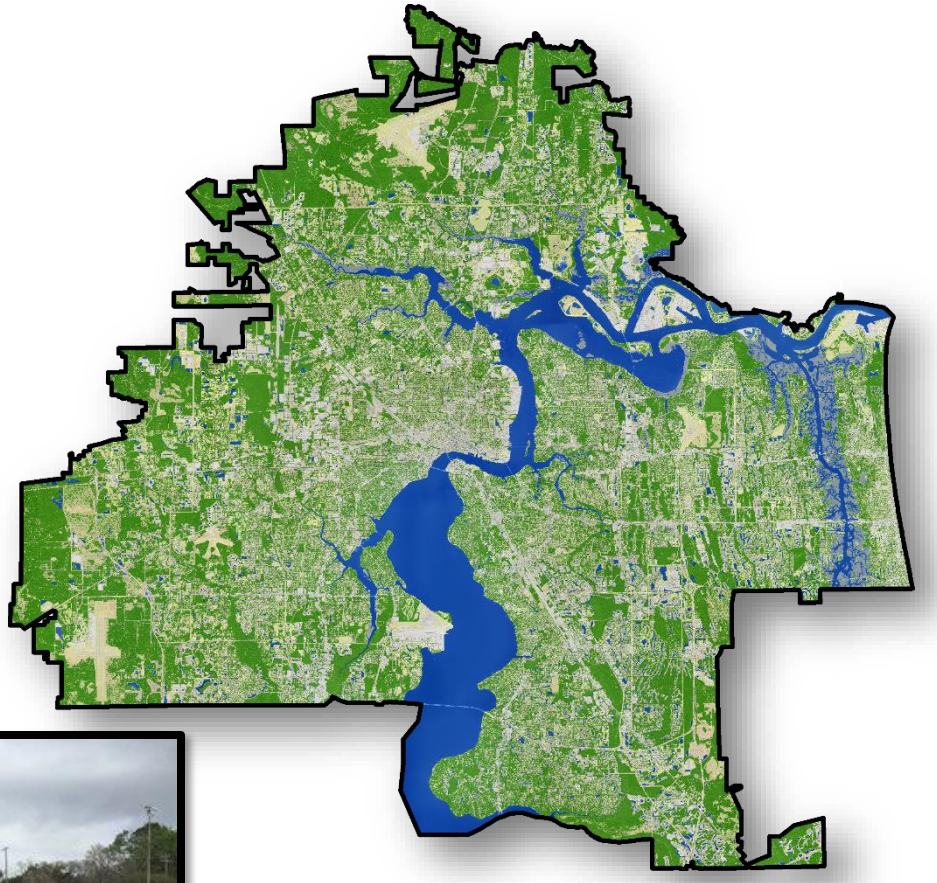
An Assessment of Urban Tree Canopy in the City of Jacksonville, Florida



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PUBLIC TRUST
Environmental Legal Institute of Florida

GREENSCAPE

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The City of Jacksonville, FL
The Public Trust Environmental Legal Institute of Florida
Greenscape of Jacksonville

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October 2017

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Executive Summary

The City of Jacksonville is located in Duval County in the northeast corner of Florida (as shown in Figure 1). According to estimates from the U.S. Census Bureau's Population Division, Jacksonville has grown from 821,784 people in 2010 to 846,951 people in 2015, representing a 3.1 percent increase. The increasing population has an interest and stake in the benefits of the urban forest. Trees and urban forests contribute positively to the well-being of the people of Jacksonville by enhancing the urban environment, providing clean air and wildlife habitats, and mitigating stormwater runoff.

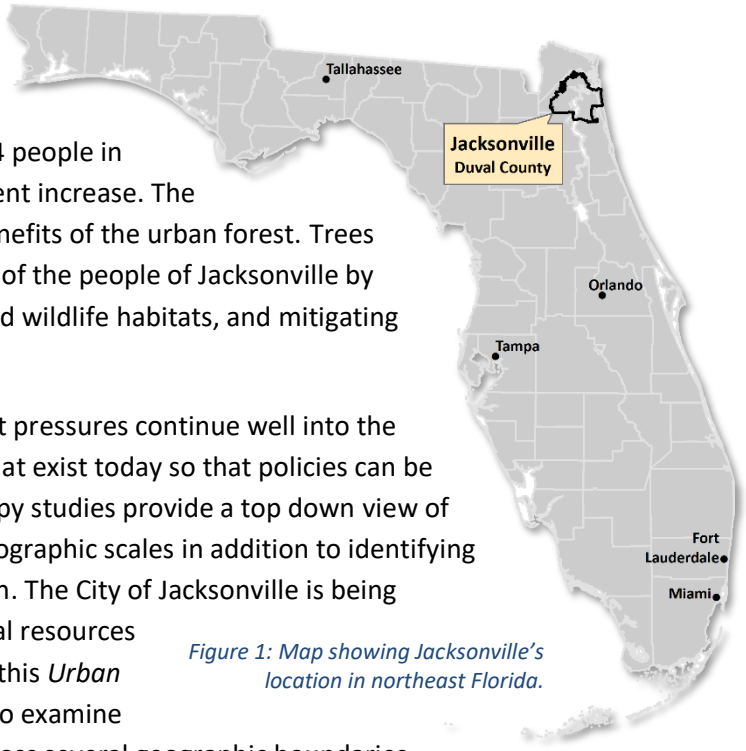

Figure 1: Map showing Jacksonville's location in northeast Florida.

As the population of Jacksonville grows and development pressures continue well into the future, it is important to identify the natural resources that exist today so that policies can be established to protect these valuable assets. Urban canopy studies provide a top down view of the urban forest and quantify this resource at various geographic scales in addition to identifying potential planting opportunities for future canopy growth. The City of Jacksonville is being proactive in their efforts to preserve Jacksonville's natural resources by conducting this assessment. The primary objective of this *Urban Tree Canopy Assessment in the City of Jacksonville, FL* is to examine urban tree canopy (UTC) in the city of Jacksonville, FL across several geographic boundaries to assist in developing an urban forest management plan.

Urban Tree Canopy in Jacksonville

Results of this study show that Jacksonville's Urban Priority Area contains 18,944 total land acres. Of those land acres, **30 percent** was covered by tree canopy (with 5,638 acres), **22 percent** was grass and open space (with 4,217 acres), **47 percent** was impervious (with 8,977 acres), and **less than 1 percent** was soil and dry vegetation. Of the grass and open space, **4,140 acres** have been identified as land that provides opportunity for additional tree canopy. This Possible Planting Area (PPA) makes up **1 percent** of the City's land area (Figure 2). Dividing the impervious surfaces into more detailed classifications shows that 2 percent of the City is covered by roads and 18 percent is classified as "Other Impervious", which includes buildings as well as parking lots and sidewalks that may offer opportunities for new trees and additional canopy cover.

30%	22%	47%
*Average Tree Canopy Cover in Urban Priority Area**	*Vegetated Possible Planting Area in Urban Priority Area**	*Impervious, including buildings and roads, in Urban Priority Area**

*Figure 2: Urban tree canopy assessment results for the Urban Priority Area. *Note that percentages are based on land area.*

Looking more broadly at Jacksonville's citywide land cover, there were 325,400 land acres. Tree canopy covered **48 percent** of that, **26 percent** was grass and open space, **23 percent** was impervious, **2 percent** was wetland, and **1 percent** was soil and dry vegetation.

