

Research papers supporting this work:

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• Grabosky, J., Bassuk, N.L., and Marranca, M.B. 2002. Preliminary Findings from Measuring Street Tree Shoot growth in two Skeletal Soil Installations Compared to Tree Lawn Plantings. Journal of Arboriculture 28(2):106-108.
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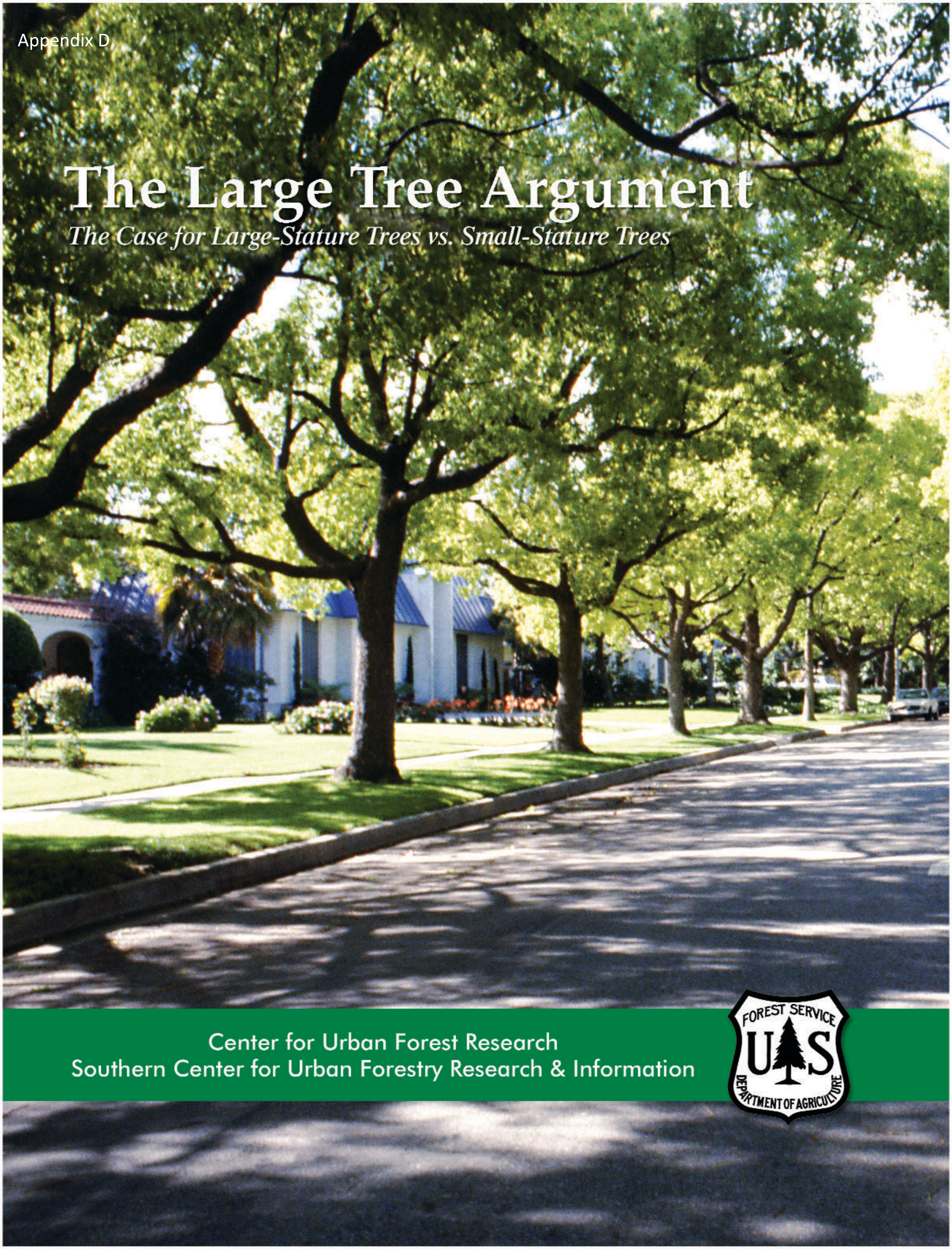
• Trowbridge, P. and Bassuk, N.L. 2004. 'Trees in the Urban Landscape: Site Assessment, Design and Installation'. Chapter 3:61-81. Wiley and Sons, Inc.

Fig 1.26 In this three-year field study a normal soil profile under sidewalk pavement as well as one with CU-Structural Soil™ were compared. Species used were hedge maple, little leaf linden, and crabapple.

Appendix D



The Large Tree Argument

The Case for Large-Stature Trees vs. Small-Stature Trees

Center for Urban Forest Research
Southern Center for Urban Forestry Research & Information

Why did we like elm trees so much?

Large stately elm trees once graced many communities throughout the US. But now they are gone. Why were entire communities so disappointed when they lost their elm trees to Dutch elm disease several decades ago?

People had a sense that these large trees were important to them, their family, and their community. And this was long before we quantified the benefits of trees. Now we have scientific evidence for what these people knew decades ago.

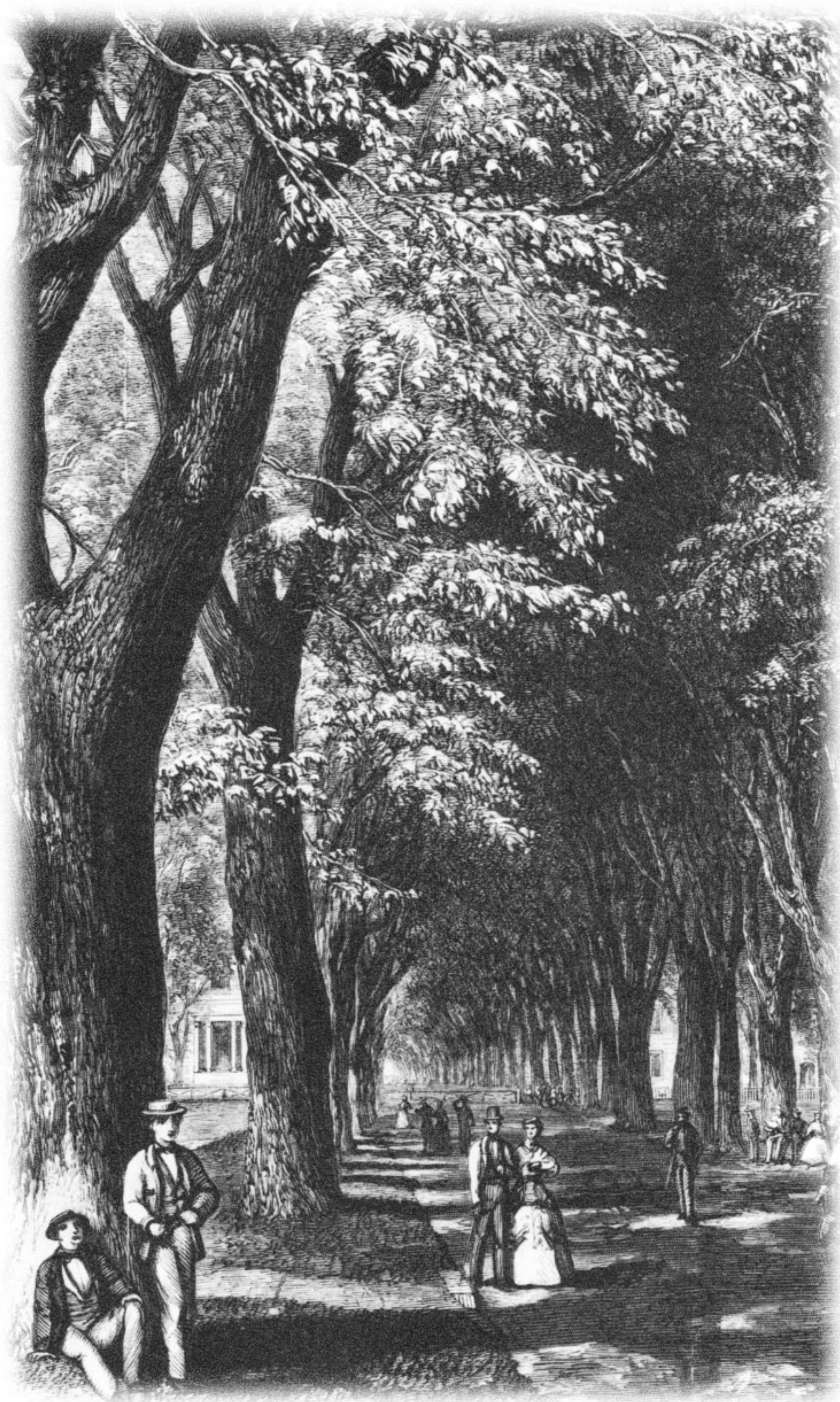
US Department of Agriculture

USDA Forest Service

Center for Urban
Forest Research
Pacific Southwest
Research Station
USDA Forest Service

Southern Center for
Urban Forestry Research
& Information
Southern Research Station
USDA Forest Service

Urban & Community Forestry
State & Private Forestry
USDA Forest Service



Large trees pay us back

We now know that, dollar for dollar, large-stature trees (see sidebar definition p.6) deliver big savings and other benefits we can't ignore. Small-stature trees like crape myrtle deliver far fewer benefits. In fact, research at The Center for Urban Forest Research shows that their benefits are up to eight times less.

Compared to a small-stature tree, a strategically located large-stature tree has a bigger impact on conserving energy, mitigating an urban heat island, and cooling a parking lot. They do more to reduce stormwater run off; extend the life of streets; improve local air, soil and water quality; reduce atmospheric carbon dioxide; provide wildlife habitat; increase property values; enhance the attractiveness of a community; and promote human health and well being. And when we use large-stature trees, the bottom-line benefits are multiplied. When it comes to trees, size really does matter.