Assessment Boundaries and Analysis Results

This study assessed Urban Tree Canopy and Possible Planting Areas at multiple geographic scales to provide actionable information to multiple audiences. By identifying what resources and opportunities exist at these scales, the City can be more proactive in their approach to protect (or expand) the urban tree canopy. Metrics were generated at the following geographies: the citywide boundary, city development boundaries, city council districts, census block groups, right-of-way by census block group, and land use categories.

Priority Planting Sites

Priority Planting Areas were recommended based on various environmental and sociodemographic criteria. These include mitigating the urban heat island effect, saving energy, improving air quality, reducing stormwater runoff, increasing wildlife habitat connectivity, and improving social equity.

Previous Studies

In 2005, American Forests conducted an "Urban Ecosystem Analysis" of Jacksonville. This study highlighted a change analysis of Jacksonville's land cover between 1992 and 2002 and offers a prior benchmark for comparison. Using Landsat satellite for the entirety of Jacksonville/Duval County, the study concluded that the city was comprised of 38 percent forest, 32 percent developed areas (impervious), 11 percent non-canopy vegetation, 10 percent water, 8 percent wetland, and 0.2 percent soil.

There are two limitations when comparing the data produced by the American Forests study and the data produced by this assessment. The first is that American Forests mapped the entire city of Jacksonville. This assessment only looked at the downtown, urban, suburban, and beaches areas of the city totaling about 167,000 fewer acres. The areas that were omitted include the rural areas on the edges of the city that are primarily comprised of forest or wetlands (e.g. Timucuan Ecological & Historic Preserve).

Since the American Forests study used Landsat Thematic Mapper imagery which has a spatial resolution of 30x30-meter pixels, it is difficult to make direct comparisons to this assessment. While Landsat imagery can be useful for land classification over a large geographic extent, land cover classification within a city is best performed using imagery with a higher spatial resolution (e.g. NAIP imagery). Because of the larger pixel size in Landsat imagery, many smaller patches of urban forest found in the urban/suburban areas of Jacksonville may not have been included causing Jacksonville's estimated tree canopy cover to be much lower in 2002 than in 2015.

Recommendations

While there are no official adopted plans that promote the urban tree canopy, it is clear that the City values its natural resources and wants to maintain a healthy and sustainable urban environment. Therefore, it is recommended that the City utilize these assessment results to preserve and promote healthy urban tree canopy, develop an urban forest management plan that provides a shared vision, and relate urban forestry efforts to greater citywide initiatives/priorities. These recommendations are a starting point for an interdisciplinary goal-setting process and determination of priorities and strategies. Additionally, the UTC assessment data are available in an online, interactive map for planning and prioritizing tree planting and maintenance.

PROJECT METHODOLOGY

This section describes the methods through which land cover, urban tree canopy, and possible planting areas were mapped. These datasets provide the foundation for the metrics reported at the selected target geographies.

Mapping Land Cover

The most fundamental component of this urban tree canopy assessment is the creation of an initial land cover data set. The process began with the acquisition of 2015 high-resolution (1-meter) aerial imagery from the USDA's National Agricultural Imagery Program (NAIP) and 2007 LiDAR data from the Florida Division of Emergency Management. An object-based image analysis (OBIA) software program called Feature Analyst (ArcGIS Desktop) was used to classify features through an iterative approach, where objects' spectral signatures across four bands (blue, green, red, and near-infrared), textures, and pattern relationships were considered. This process resulted in five initial land cover classes as shown in Figure 3. After manual classification improvement and quality control, additional data layers from the city, (such as buildings, roads, and other impervious surfaces) were utilized to capture finer feature detail and further categorize the land cover dataset.

Urban Tree Canopy	***Non-Canopy Vegetation***	***Impervious Surfaces***	***Bare Soil***	***Water Bodies***
Tree cover when viewed and mapped from above	Grass and open space vegetation	Hard surfaces where rainfall cannot permeate	Not included in possible planting areas	Bodies of water removed from total land cover

Figure 3: Five primary land cover classes generated from aerial imagery-based analysis

Identifying Possible Planting Areas and Unsuitable Areas for Planting

Possible Planting Areas were derived from the Non-Canopy Vegetation land cover class. "Unsuitable" areas were incorporated into the data set to identify where it is not feasible to plant trees. Sports fields, golf courses, and airports were delineated as unsuitable areas (Figure 4). The final results are reported with vegetated possible planting areas (PPA-Veg), total possible planting areas (To-PPA), unsuitable impervious (roads and buildings), other unsuitable (sports fields, etc), and total unsuitable.

Figure 4: Sports Fields, golf courses, and airports are considered unsuitable for planting

Defining Assessment Levels

To better inform various stakeholders (city officials, city staff, and citizens alike), urban tree canopy and associated information was calculated for a variety of geographic boundaries. These include the citywide boundary, city council districts, census block groups, land use, and Right-of-Way by census block group. Outputs include total area (in acres) and relative values (as percentages) for urban tree canopy, possible planting areas, impervious surfaces, and unsuitable areas. Assessment levels include the following geographic boundaries:

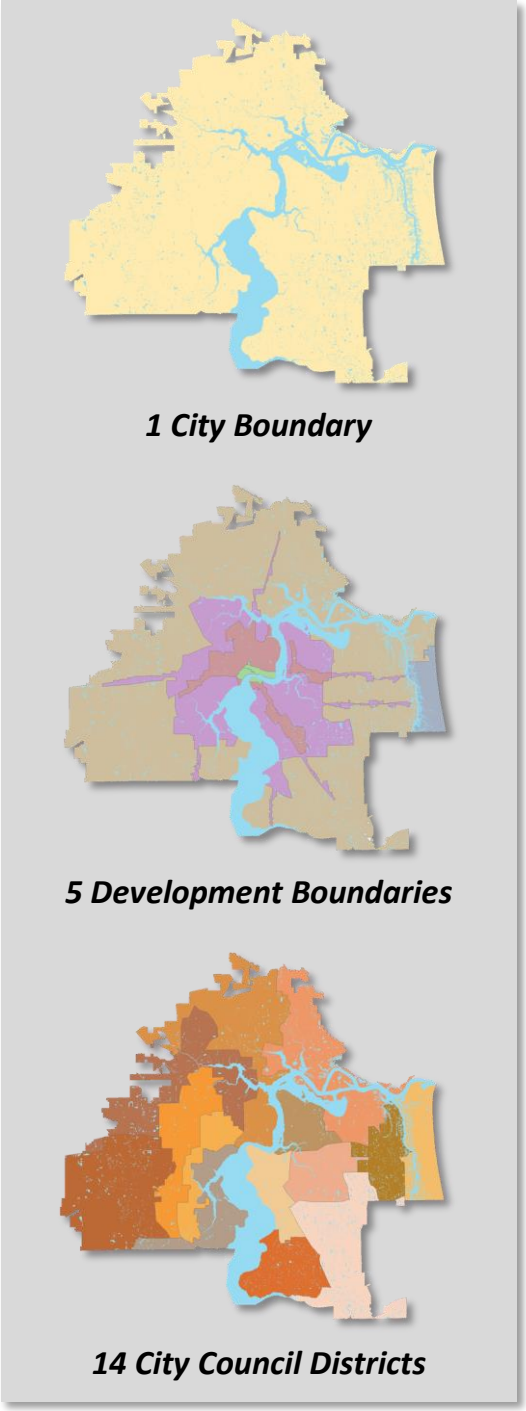

Figure 5: Examples of assessment geographies

- The City of Jacksonville **city boundary** is the one (1) main overarching area of interest for which all metrics are summarized (Figure 5).

- Five (5) **Development Boundaries** (i.e. Downtown, Urban Priority Area, Suburban Area, etc.) were analyzed to distinguish land cover in locations with differing levels of development in Jacksonville (Figure 5).

- Fourteen (14) **City Council Districts** were evaluated to identify the amount of tree canopy as it relates to the individual voter districts and potentially to inform the council members and citizens residing in them (Figure 5).

- **Census Block Groups** originate from the U.S Census Bureau and are used for statistical consistency when tracking populations throughout the U.S. They can be used to provide indicators of environmental justice.

- The City's **Land Use Classes** were created and analyzed to represent current human uses and land characteristics, totaling 21 classifications.

- The public **Right-of-Way** (ROW) includes land that is generally managed by the City, such as land within street medians and land between the street and sidewalk. By breaking down the land classification and tree canopy data within the **ROW** by **Census Block Groups**, the City of Jacksonville can make educated and precise decisions on where to direct resources for tree planting and management efforts on public lands.

STATE OF THE CANOPY & KEY FINDINGS

This section presents the key findings of this study, including the land cover base map as well as the canopy analysis results, which were analyzed across various geographic assessment boundaries. These results, or metrics, help inform a strategic approach to identifying future planting areas.

Citywide Land Cover

In 2015, **41 percent** of Jacksonville was covered by tree canopy, **22 percent** was grass and open space, **20 percent** was impervious, **1 percent** was soil and dry vegetation, and **2 percent** was marsh/wetland. Further dividing the impervious surface areas into more detailed classifications shows that two percent of the City is covered by roads and 18 percent is covered by land classified as "Other Impervious". This remaining 17 percent includes buildings, parking lots, and sidewalks. Parking lots and sidewalks may offer opportunities for new tree plantings and additional canopy cover. However, data for these opportunistic impervious land classifications would need further analyses to determine their planting suitability. Table 1 shows the generalized land cover results, while Figure 7 shows the more detailed map and distribution.

Table 1: Generalized land cover classification results

Total Acres	Tree Canopy (acres)	Tree Canopy %	Grass / Open Space (acres)	Grass / Open Space %	Impervious (acres)	Impervious %
376,388	155,446	41%	84,338	22%	74,708	20%

Water (acres)	Water %	Soil / Dry Vegetation (acres)	Soil / Dry Vegetation %	Marsh / Wetlands (acres)	Marsh / Wetlands %
50,988	14%	3,850	1%	7,059	2%

Citywide Urban Tree Canopy

This urban tree canopy assessment utilized the land cover map as a foundation to determine Possible Planting Areas throughout the City. Additional layers and information regarding land considered unsuitable for planting were also analyzed. It should be noted that the results of this study are based on land area, not total area (note the difference between Total Acres in Table 1 and Land Area in Table 2). Results show that within the City of Jacksonville, FL, **155,446 acres** are covered by urban tree canopy, making up **48 percent** of the 325,416 land acres, and **77,918 acres** of land has been identified as non-canopy vegetation that provides the possibility for additional tree canopy. This Possible Planting Area (PPA Vegetation) makes up **24 percent** of the City. **28 percent** of the City's land has been identified as unsuitable for planting. This includes sport fields, golf course fairways, buildings and roads, and soil/dry vegetation. Figure 6 provides a detailed map of Jacksonville Land Cover classification.

*Table 2: Urban tree canopy assessment results. *Note that percentages are based on land area.*

Land Area (acres)	UTC (acres)	UTC* %	Total Possible Planting Area (acres)	Total Possible Planting Area* %	Unsuitable UTC* (acres)	Unsuitable UTC* %
325,400	155,446	48%	77,918	24%	92,036	28%