Don't forget the established "Old Guard"

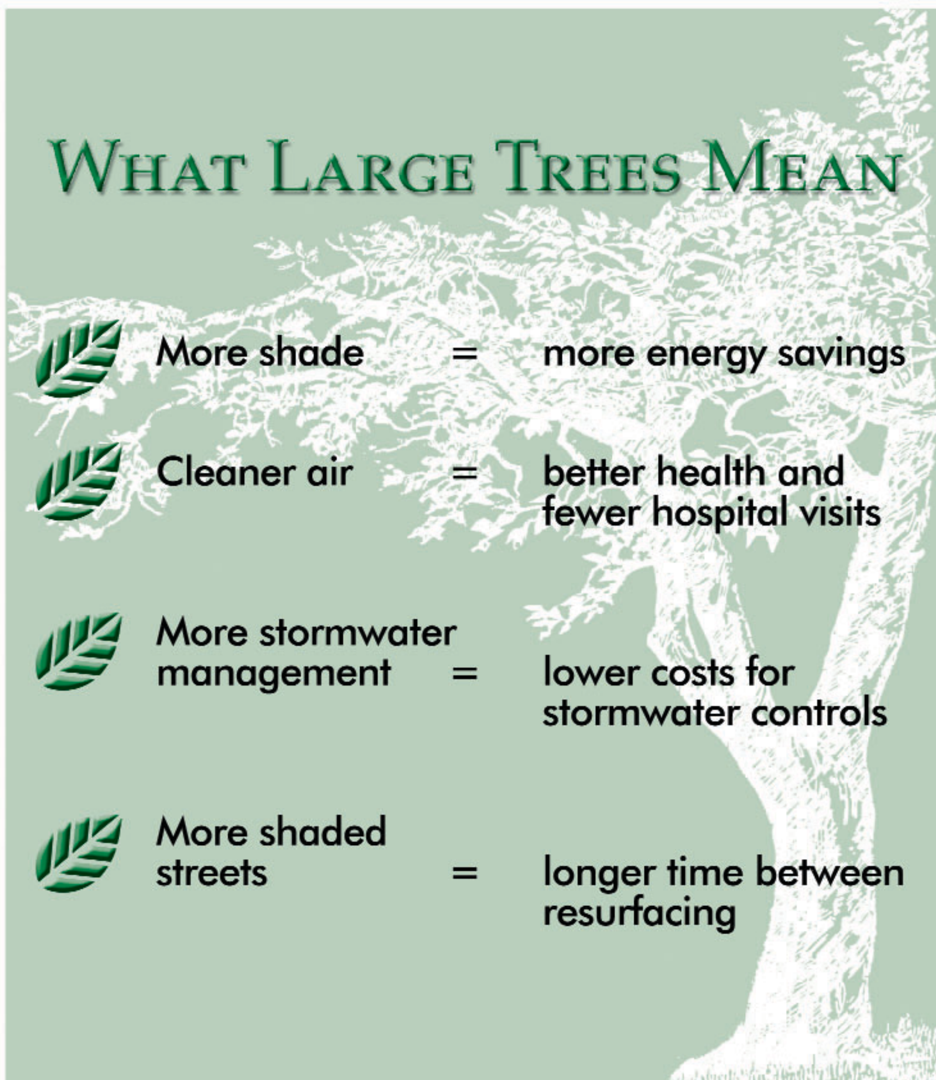
We can't forget the already-established trees. These older trees provide immediate benefits. The investment that community leaders made 30, 40, 50 years ago is producing dividends today. Dr. McPherson, Director of the Center for Urban Forest Research, points out that "since up-front costs to establish these large-stature trees have already been made, keeping these trees healthy and functional is one of the best investments communities can make."

What do you lose if you don't plant large trees?

Municipal tree programs are dependent on tax-payer supported funding. Therefore, communities must ask themselves, are large-statured trees worth the price to plant and care for? Our research has shown that benefits of large-statured trees far outweigh the costs of caring for them, sometimes as much as eight to one. The big question communities need to ask is: can we afford not to invest in our trees? Are we willing to forego all of these benefits? Or, would we rather make a commitment to provide the best possible care and management of our tree resource and sustain these benefits for future generations.

Costs vs benefits

In most areas of the country, communities can care for their largest trees for as little as $13 per year, per tree. And, each tree returns an average of $65 in energy savings, cleaner air, better managed stormwater, extended life of streets, and higher property values. Even at maturity, small-stature trees do not come close to providing the same magnitude of benefits.



A hypothetical example

A few years ago, the community of Greentree was faced with a budget crisis and decided to save money by downsizing its community forest—planting a majority of small-stature trees like crape myrtle in favor of large-stature trees like ash and even replacing large trees with smaller ones (see below). It made choice X. Unfortunately, this is not an uncommon story in communities today. But the real question is, what did they give up in return, and was downsizing a wise choice?

Table 1: Large trees vs small trees

The city of Greentree chose planting scenario X. By year 20 it was already a $60,000 annual mistake (see discussion above).

		CHOICE X		CHOICE Y	
	Avg. Ann. Benefit Avg. Ann. Cost	# Trees	Total Benefit Total Cost	# Trees	Total Benefit Total Cost
Large Trees	$65.18 $13.72	259	$16,882.00 $3,553.00	1,693	$110,350.00 $23,228.00
Medium Trees	$36.04 $6.87	753	$27,138.00 $5,173.00	753	$27,138.00 $5,173.00
Small Trees	$17.96 $6.23	1,693	$30,406.00 $10,547.00	259	$4,652.00 $1,614.00
Total Trees		**2,705**		**2,705**	
Total Benefits **Total Costs**			**$74,426.00** **$19,273**		**$142,140.00** **$30,015.00**
Annual Net Value to Community			**$55,153.00**		**$112,125.00**

Note: Each "tree" represents 259 trees planted.

In this case, the city decided that planting 1693 small-stature trees and only 259 large-stature trees would be a good budget-cutting strategy. Over the short term this may save the city a little money. But over the long term they will have decidedly fewer benefits and a decreased quality of life. City elected officials failed to consider what the city would be giving up over the life of those trees.

Will people want to live, work, recreate, do business, and shop in this community? And will the new trees provide all of the benefits that the residents seek—energy conservation, clean air, clean water, attractive surroundings, and enhanced real estate values. The answer is a resounding NO! The growth of these trees was modeled by The Center for Urban Forest Research over 40 years. By year 20, the decision-makers had already made nearly a $60,000 dollar annual mistake.

Choice Y is clearly the way to go to maximize their return on budget dollars. The model shows that once the trees are mature the community will receive an annual return on investment of nearly $60,000 over choice X. Plus, the community will look quite different in the future and be a healthier and safer place to live.

Is it possible to recreate the past ?

We may never have the arching canopies we once had with the stately elms of a few decades ago. But, we can still achieve large, extensive and functional canopies and reap all the benefits. It will take planting large-stature trees in as many appropriate places as possible while creating the best possible site that maximizes space and allows for adequate exchange of gases and water. And yes, it is possible!

Editors Note

We recognize that on some restricted sites small-stature trees may be the best choice. However, let's not succumb to the limited space argument so easily. We need to continue to fight for more space for trees in every new project and every retrofit. The bigger the tree, the bigger the benefits and, ultimately, the better our quality of life.

The Future Without Large Trees

Cities that are using small-stature trees to reduce costs may achieve some short-term savings, but over the long term, they have destined themselves to a future with fewer and fewer benefits as large-statured trees are replaced with smaller ones.

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What are trees worth?

The value of tree benefits varies widely, but can be as much as $80 to $120 per tree per year for a large tree. Small trees that never get very large, like the crape myrtle, provide not much more than $15 in benefits on average. In some cases they are a net loss to communities after the costs are subtracted. The Center for Urban Forest Research has studied large, medium, and small trees in a number of locations throughout the West and found that, on average, mature large trees deliver an annual net benefit two to six times greater than mature small trees:

Mature tree size
The approximate tree size 40 years after planting.

Relative Size at Maturity:

Small-stature
Less than 25 feet tall and wide with trunk diameters less than 20 inches.

Medium-stature
25 - 40 feet tall and wide with trunk diameters 20 - 30 inches.

Large-stature
Greater than 40 feet tall and wide with trunk diameters commonly over 30 inches.

Large Tree

- Total benefits/year = $55
- Total costs/year = $18
- Net benefits/year = $37
- Life expectancy = 120 years
- Lifetime benefits = $6,600
- Lifetime costs = $2,160
- Value to community = $4,440

Medium Tree

- Total benefits/year = $33
- Total costs/year = $17
- Net benefits/year = $16
- Life expectancy = 60 years
- Lifetime benefits = $1,980
- Lifetime costs = $1,020
- Value to community = $960

Small Tree

- Total benefits/year = $23
- Total costs/year = $14
- Net benefits/year = $9
- Life expectancy = 30 years
- Lifetime benefits = $690
- Lifetime costs = $420
- Value to community = $270

—hypothetical case using data for trees at year 30, projected to life expectancy from McPherson, E.G.; et. al. 2003. Northern mountain and prairie community tree guide: benefits, costs and strategic planting. Center for Urban Forest Research, Pacific Southwest Research Station, USDA Forest Service. 92p.

Fact Sheet: Making the Case for Large Trees

Large-stature trees need to be "marketed" as maximizing urban benefits:

- Cooling the air
- Shading paved surfaces
- Improving air and water quality
- Preventing water runoff and soil erosion
- And enhancing residential and commercial value

Even with these well-documented benefits, the challenges for increasing the number of large trees are consistently related to construction and preservation issues, space and persuading the community. Increasing the number of larger trees requires a combination of strategies that address these obstacles.