Land Cover in Jacksonville, FL

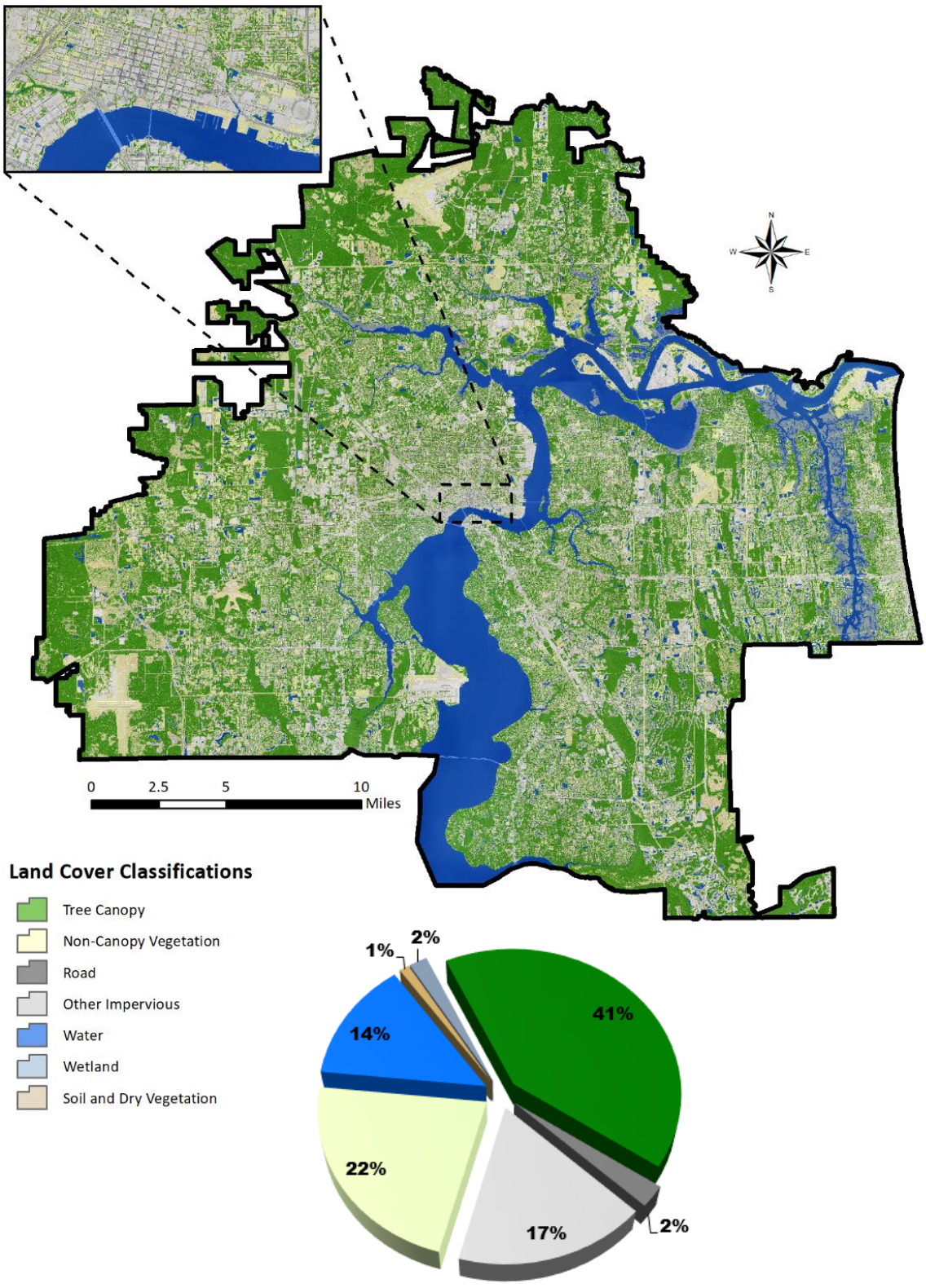

Figure 6: Detailed Land Cover Classifications and Distribution

Development Boundaries

This study assessed urban tree canopy totals and possible planting area for 5 development boundaries within the City of Jacksonville (Table 3). Suburban areas within the City of Jacksonville contain both the highest amount of UTC and the highest amount of PPA at 52 percent and 25 percent, respectively. Downtown Jacksonville is the only development boundary with less UTC than PPA at 11 percent and 18 percent, respectively. The City of Jacksonville could utilize the relatively high amount of PPA downtown to create more urban tree canopy in the area that it is most needed. Figure 7 shows the percentage of UTC and PPA for all development boundaries, and Figure 8 provides a map of UTC percent within each development area.

*Table 3: Urban tree canopy assessment results by development boundary. *Note that percentages are based on land area.*

Development Boundary	Land Area (acres)	UTC (acres)	UTC* %	Total Possible Planting Area (acres)	Total Possible Planting Area* %	Unsuitable UTC* (acres)	Unsuitable UTC* %
Beaches	**8,214**	**2,366**	**29%**	**1,622**	**20%**	**4,226**	**51%**
Downtown	**1,656**	**188**	**11%**	**292**	**18%**	**1,177**	**71%**
Suburban	**229,790**	**119,714**	**52%**	**56,559**	**25%**	**53,518**	**23%**
Urban	**66,711**	**27,494**	**41%**	**15,274**	**23%**	**23,942**	**36%**
Urban Priority	**18,944**	**5,638**	**30%**	**4,140**	**22%**	**9,166**	**48%**

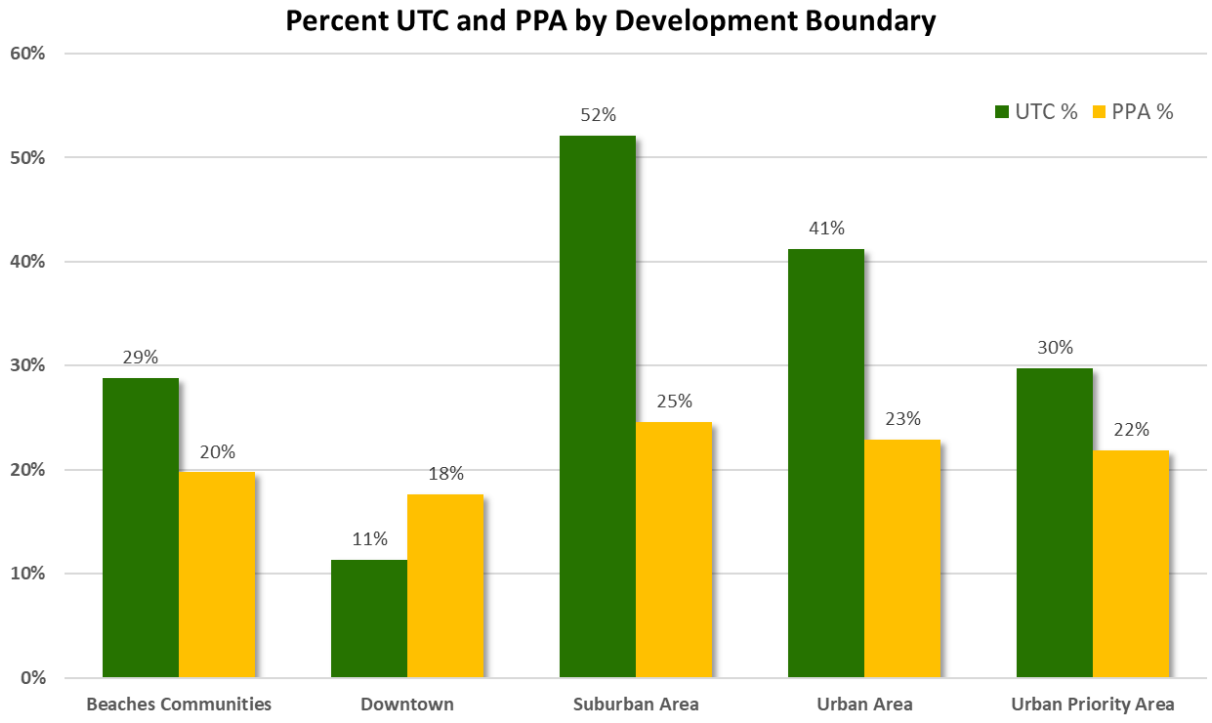

Figure 7: Percent Urban Tree Canopy and Possible Planting Area by Development Boundary