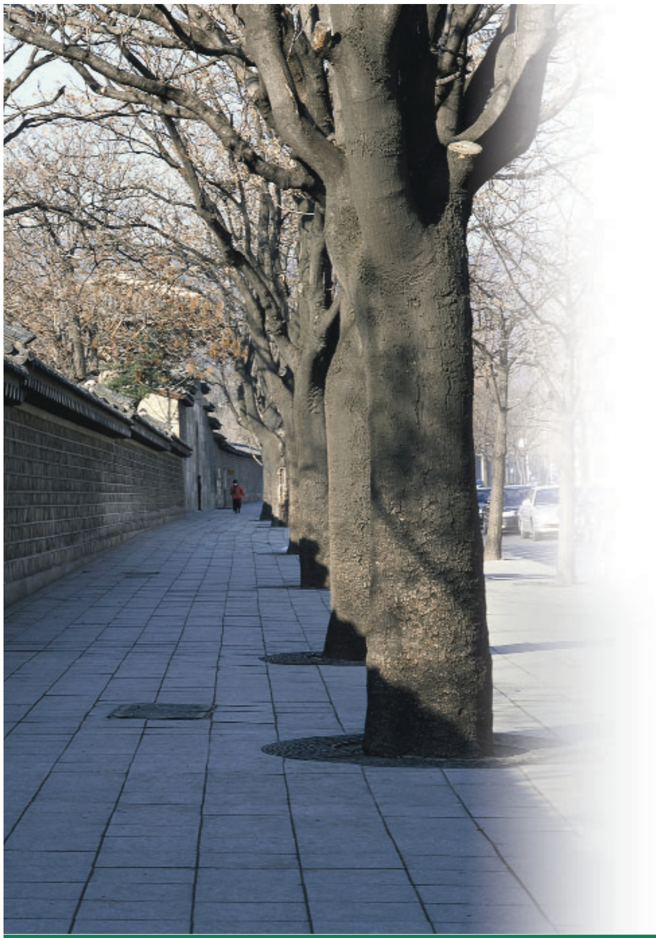
Construction and preservation obstacles

Consider both the preservation and planting of large trees in planning and design. Preserving large trees during construction:

- Start early in the process.

  Designate which trees need to be preserved. Larger more mature trees (that are in good condition) provide more value and benefits than smaller ornamental trees.
- Advise construction management of project schedules related to season-specific activities such as root pruning, fertilization, and insect control.
- Educate construction crews and the community about their role in preserving trees:
  - Soil compaction
  - Trunk and branch damage
  - Over or under watering
  - Chemical spills
- Pay careful attention to accidental damage, utility activities, or onsite crews that may impact the root system or soil composition.
- Accommodate utility lines near the critical root zone (CRZ), especially for larger trees by:
  - Tunneling under the tree root mat to install utility lines. This does little damage compared to trenching through the roots.
  - Use a pneumatic excavating tool for excavation work that must happen inside the CRZ. This tool can remove soil around tree roots without harming them.
- At the end of construction, plan for additional care as part of a recovery phase including watering, insect and disease control, and pruning.

- adapted from work by Charlotte King, President, Snowden & King Marketing Communications



Finding space

Accommodating larger trees is an ongoing challenge that is complicated by the competing needs for utility lines and impervious surfaces. Here are a few suggestions to address the issue of space during the planning and design phase:

- Recommend planting large-stature trees as part of transportation corridors whenever possible.
- Tree roots generally stay in the upper 18 inches of soil; therefore, ensure that pipes such as gas, electric, communication and water are installed deeper and use the space above for trees.
- A new publication, "Reducing Infrastructure Damage by Tree Roots: a Compendium of Strategies," clearly outlines ways to install large trees in limited space so they coexist in harmony with hardscape. It is available through the Western Chapter ISA at http://www.wcisa.net.

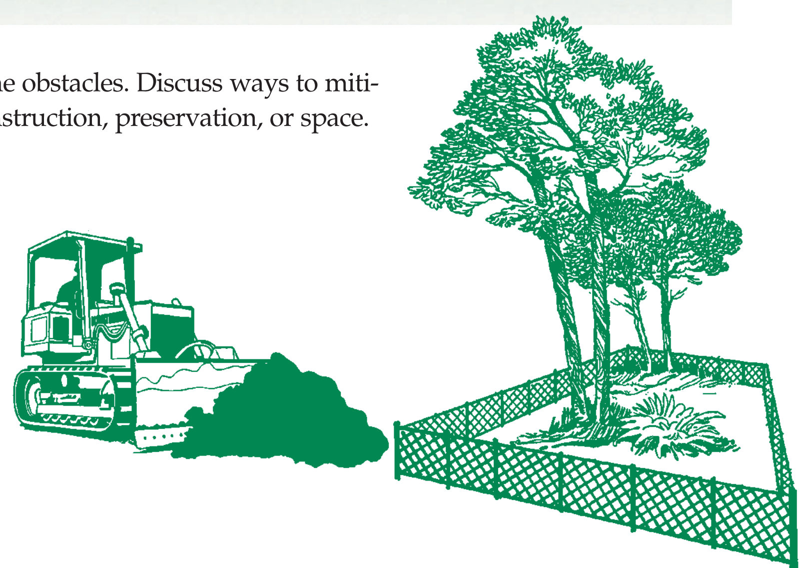
Persuading the Community

You are the tree expert, and the public is looking to you for guidance and best practices that they can rely on for critical decisions related to budgeting, construction, esthetics, and long-term environmental impact. You also have an opportunity to talk with them about selection, preservation, and critical maintenance of trees, and persuade them that the benefits of larger trees far outweigh the costs:

1. Explain the benefits of the larger trees and point out the obstacles. Discuss ways to mitigate these obstacles as described above in terms of construction, preservation, or space.

2. Play an active role in the construction process to limit the damage done to trees, and identify post-construction tree care. Make sure the community understands the ongoing tree care requirements.

3. Increase your "marketing expertise" in leveraging the value of community partners, media recognition, or historic preservation status. A little recognition combined with community education can make a big difference in changing the commitment to including larger trees in community projects.



Applying mulch

- Apply mulch so it covers the sides of the root ball. Be sure that when you are finished planting, there is no mulch or just a thin layer (1-2 inches deep) of mulch over the top of the root ball.
- DO NOT pile mulch against the tree trunk.

Watering after planting

- Irrigate daily for 1 week, then irrigate every two days for 4-6 weeks. Continue once a week watering for 1-2 years.
- Apply 3 gallons per inch of trunk diameter to the root ball each time you irrigate. Apply the water so that it soaks into the root ball.

Enjoy your tree!

If you have other questions, please contact

Carrie Stevenson
Florida Yards & Neighborhoods Agent
ctsteven@ufl.edu

Beth Bolles
Horticulture Agent
bbolles@ufl.edu

Escambia County Extension
850-475-5230

Jimmie Jarratt
Urban Forester
Escambia County
Neighborhood & Environmental
Services Department
Jimmie_jarratt@co.escambia.fl.us
850-595-3535

Or visit these websites:

http://escambia.ifas.ufl.edu/FYN_Index.htm

www.floridayards.org

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FLORIDA YARDS & NEIGHBORHOODS

Planting Trees

More than digging a hole!

A Guide for Homeowners

Why plant trees?

Your new tree will provide many benefits to your home. Trees not only provide wildlife habitat and add beauty and grace to your home, but they also improve air quality by producing oxygen and removing carbon dioxide. Trees help control stormwater runoff, moderate temperatures, buffer wind, and reduce energy use. Trees positively affect property values and provide privacy.

How to plant your tree

Successful tree planting does not happen by chance--it requires thought, planning, and attention to detail. Read these steps prior to and while planting your new tree. For more detailed information visit: http://hort.ifas.ufl.edu/woody/index.htm.

Before you start

Select a planting site. Look up and around. If there is a power line, security light, sidewalk, driveway, or building nearby that could interfere with proper development of the tree canopy and root system as it grows, plant elsewhere. Keep in mind that the root system will stretch out 2-3 times as far as the branch canopy!

Digging the hole

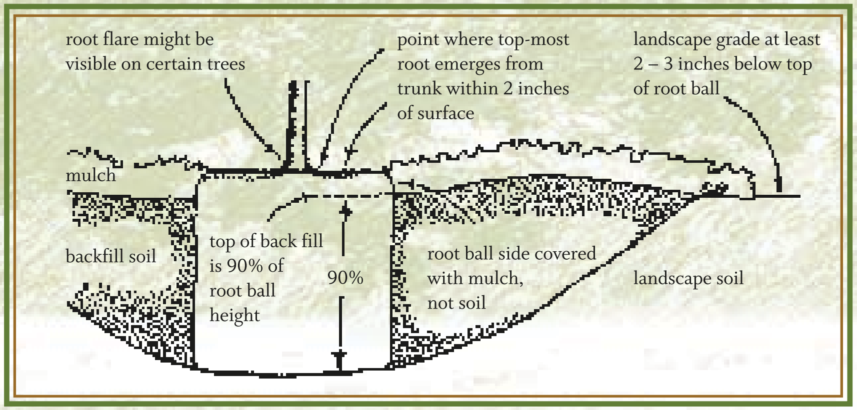
- Measure the root ball. Dig the hole this deep or slightly shallower than this depth. *Important: Do not dig the hole deeper than the root ball.*
- Dig the hole at least 3 -5 times the width of the root ball.
- Loosen the soil in the hole with a shovel, or another tool.

Placing the tree in the hole

- Remove all synthetic materials from around the trunk and root ball. String, rope, synthetic burlap, strapping, plastic, and other materials that will not decompose in the soil must be removed at planting.
- Position the root ball in the hole shallow enough so the topmost root flare is at the same level as the landscape soil. You may need to scrape away soil from the top of the root ball to find this level.
- Cut any roots that circle the top of the root ball.
- Straighten the tree in the hole. View the tree from two directions perpendicular to each other to confirm the tree is straight. Fill in with more backfill soil to secure the tree in the upright position.

Filling in the hole

- Backfill hole with remaining soil and landscape soil to a level slightly lower than the top of the root ball. Attempt to break up any soil clumps as much as possible. *Note: The top 1 to 2 inches of the root ball will be above grade.*
- DO NOT step firmly on the backfill soil because this could compact it and restrict root growth. Instead, water the soil to allow backfill to settle and add soil as necessary.



Trees

Power Outages

Trees and branches that fall on or grow into power lines are one of the main causes of power outages in our area. So before you plant a tree, please take into account the size it will grow as it matures — and the location of overhead lines. Every year, customers plant trees too close to existing power lines. These can become a potential hazard to public safety and reliable electric service and must be trimmed.

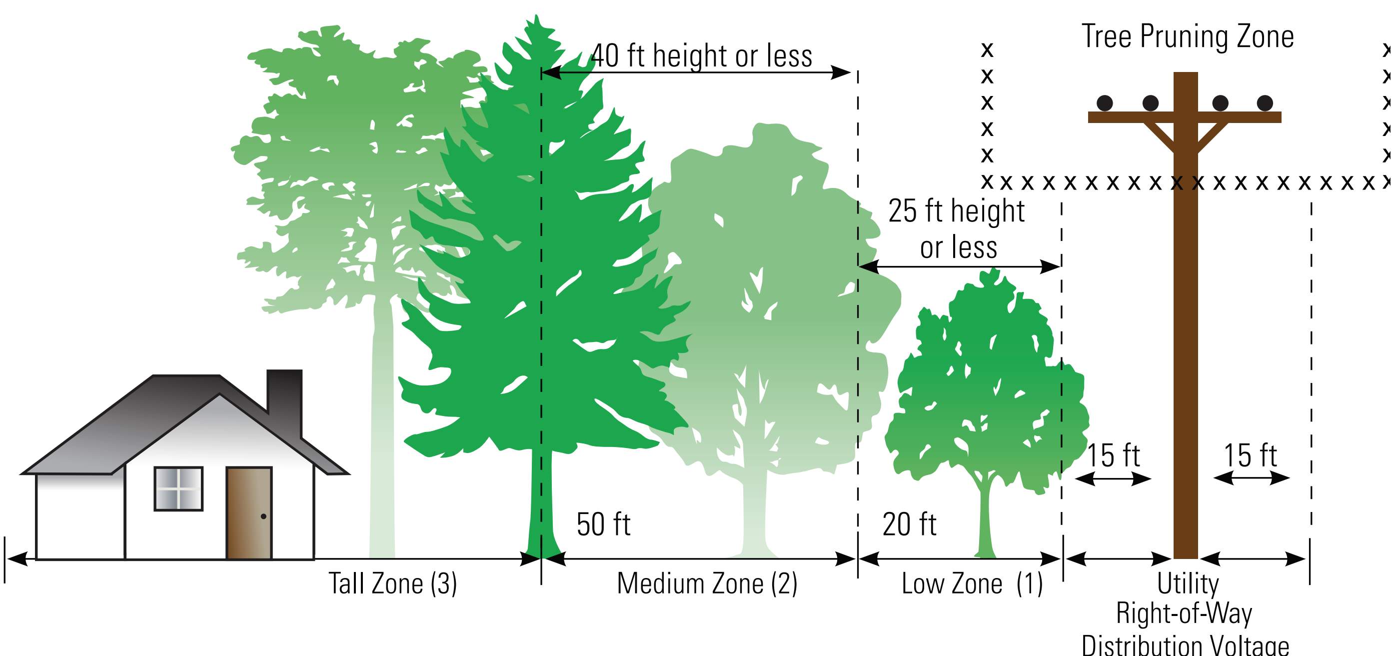
Gulf Power only trims trees near our primary lines going from pole to pole (in the right-of-way). We do not trim trees on your property from the pole to the house (called a service drop). If you need to trim the trees on your property, Gulf Power will come out and disconnect and reconnect your service for free.

When planting, please follow these guidelines:

- Small trees (Low Zone) can be planted near power lines.
- Medium-sized trees (Medium Zone) should be planted 25 to 40 feet from power lines.
- Large trees (Tall Zone) should be planted more than 50 feet from power lines.

Safety

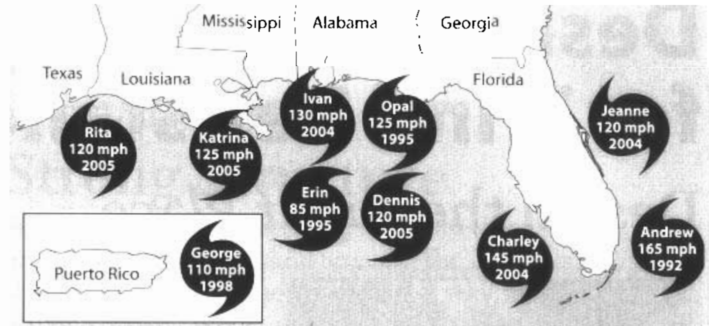
Tree limbs that are too close to power lines may become energized or may break and fall, bringing the power lines to the ground. If this occurs, stay away from the lines and call 911 immediately. For more information on trees that can be planted near power lines, please visit or contact your local nursery or the County Extension Service.



For all tree and vegetation concerns, please email treegulf@southernco.com or call Customer Service at 800-225-5797.

Wind Resistant Tree Species

These wind resistant tree lists were developed from research of ten hurricanes which struck the Southeast U.S. Coastal Plain, South Florida and Puerto Rico between 1992 and 2005. In addition, a survey of arborists, scientists and urban foresters contributed information to rank wind resistance. The recommended tree species are divided into the Southeast U.S. Coastal Plain region (which includes USDA hardiness zones 8 and 9) and Tropical and Subtropical regions (including USDA hardiness zones 10 and 11).



In the University of Florida/IFAS wind resistance study, urban forests were measured after 10 hurricanes. For each hurricane, the maximum sustained wind speed at landfall (mph) and year are listed.

U.S. Southeast Coastal Plain

American hophornbeam, *Ostrya virginiana*
Baldcypress, *Taxodium distichum*
Beech, blue, *Carpinus caroliniana*
Chickasaw plum, *Prunus angustifolia*
Common persimmon, *Diospyros virginiana*
Crape myrtle, *Lagerstroemia indica*
Dogwood, *Cornus florida*
Fringe tree, *Chionanthus virginicus*
Hickory, Florida scrub, *Carya floridana*
Hickory, mockernut, *Carya tomentosa*
Hickory, pignut, *Carya glabra*
Holly, American, *Ilex opaca*
Holly, dahoon, *Ilex cassine*
Holly, yaupon, *Ilex vomitoria*
Inkberry, *Ilex glabra*
Magnolia, saucer, *Magnolia x soulangiana*
Magnolia, southern, *Magnolia grandiflora*
Magnolia, sweetbay, *Magnolia virginiana*
Maple, Florida sugar, *Acer saccharum* subsp. *floridanum*
Maple, Japanese, *Acer palmatum*
Oak, live, *Quercus virginiana*
Oak, myrtle, *Quercus myrtifolia*
Oak, post, *Quercus stellata*
Oak, sand live, *Quercus geminata*
Oak, Shumard, *Quercus shumardii*
Oak, swamp chestnut, *Quercus michauxii*
Oak, turkey, *Quercus laevis*
Podocarpus, *Podocarpus* spp.
Pondcypress, *Taxodium ascendens*
Redbud, *Cercis canadensis*
River birch, *Betula nigra*
Sparkleberry, *Vaccinium arboreum*
Sweetgum, *Liquidambar styraciflua*
Tupelo, black, *Nyssa sylvatica*
Tupelo, water, *Nyssa aquatica*
White ash, *Fraxinus americana*
Winged elm, *Ulmus alata*

Palms

Cabbage, *Sabal palmetto*
Date, Canary Island, *Phoenix canariensis*
Date, *Phoenix dactylifera*
Pindo, *Butia capitata*

Tropical and Subtropical

Baldcypress, *Taxodium distichum*
Buttonwood, *Conocarpus erectus*
Cocoplum, *Chrysobalanus icaco*
Crape myrtle, *Lagerstroemia indica*
False tamarind, *Lysiloma latisiliquuum*
Geiger tree, *Cordia sebestena*
Gumbo limbo, *Bursera simaruba*
Hickory, Florida scrub, *Carya floridana*
Holly, dahoon, *Ilex cassine*
Ironwood, *Krugiodendron ferreum*
Lignumvitae, *Guaiacum sanctum*
Lychee, *Litchi chinensis*
Magnolia, southern, *Magnolia grandiflora*
Magnolia, sweetbay, *Magnolia virginiana*
Mahogany, *Swietenia mahagoni*
Mastic tree, *Sideroxylon foetidissimum*
Oak, live, *Quercus virginiana*
Oak, sand live, *Quercus geminata*
Paradise tree, *Simarouba glauca*
Pigeon plum, *Coccoloba diversifolia*
Podocarpus, *Podocarpus* spp.
Pondapple, *Annona glabra*
Pondcypress, *Taxodium ascendens*
Satinleaf, *Chrysophyllum oliviforme*
Sea grape, *Coccoloba uvifera*
Stopper, boxleaf, *Eugenia foetida*
Stopper, redberry, *Eugenia confusa*
Stopper, white, *Eugenia axillaris*
Sweetgum, *Liquidambar styraciflua*
Tupelo, black, *Nyssa sylvatica*

Palms

Alexander, *Ptychosperma elegans*
Areca, *Dypsis lutescens*
Bottle, *Hyophorbe lagenicaulis*
Blue latan, *Latania loddigesii*
Cabbage, *Sabal palmetto*
Chinese fan, *Livistona chinensis**
Coconut, *Cocos nucifera*
Date, Canary Island, *Phoenix canariensis*
Date, *Phoenix dactylifera*
Date, pygmy, *Phoenix roebelenii*
Fishtail, *Caryota mitis*
Florida silver, *Coccothrinax argentata*
Manila, *Adonidia merrillii*
Pindo, *Butia capitata*
Royal, *Roystonea elata*
Spindle, *Hyophorbe verschaffeltii*
Thatch, key, *Thrinax morrisii*
Thatch, Florida, *Thrinax radiata*
Triangle, *Dypsis decaryi*

** Caution: manage to prevent escape (as recommended by IFAS http://plants.ifas.ufl.edu/assessment.html)*

We present these lists with the caveat that no tree is perfectly wind-proof and that many other factors contribute to wind resistance including soil conditions, wind intensity, previous cultural practices, tree health and age. These lists do not include all trees that could be wind resistant. They list those species encountered during our studies in large enough numbers to run statistical comparisons.

FOR231

UF UNIVERSITY of FLORIDA
IFAS Extension

Southern Escambia County, Florida's Urban Forests[1]

Francisco Escobedo, Sebastian Varela, Christina Staudhammer, Benjamin Thompson, and Jimmie Jarratt[2]

Introduction

The urban forest provides a community numerous benefits and is composed of a mix of native and non-native species. The mix of tree sizes and conditions, as well as the distribution of trees is determined by climate, urbanization patterns, and human preferences. To better understand southern Escambia County's urban forest and its social, economic, and environmental benefits, we developed this publication to help assess: 1) composition and structure, 2) canopy cover, 3) carbon sequestration and storage, 4) air pollution removal, and 5) energy effects on residential buildings. We then compare southern Escambia County's urban forest with forests in other cities in the state of Florida. The information in this publication can provide useful benchmarks and information to urban foresters, residents, and planners so they can better manage this resource (Escobedo et al. 2007).