Tree Canopy Cover
by Development Boundary

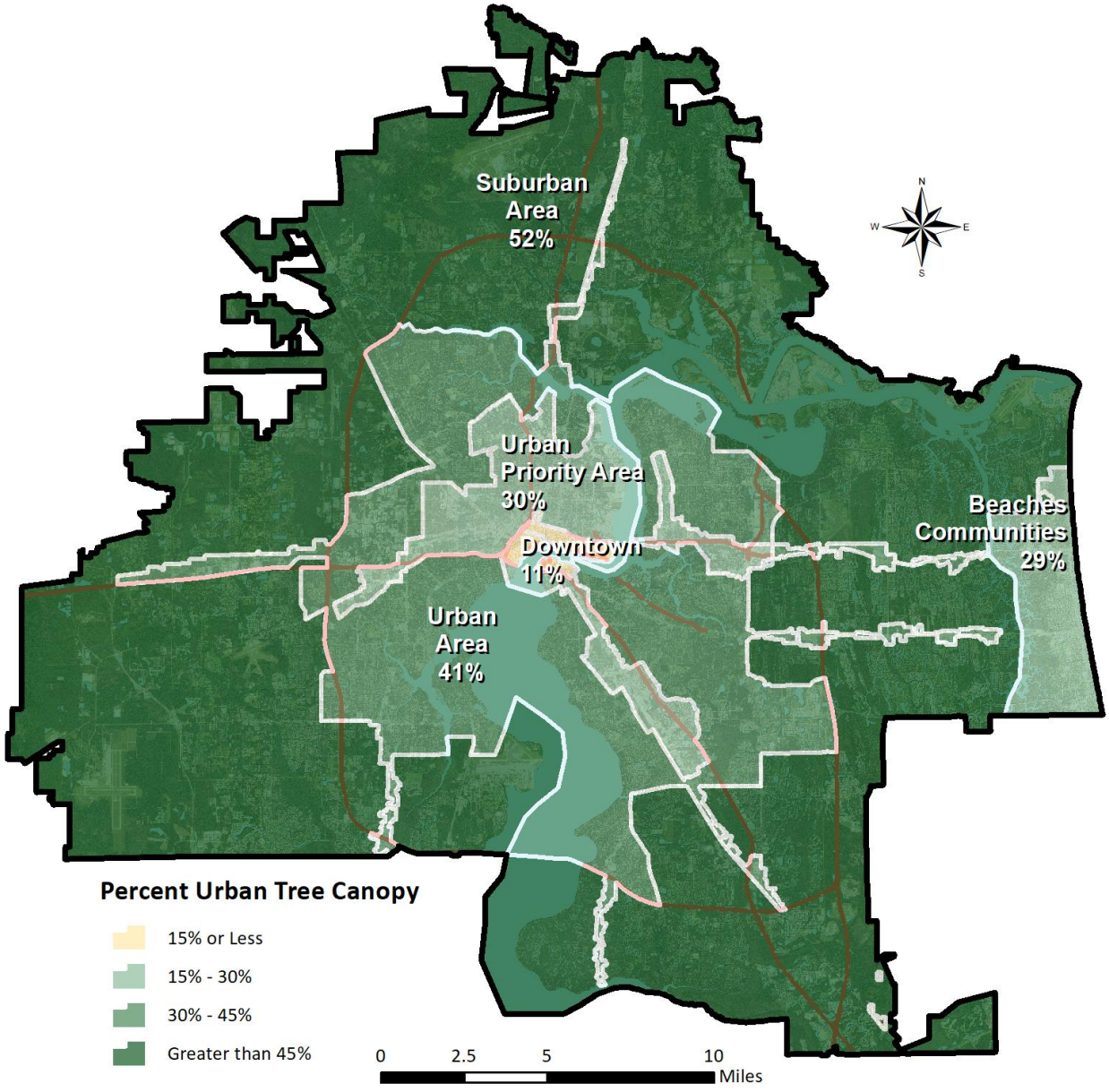

Figure 8: Percent urban tree canopy by development boundary

City Council Districts

This study assessed UTC totals and PPA for 14 City Council Districts. The 7th city council district currently boasts the greatest percentage of UTC with 54 percent canopy coverage. The 8th, 11th, and 12th city council districts follow with 53 percent relative UTC. As the largest city council district, the 12th, also has the greatest amount of total canopy at 24,200 acres. The 12th city council district contains 16 percent of the entire city's UTC.

In terms of possible planting area and opportunities to expand the urban tree canopy, the 8th city council district has the greatest relative amount of PPA with 30 percent. Figure 9 shows UTC and PPA statistics of all Jacksonville city council districts, and Figure 10 shows the percentage of UTC per city council district in a map.

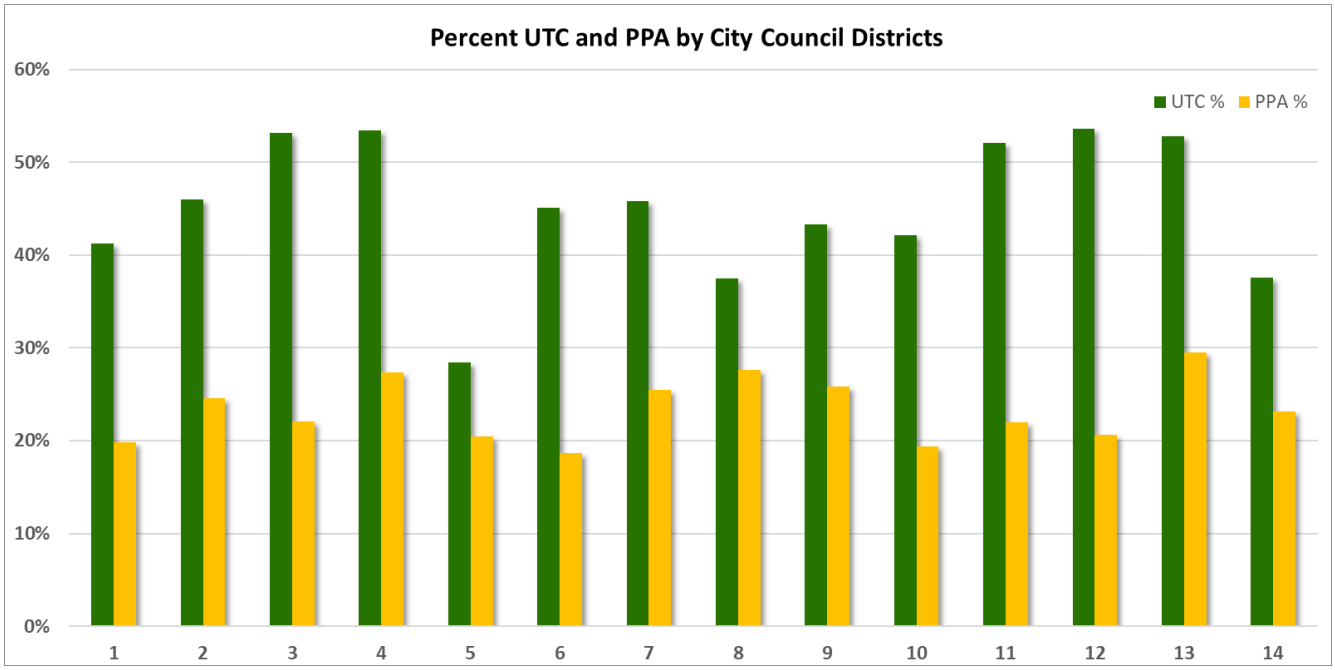

Figure 9: Percent of Urban Tree Canopy and Possible Planting Area by City Council District