Methodology

Data was collected by sampling 79, random, 0.04-ha (0.10-acre) plots during 2008 over an area of 2,289 hectares (ha) (5,654 acres) in southern Escambia County, Florida (Figure 1). In these plots we measured tree diameter at breast height (DBH) (e.g. woody species with DBH greater than 2.5 cm regardless of growth habit), species, height, crown characteristics, location, as well as distance and direction relative to residential buildings. We also collected information on tree canopy cover, land use conditions, and shrub and surface cover. The data were analyzed using USDA Forest Service's Urban Forest Effects (UFORE) model (http://www.ufore.org). Key parameters estimated by the model include *leaf area*, which is the sum of all tree leaf surfaces; *carbon storage*, which in our model is the proportion of woody biomass held in the tree's stem and branches over its lifetime; and *carbon sequestration*, which is the estimated amount of annual carbon removed by trees through their growth.

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1. This document is FOR231, one of a series of the School of Forest Resources and Conservation Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date December 2009. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.

2. Francisco Escobedo, assistant professor; Sebastian Varela, research technician; Christina Staudhammer, assistant professor; Benjamin Thompson, graduate research assistant; and Jimmie Jarratt, environmental specialist, Escambia County, Florida; School of Forest Resources and Conservation, Institute of Food and Agricultural Sciences, University Florida

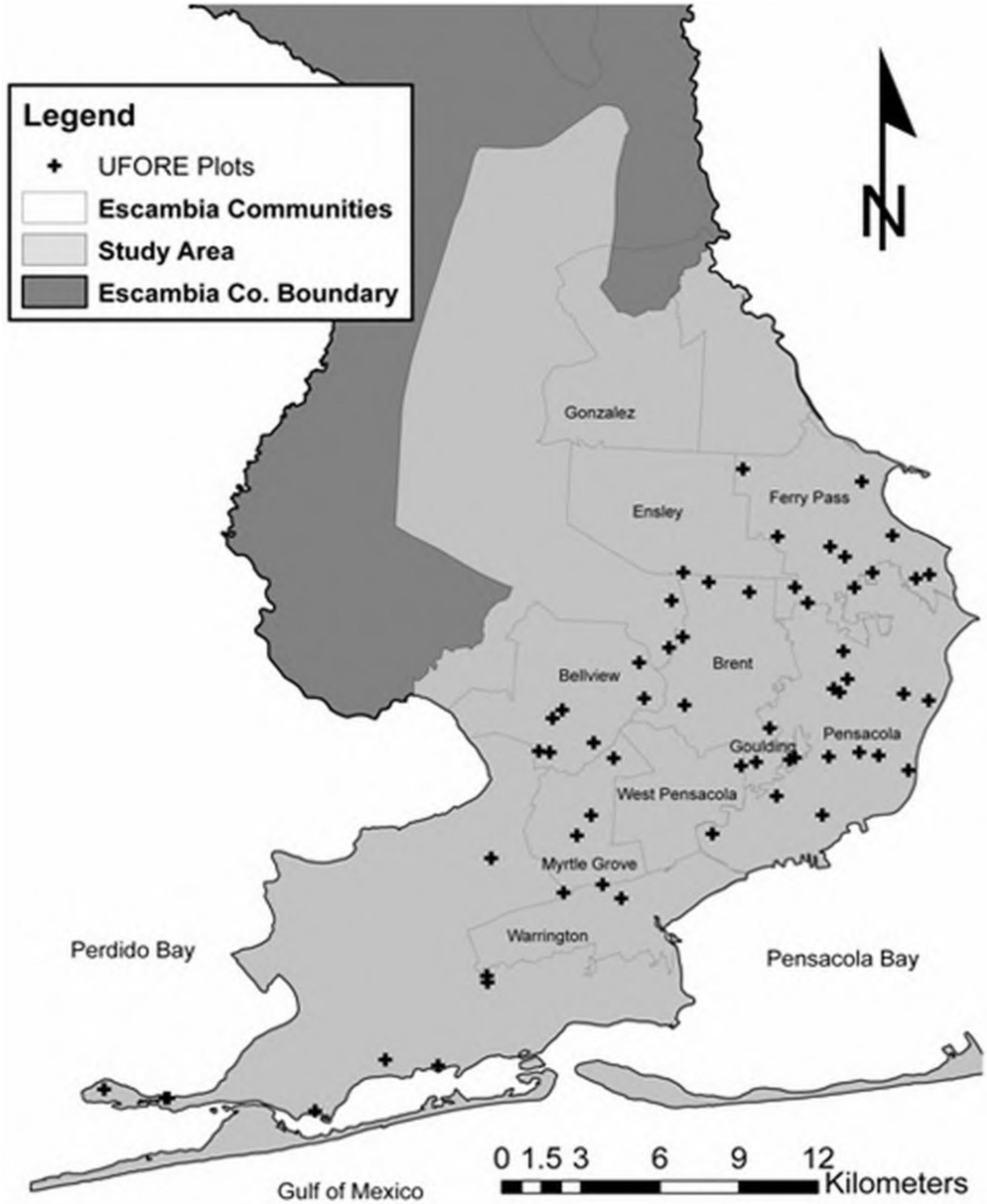

Figure 1. Urban forest effects (UFORE) analysis in the southern Escambia County area.

To estimate carbon storage, the model uses the relationship between a tree's size and its dry weight biomass (Escobedo et al 2009c). Approximately 50% of a tree's dry weight biomass is carbon. The average annual growth for specific types of trees, as well as their size, and condition were accounted for in estimating carbon sequestration rates (Nowak and Crane 2002). Since carbon sequestered by trees is often exchanged in markets in units of carbon dioxide, carbon estimates were converted to carbon dioxide (CO2) equivalents by multiplying by 3.67. Values were multiplied by $4 per metric ton of CO_2 equivalents ($4/mtCO2) based on the current market value (August 2008) on the Chicago Climate Exchange (2008).

The amount of air pollution removal by trees in southern Escambia County was estimated using tree cover and leaf area data as well as available hourly pollution and weather data for 2000. The amount of pollution removal was calculated for ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter less than ten microns (PM_{10}). Finally, estimates of urban tree effects on residential buildings energy use (e.g. heating and cooling) were based on field measurements of the distance and direction of trees greater than 20 feet tall relative to space-conditioned residential buildings less than 2 stories high. The UFORE model also incorporated tree type (e.g. evergreen or deciduous), building type and age, regional climate characteristics, and common carbon dioxide emissions from the generation of electricity in the southeastern United States (McPherson and Simpson 1999, Nowak and others 2006).

Urban forest structure and composition

Southern Escambia County's urban forest was composed of a relatively diverse number of species (Escobedo et al. 2009a). A total of 616 trees were measured and 65 different species were identified. Approximately 13 percent of all trees sampled were non-native to the state of Florida. Increased tree diversity can minimize the overall impacts by a species-specific insect or disease. An increase in the number of exotic-invasive plants can pose a risk to native plants if these out-compete and displace native plants.

The 10 most common species accounted for 82 percent of all trees. The three most common species in the city were laurel oak (*Quercus laurifolia*), swamp cyrilla (*Cyrilla racemiflora*), and loblolly pine (*Pinus taeda*), at 38, 10, and 8 percent of the total tree population, respectively (Figure 2). Tree composition varied by land use. Chinese tallow tree (*Triadica sebifera*; 71 percent) dominated commercial lands, crape myrtle (50 percent) dominated industrial lands, and laurel oaks dominated residential areas (22 percent) as well as forest and vacant lands (46 and 33 percent, respectively).

The study area had an estimated 720,720 trees. Trees with diameters at breast height between 2.5 and 13 cm (1 and 6 inches) account for 80 percent of southern Escambia County's total tree population. This is not uncommon for urban forests (Escobedo et al 2009a). The highest tree density occurs on forest lands with 1,705 trees per hectare (690 trees/acre) followed by vacant lands with an average of 890 trees per ha (360 trees/acre), followed by residential areas with 141 trees/ha (57 trees/acre) and then by commercial and industrial lands both with 49 trees/ha (20 trees/acre) (Figure 3). The average tree density in southern Escambia County, taking into account all of its land uses, is 315 trees/ha (127 trees/acre), which is greater than many other cities in the United States, which average 14 to 119 trees/acre (Nowak and others 2006). The high average number of trees per acre in southern Escambia County might be due to the abundance of remnant, naturally forested areas with high regeneration rates in the understory and an abundance of smaller sized trees.

Tree crown condition also varies by land use. Overall, 78 percent of the trees were classified as being in good and excellent condition, and 14 percent were classified as being in poor condition, declining, or dead. Industrial land use had the greatest percentage of excellent and good trees, whereas forest land use had the highest percentage of trees with poor or worse condition most likely due to lack of active tree maintenance, past hurricanes impacts and removals.

In summary, a large percentage of southern Escambia County's trees are smaller, which, in most cases, indicates a younger urban forest. Many different native trees can be found throughout the city. More than a half of all trees are found on forested lands. Land use change and hurricane impacts could have affected the urban forest structure assessed in this publication.

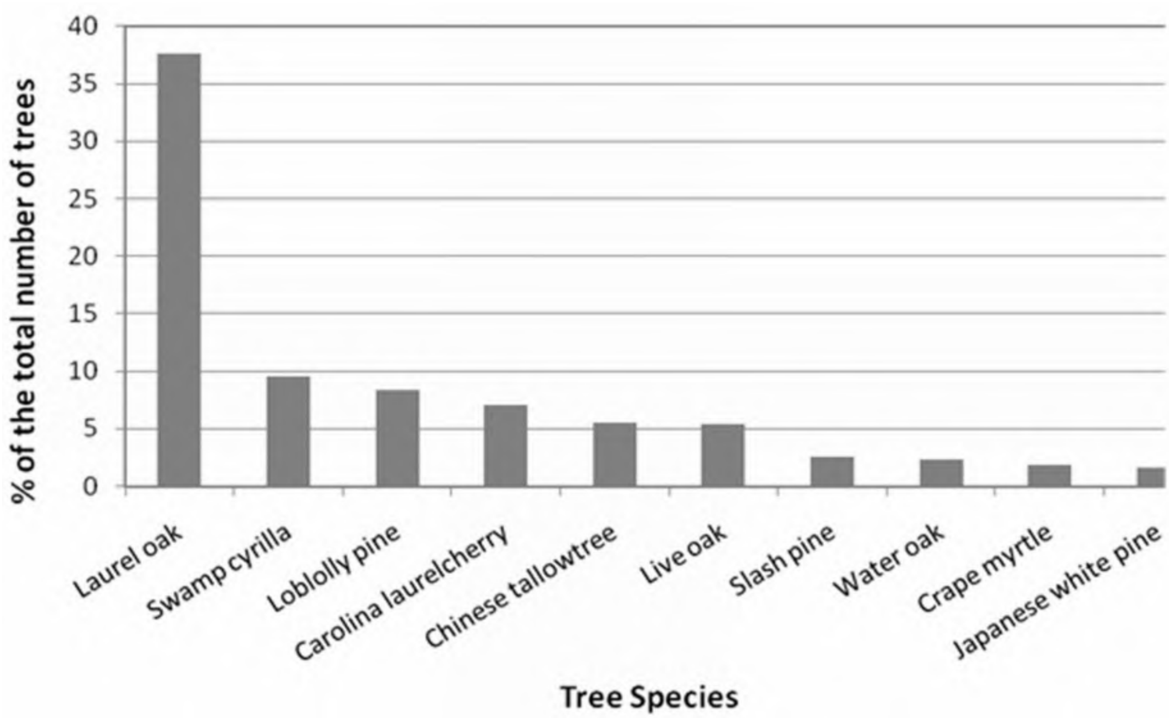

Figure 2. Top 10 most common trees sampled in southern Escambia County's urban forest in 2008.

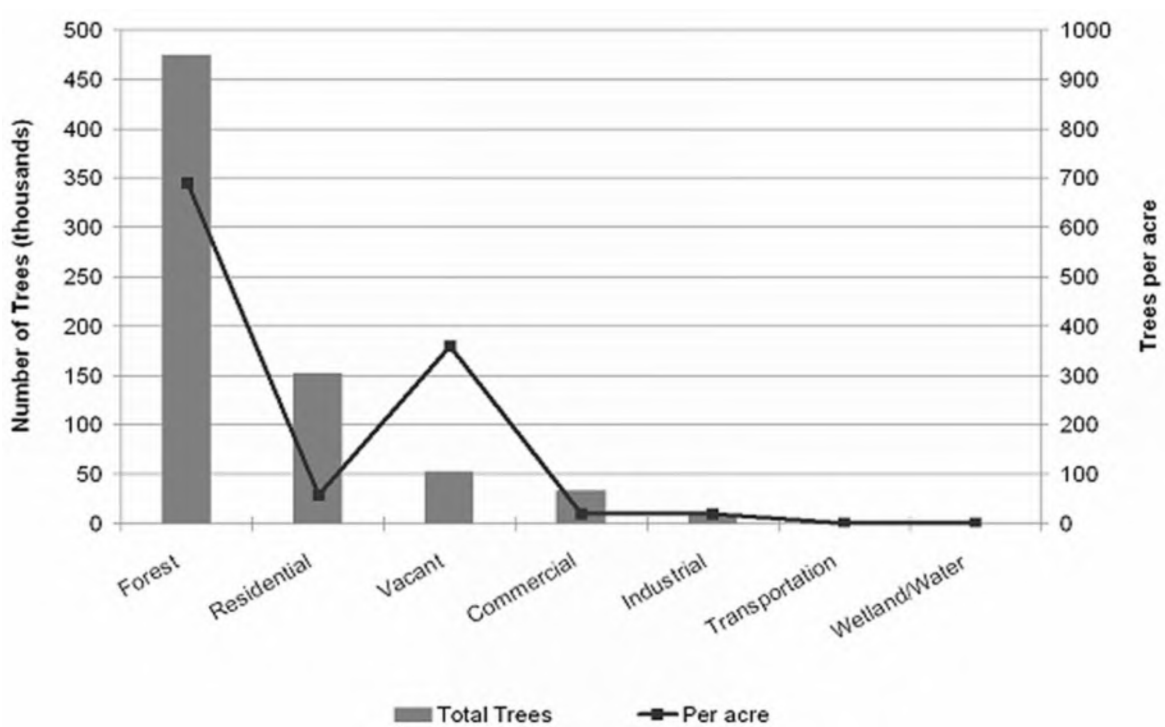

Figure 3. Tree distribution by land use of southern Escambia County's urban forest.

Canopy cover, ground cover and leaf area

Most ecosystem services from trees are linked directly to the amount of healthy urban forest canopy cover (Escobedo et al 2008b). Urban forest cover is dynamic and changes over time due to factors such as urban development, hurricanes, removals, and growth. The amount of a city's canopy cover depends on its land use, climate, and people's preferences. This section examines how tree composition and location influence urban forest canopy and leaf area, and how tree and ground surface covers vary across southern Escambia County.

Results obtained from the UFORE model and field data indicate *tree cover* in southern Escambia County was 14 percent while *shrub cover*, often present under trees, was 24 percent. Herbaceous surface cover (e.g. lawns, gardens, pastures) was 41 percent, impervious surface cover (e.g. concrete, roads, tar) was 22 percent, and buildings covered 11 percent of southern Escambia County (Figure 4). The amount of urban forest and impervious cover is often used as an indicator or standard by planners to establish future goals and targets. Over half of all trees were found in residential, industrial and vacant areas. Impervious and building surfaces are predominantly found in transportation and commercial areas.

While all tree species contribute to the community's overall urban forest cover, some species contribute more than others because of their size (e.g., crape myrtle versus a live oak). Approximately 57 percent of southern Escambia County's tree cover is evergreen (evergreen trees maintain their leaves year round and provide year-round functions). In southern Escambia County, trees that dominate in terms of leaf area are laurel oak (*Quercus laurifolia*), live oak (*Quercus virginiana*), and swamp cyrilla (*Cyrilla racemiflora*). Tree species that dominate in terms of actual numbers are laurel oak, swamp cypress, and loblolly pine (*Pinus taeda*).

Figure 5 shows a comparison between the top ten tree species contributing to the canopy cover in southern Escambia County as defined by leaf area relative to their total numbers. For example, even though Carolina laurel cherry (*Prunus caroliniana*) and Chinese tallowtree are common in southern Escambia County, their overall leaf area contributes less to the area's canopy than their numbers would indicate. Live oaks, on the other hand, comprise only 5 percent of all trees in southern Escambia County, yet they contribute to 28 percent of the area's total leaf area.

It is important to realize that urban forest cover can change over time due to urban development, windstorms, tree growth, and land use. Many tree benefits are linked directly to the amount of healthy leaf surface area (Escobedo et al 2008b). By planning and managing tree canopy cover and the extent by tree species, the urban forest manager can develop comprehensive management goals and objectives to improve ecosystem services.

Carbon sequestration and storage

Climate change is an issue of global concern. Urban trees can help reduce concentrations of atmospheric carbon dioxide through their growth and by reducing energy use in buildings through shading and modifying winds. This reduction in building energy use can reduce carbon dioxide emissions produced at fossil-fuel based power plants as part of the process of generating electricity. By estimating the amount of carbon dioxide removed by trees and their shading and windbreak effects on buildings, we can determine the role of urban forests in mitigating climate change and also assign an economic value to the amount of carbon sequestered by an urban forest.

Young trees with a small DBH sequester little carbon due to the limited growth and size. Eventually if they continue to stay healthy and grow they will accumulate more carbon as their biomass increases. Large trees in southern Escambia County greater than 77 inches in DBH continue to sequester the most carbon (Table1). Live oaks, laurel oaks and slash pines store 53, 27 and 4 percent of all carbon respectively. Laurel oaks, live oaks, and slash pine sequester 36, 32 and 3 percent of all carbon, respectively.

Healthier and larger trees sequester the greatest amount of carbon annually (Escobedo et al 2008c). As trees grow, they store more carbon by assimilating it in their woody tissue. As trees die and decay, they release much of the stored carbon back into the atmosphere. Southern Escambia County's trees sequestered 10,189 $mtCO_2$ per year with an economic value of $56,411. Figure 6 depicts a comparison of the economic value and net carbon dioxide sequestered by trees located in areas dedicated to

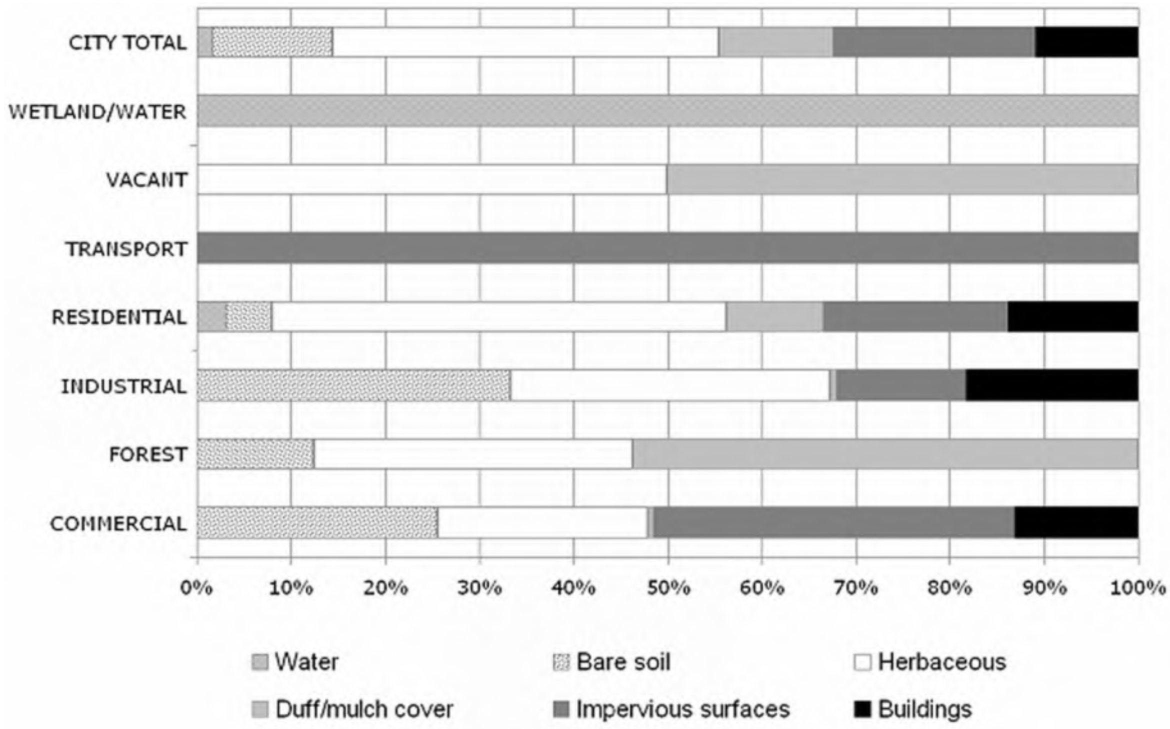

Figure 4. Surface ground covers by land use in southern Escambia County's urban forest.