Tree Canopy Cover
by City Council Districts

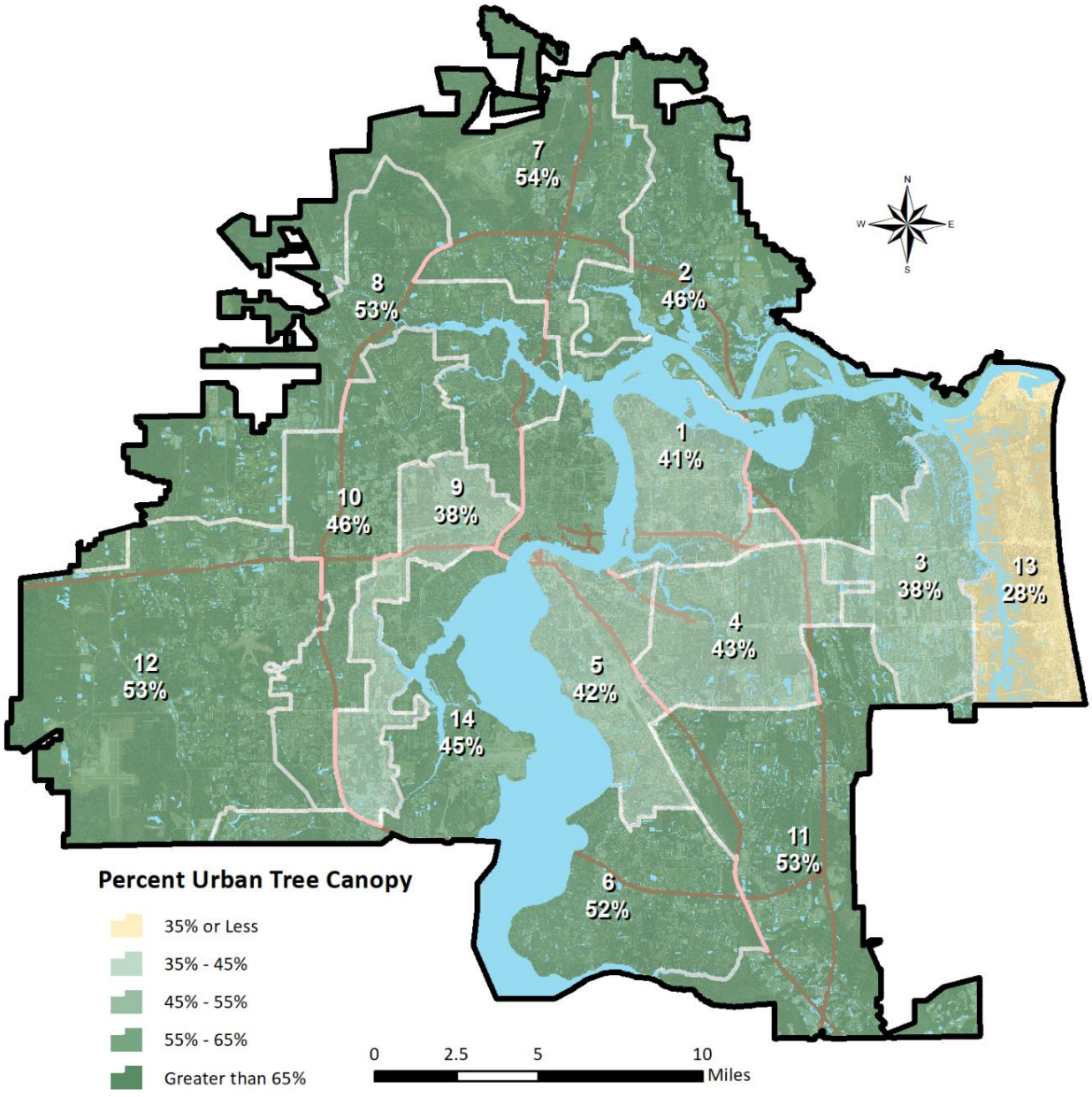

Figure 10: Percent urban tree canopy by city council district

Land Use

This study processed urban tree canopy totals and Possible Planting Areas data for Jacksonville land use classes. Twenty-one (21) land use classes (as shown in Figure 11) were created to reflect current human use and land cover information as they relate to UTC. Conservation and Recreation/Open Space land use have the highest canopy cover at 81 percent and 65 percent, respectively. However, these two classes make up a combined 7 percent of all canopy citywide, while Low Density Residential land use properties average 49 percent canopy cover, accounting for 42 percent of all canopy in the study area.

The greatest opportunity to expand the urban tree canopy is within the Low Density Residential land use classification. This land use classification contains 28 percent PPA. Low Density Residential land use also contains 49 percent (36,989 acres) of the City's total PPA. Rural Residential (25 percent PPA) and Neighborhood Commercial (25 percent PPA) land use also present significant opportunities for canopy growth.

Figure 12 shows a map of generalized land use classifications throughout the City of Jacksonville. Data coverage was not available for the Beaches communities.

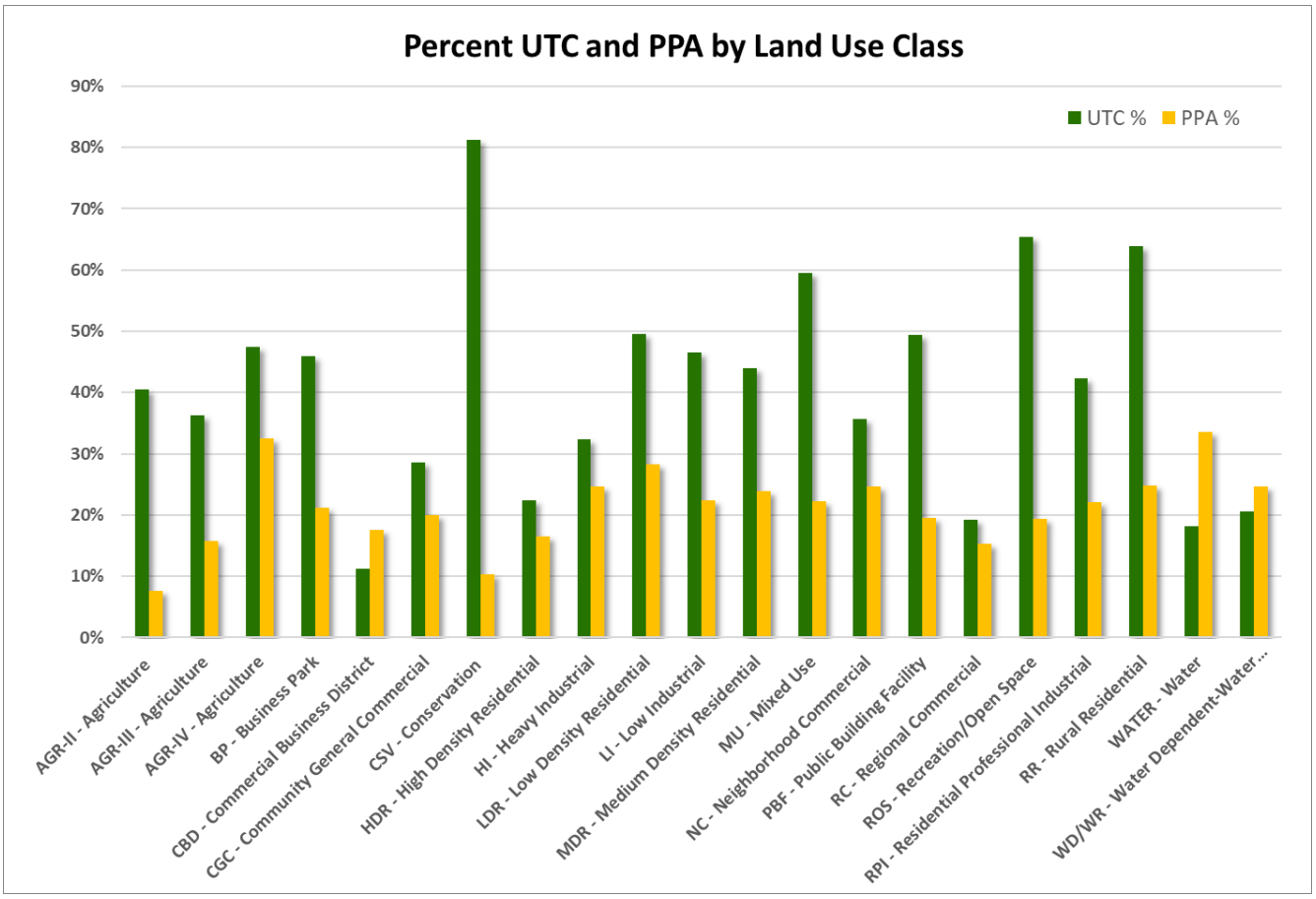

Figure 11: Percent of urban tree canopy and possible planting area by land use class