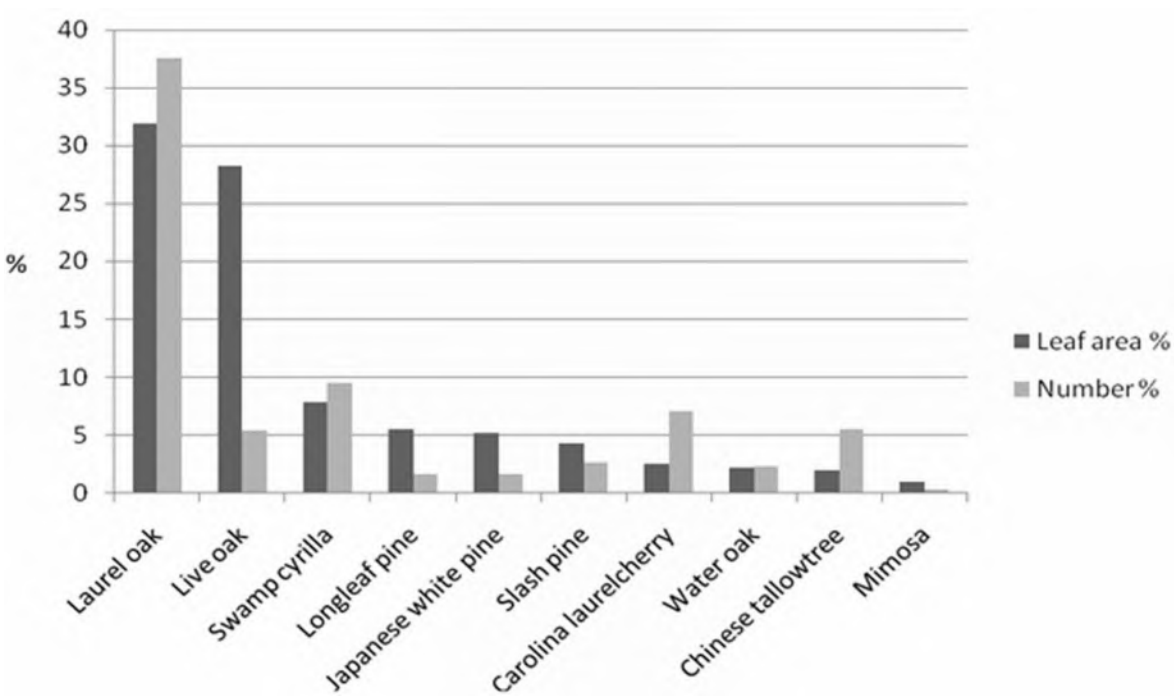

Figure 5. The top ten trees with highest total leaf area compared to their numbers in southern Escambia County's urban forest.

different land uses. Trees located on forest lands sequester more CO_2 than residential due to greater tree density in forest versus residential land uses.

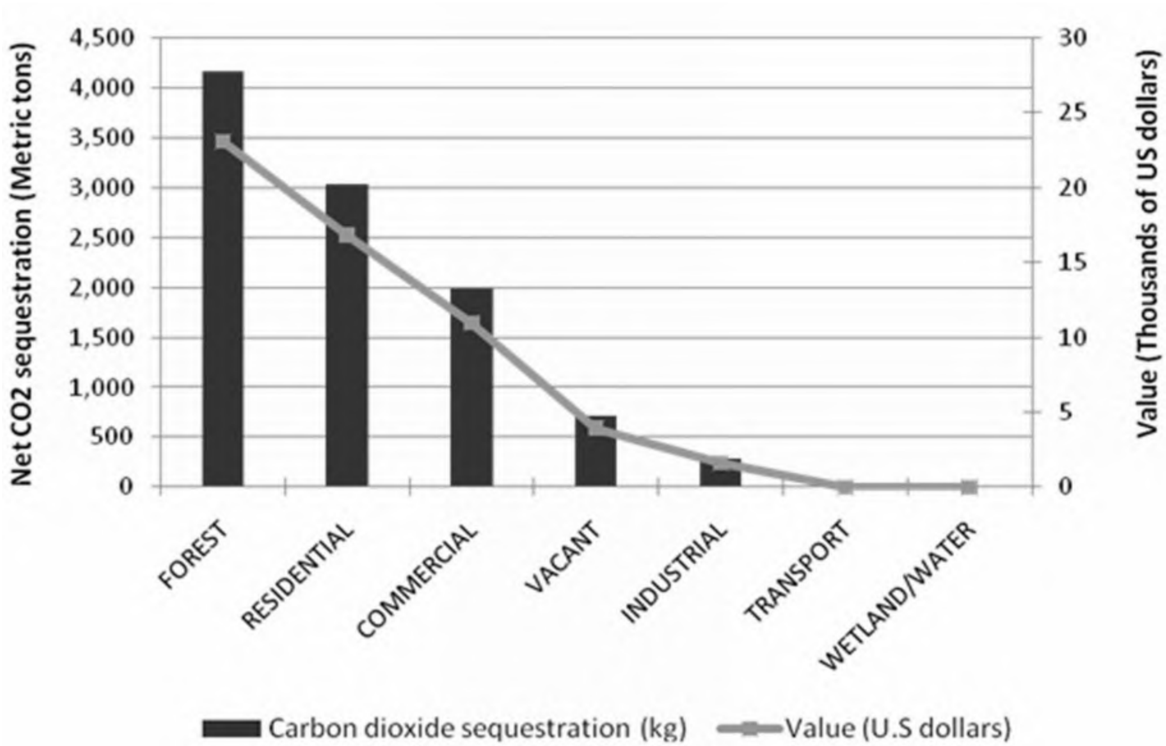

Figure 6. Net CO_2 sequestration per land use area and its associated value in southern Escambia County's urban forest.

Air pollution removal

On average, 1 square meter of tree cover removes 7 grams of air pollutants in southern Escambia County. Total pollution removal was greatest for particulate matter less than ten microns, followed by ozone, carbon monoxide, nitrogen dioxide and sulfur dioxide. Figure 7 compares the pollution removed and the resulting economic health benefits to society at large. It is estimated that annually trees in the study area removed 25 tons of air pollution (CO, NO_2, O_3, PM_{10}, SO_2). This is approximately $146,000 US dollars in health benefits per year.

Energy effects on residential buildings

Trees affect energy use by shading buildings, reducing temperatures by providing evaporative cooling, and blocking winter winds. Trees tend to reduce building air conditioning use in the summer months and can either increase or decrease building energy use in the winter months depending on the location of trees relative to a building. Based on the size of a building and the surrounding trees, we can place an economic value on the effects on energy use in residential buildings (Escobedo et al 2008d).

Based on the 2007 average retail price of electricity in Florida (EIA 2007), trees in southern Escambia County are estimated to provide about $306,000 in savings due to reduced air conditioning and heating use. However, trees can also increase heating use in winter by approximately $32,000 dollars annually due to the shading of the sun which results in increased heating. Table 2 provides a breakdown of the air conditioning and heating use and price savings as well as heat emissions costs by residential trees.

Trees clustered together near a building can create a microclimate cooling system via evapotranspiration (the evaporation of water from plant surfaces and bodies of water) and shade. Finally, trees properly positioned around a building can direct wind air flow to the building to help cool it down in warmer months or away from the building to diminish cooling effects during cooler months (Meerow and Black 2003).

The placement of trees around a building can influence the amount of energy required to maintain acceptable temperatures inside the building. Trees planted on the west side block the increase of solar heat in the afternoon during summer, and trees on the east and south sides of the house will block the solar heat in the summer. In more northerly areas of Florida, the same trees will increase the heating requirement for the structure in the winter if they are not deciduous trees (McPherson and others 1999). This negative shading effect is caused by evergreen trees blocking solar heat from reaching a structure to warm it during north Florida's colder months. Relying on the principle of "the right tree in the right place" will allow the sun's heat to reach a structure if deciduous trees, which lose their leaves in the fall, are planted on the south and east sides. Ultimately homeowners determine how cool or warm they prefer the inside of their homes to be and tree placement effects may vary from person to person and home to home.

By influencing energy production in power plants, trees can also affect emissions of carbon dioxide (CO_2) and other green house gases. In doing so trees can indirectly lower (or increase) CO_2 emissions by power plants and this offset of avoided emissions can result in economic savings to the community (McPherson and others 1999). Using the average price of CO_2 on the Chicago climate exchange of $4 per ton of CO_2 emissions avoided (August 2008), the effect of trees on residential building energy use can result in $13,770 in benefits and $3,377 in costs; a benefit-cost ratio of 4:1. Table 3 provides a breakdown of the energy savings and costs due to southern Escambia County's urban forests.

In summary, it is important for homeowners to plant trees in the right place to maximize cooling benefits in the summer and solar heat gain in the winter. See Meerow and Black (2003) for more specific landscaping suggestions. It is important to consider that energy savings are also affected by the occupant's use of the air conditioning and heating systems as well as the energy use efficiency characteristics of buildings and heating-cooling units (Escobedo et al 2008d). It is important for homeowners and landscape architects to carefully consider placement of trees around structures to maximize energy benefits.

Comparing southern Escambia County's urban forest with others in Florida

It can be difficult to determine which tree species are the most important contributors to an urban forest. This is because certain species are numerous in an urban forest yet they have low leaf area and vice versa. But in general there are some methods to determine the overall role of a particular tree species in the urban forest. Ecologists overcome this uncertainty by calculating the Importance Value (IV) for each species based on its relative frequency (% of population) and relative leaf area. When these values are summed the IV can be used to standardize tree species and rank and compare the importance of tree species (Figure 8). Laurel and live oak are particularly important species in southern Escambia County relative to other tree species found in other urban areas in Florida. Certain tree species are found in high numbers only in southern Escambia County, while others are found only in other Florida cities.

Urban forests in southern Escambia County have a greater tree density (number of trees per hectare) in comparison to Gainesville, Miami-Dade County and Tampa (Table 4). Tree cover numbers in southern Escambia County are likely a result of the study area encompassing coastal, highly urbanized portions of the county. Larger trees in Gainesville might explain that city's larger amounts of carbon storage compared to other Florida cities.

The information presented in this document can be used to establish baselines and provide an insight into existing urban forest structure and its ecosystem services. It can be used to formulate management strategies and goals that maximize benefits and minimize safety risks to citizens. The information is especially useful for developing and establishing medium and long-term management goals and objectives (Escobedo et al. 2007). Understanding a community's urban forest structure, community perceptions and available resources can be used to maximize the benefits of an urban forest.

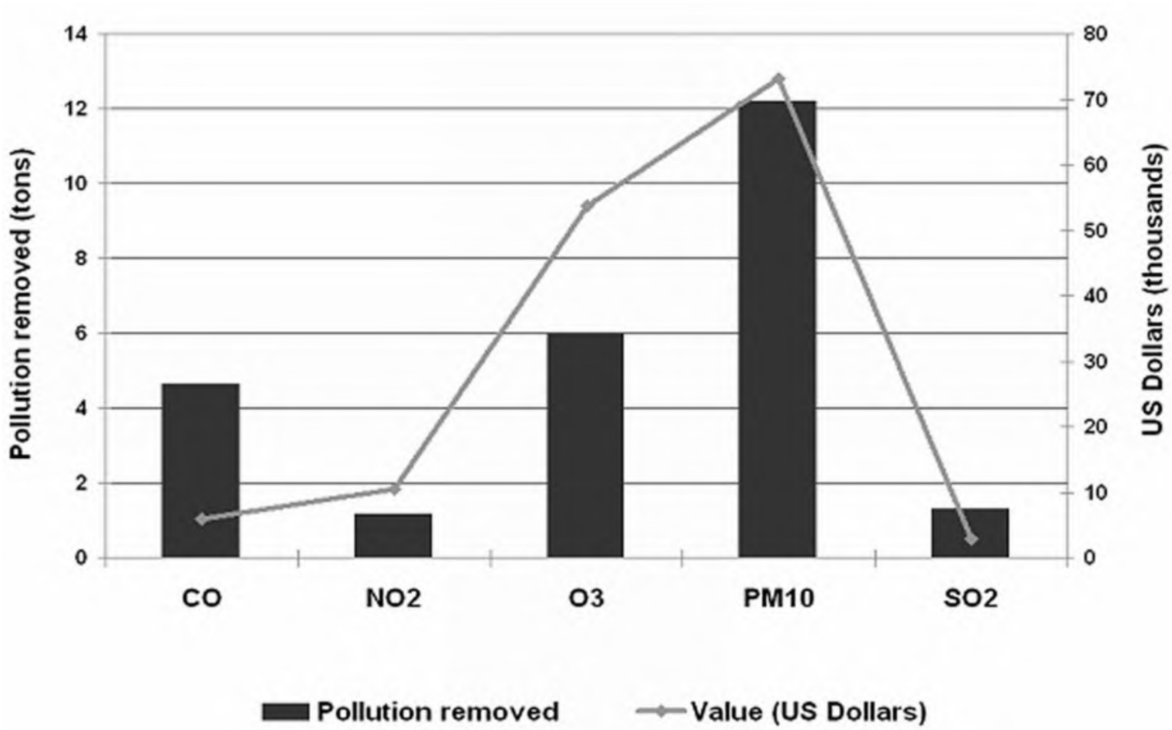

Figure 7. Comparison of the annual pollution removed in metric tons and the resulting health benefits in southern Escambia County.

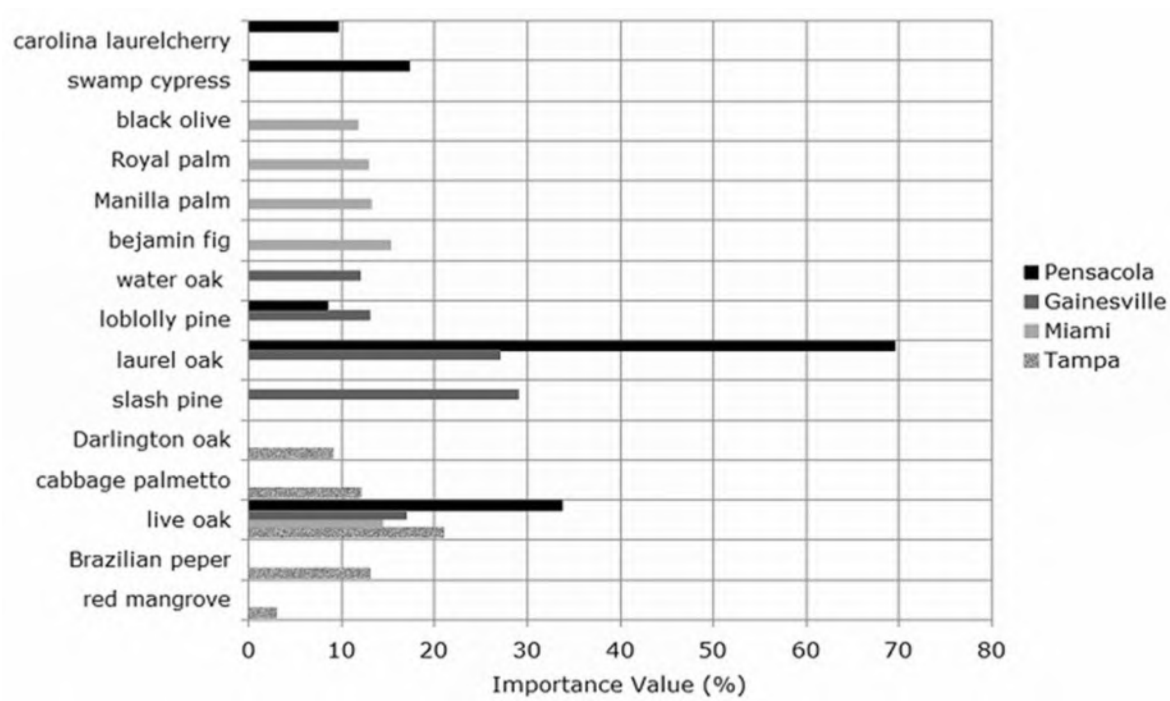

Figure 8. Importance values for species found in southern Escambia County and other urban areas in Florida.

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Table 1. Comparison of estimated average carbon stored and sequestered per tree in one year by diameter at breast height (DBH) size classes in southern Escambia County.

DBH Class (cm)	Per Tree C Storage (kg)	Per Tree Net Sequestered (C kg/year)	Per Tree Net Sequestered (CO_2 kg/year)
0 – 15	22	4.0	14.7
16 – 30	250	16.8	61.6
31 – 45	604	18.5	67.9
46 – 60	1,169	35.6	130.6
61 – 76	2,664	72.7	266.4
77+	15,034	187.3	686.7

Table 2. The benefits and costs based on energy use effects due to tree shading, windbreak, and climate effects near residential buildings in southern Escambia County.

	MWhs[1]	**Benefits***	**Cost***
Heating avoided due to wind break	287	$31,570	
Heating avoided due to tree effects on surrounding climate	460	$50,600	
Air conditioning use avoided due to tree shading	1,481	$162,910	
Air conditioning use avoided due to tree effects on surrounding climate	556	$61,160	
Increased heating due to shading	294		$32,340
Annual Sum of Benefits and Costs		$306,240	$32,340

1 Kwh = 0.001 megawatt hours (MWh), *assuming $0.11 average price per kilowatt hour for Florida end-user (EIA 2007).

Table 3. Annual energy savings and costs due to tree location around residential buildings in southern Escambia County.

	Benefit or Cost	**C mt/yr**	**CO_2 mt/yr**	**US\$ CO_2 savings/year**
Heating avoided due to windbreak	Benefit	239	877	3,509
Heating avoided due to local climate effects	Benefit	373	1369	5,476
Cooling avoided due to shading	Benefit	237	870	3,479
Cooling avoided due to climate effects	Benefit	89	327	1,307
Heating emissions due to shading	Cost	230	844	3,377

C, Carbon; CO_2, Carbon dioxide

Table 4. Urban forest cover, composition and carbon storage for four cities within the state of Florida.

Urban area	Urban forest cover	Most common trees and palms (Average number of trees or palms per ha)	Average tree density (Number of trees/ha)	Average C storage kg/ha
Gainesville	Tree 50% Palm 1% Shrub 16%	Laurel oak (23) Carolina laurel cherry (21) Slash pine (15)	242	30,800
Southern Escambia County	Tree 13% Palm 1% Shrub 24%	Laurel oak (31) Chinese tallow tree (11) Carolina laurel cherry (9)	315	27,400
Miami-Dade County	Tree 9% Palm 3% Shrub 5%	Surinam cherry (6) Christmas palm (5) Live oak (5)	83	9,300
Tampa*	Tree 28% Palm 7% Shrub 14%	Black mangrove (30) White mangrove (16) Laurel oak (15)	257	15,331

*http://www.sfrc.ufl.edu/urbanforestry/Files/TampaUEA2006-7_FinalReport.pdf