Land Use Classes in Jacksonville, FL

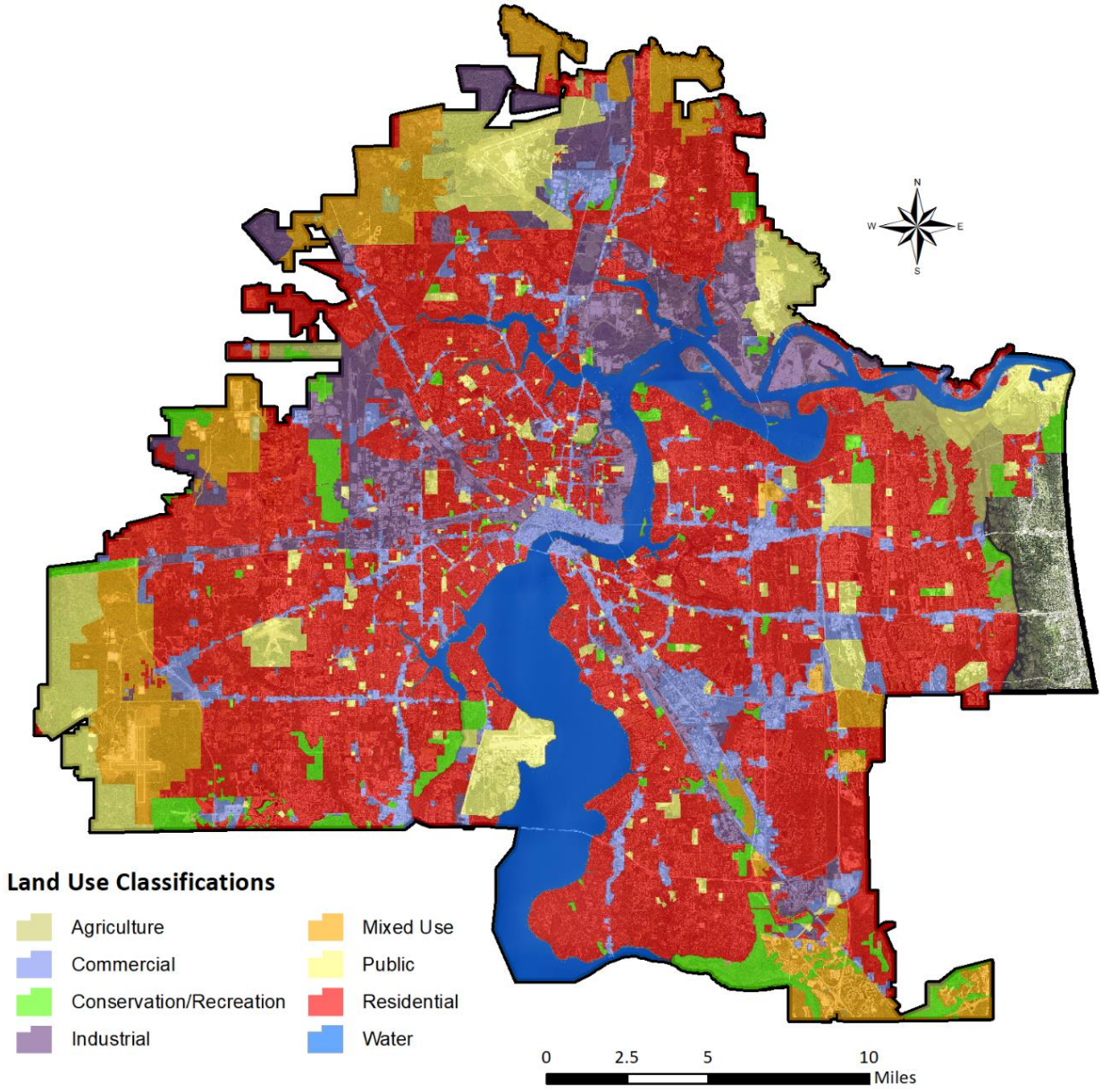

Figure 12: Grouped land use classifications for the City of Jacksonville

Census Block Groups

The United States Census Bureau provides population estimates, socioeconomic data, and demographic data for the U.S. summarized by various geographic scales. Census block groups are one of the smallest of these geographic scales and can be used to identify general trends and specific area needs based on UTC and PPA data. There were 488 census block groups within the City of Jacksonville that were analyzed. See Figure 13 for a geographic representation of urban tree canopy percentage by Census Block Group.

Tree Canopy Cover
By Census Block Groups

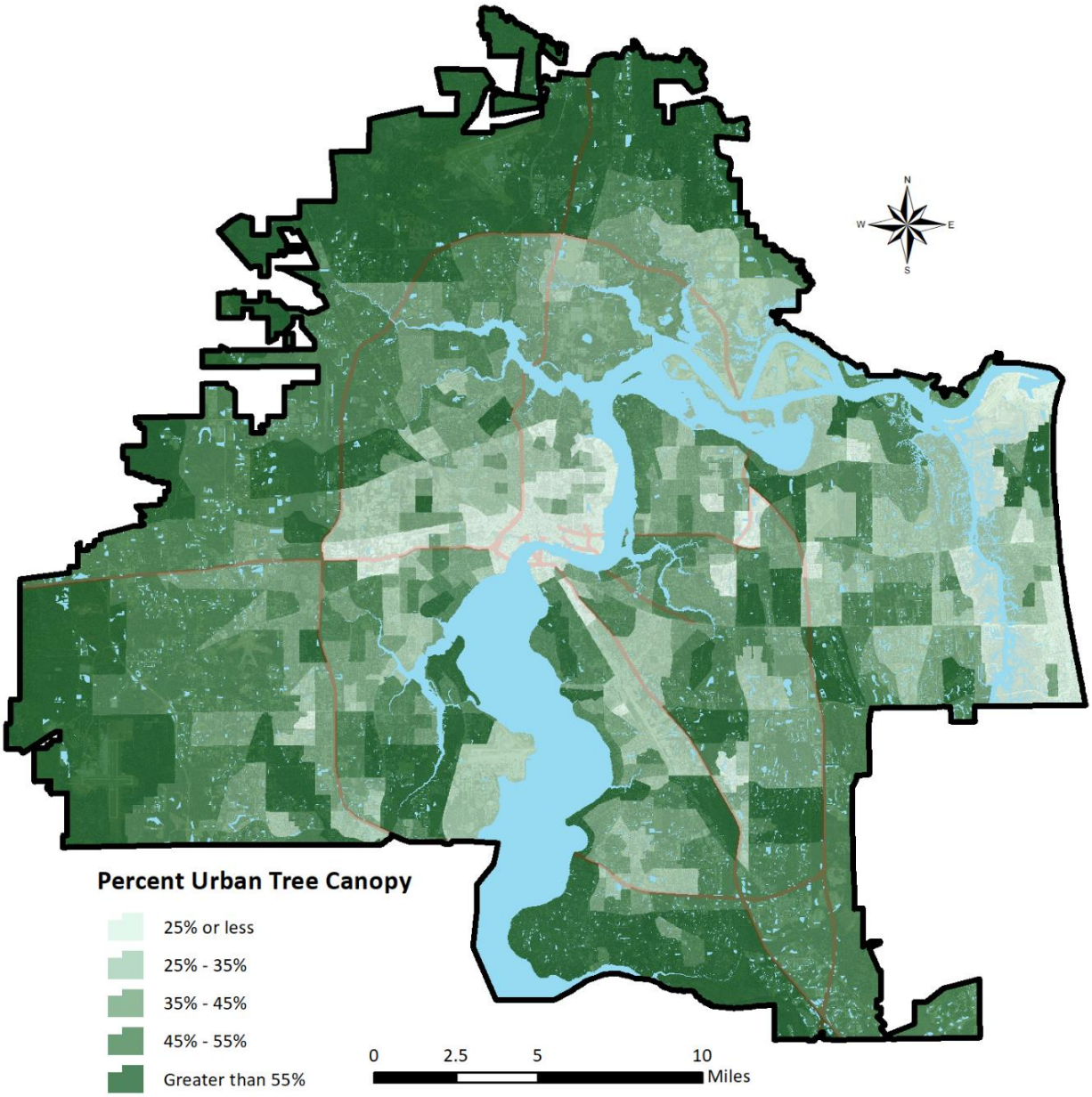

Figure 13: Percent UTC within census block groups

Right-of-Way by Census Block Groups

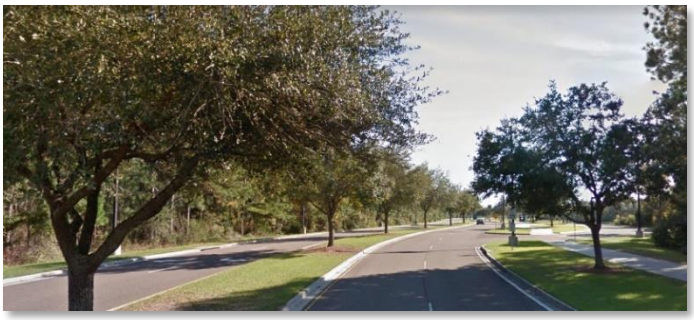

Figure 14: Trees within the right-of-way near the University of North Florida (Source: Google Maps)

Urban tree canopy coverage and possible planting areas have been evaluated for Rights-of-Way (ROW) citywide and at the census block group scale. The total land area of ROW in Jacksonville (excluding water) is **39,396 acres**. 9,014 of these acres contain UTC (or 23 percent of the ROW), with an additional **9,987 acres**, or 25 percent, of possible planting area. While much of the ROW is impervious road surface, this PPA offers an opportunity to help increase air quality and combat the urban heat island. Because ROW is owned and managed by the City, possible planting areas located within them are easy targets for increasing tree canopy cover (as shown in Figure 14). Using census data allows the City to analyze the distribution of UTC in comparison with a variety of demographic and socioeconomic measures including median income levels, median home value, educational attainment, owner occupancy, and race. Combining ROW, census block group data, UTC, and PPA provides the City with the tools to determine where tree planting and management efforts on public lands will be most effective. Figure 15 shows PPA in the ROW by census block groups in the Downtown area.

Table 4: Assessment Results of Citywide Right-of-Way by Census Block Groups

Citywide Land Area (acres)	ROW Land Area (acres)	UTC in ROW (acres)	UTC in ROW %	Citywide Distribution of UTC in ROW %	Total Possible Planting (acres)	Total Possible Planting %
325,400	39,396	9,014	23%	6%	9,987	25%

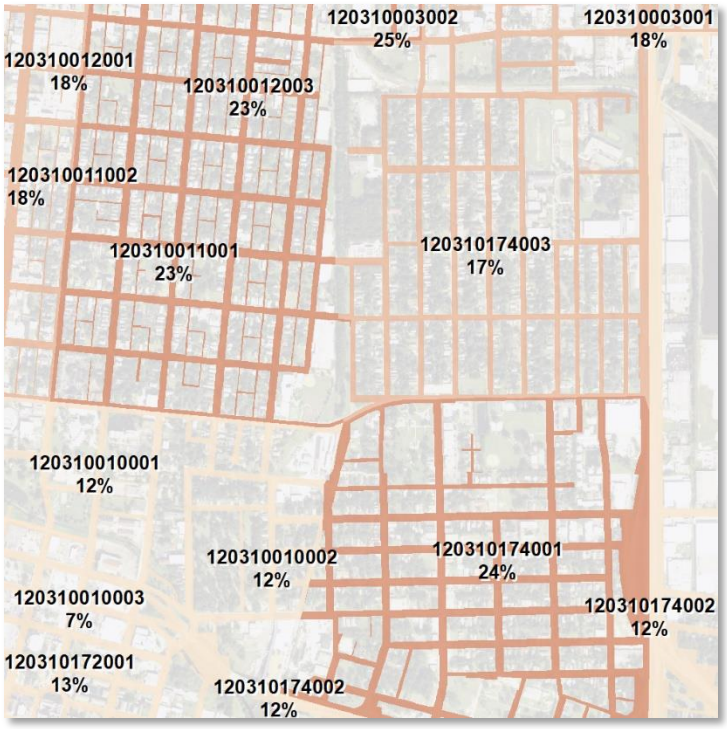

Figure 15: Percent of possible planting area within the ROW of census block groups

PRIORITIZING PLANTING AREAS

Urban tree canopy provides a multitude of direct and indirect benefits. After generating metrics for UTC and PPA throughout the assessment geographies, eight (8) priority planting themes were identified to promote the City's greater goals. The environmental themes include air quality improvement, energy conservation, stormwater reduction, urban heat island mitigation, and wildlife habitat connectivity. Other UTC benefits are more difficult to measure, such as how trees contribute to livability, home value, educational attainment, health, and well-being. As part of this study, the relationship between tree canopy and socioeconomics was explored to target planting locations in areas with large minority populations, underserved populations, and vulnerable populations. Urban Tree Canopy was related to data collected through the U.S. Census 2011-2015 American Community Survey (ACS) 5-year estimates at the Block Group level.

Priority planting locations can generally be identified by looking at areas with low UTC and high PPA. This study not only analyzed the data to find areas that have space for planting trees but also to find locations where planting new trees will contribute to these greater goals. Table 5 outlines each prioritization criteria, its importance, and how it was created. The study uncovered a clear relationship between canopy cover and socio-demographics.

Table 5: Citywide Criteria Guiding the Identification of Priority Planting Areas

Criteria	Rationale	Methodology
Air Quality	Trees absorb, trap, offset, and hold pollutants such as particulates, ozone, sulfur dioxide, carbon monoxide, and CO_2.	Calculate percentage of area made up by roads within a geographic boundary.
Energy Conservation	Trees provide a reduction in energy use in the summer by providing shade and in the winter by reducing wind.	Identify residential properties that have less than the citywide average of UTC and greater than the residential average of PPA.
Stormwater Reduction	Trees can be integrated to help manage stormwater, specifically when targeting impervious surfaces.	Identify PPA within 100' of all surface water, such as streams and ponds.
Urban Heat Island	Tree canopy that covers impervious surfaces reduces the urban heat island effect, which is damaging to the environment and unhealthy for people. Disproportionally affects lower income populations.	Identify areas of high UHI using percent impervious. Locate possible planting areas in residential, commercial, and industrial areas.
Wildlife Connectivity	Large tracts of canopy can improve habitat for local wildlife.	Identify PPA that are within 100' large tracts of existing canopy (> 5 acres).
Minority Populations	Tree canopy is negatively correlated with the percentage of minority residents. Planting trees in communities with higher percentages of minority residents can support environmental equity.	Consider areas where there is below average UTC and a high percentage of minority populations.
Underserved Populations	Tree canopy is positively correlated with higher median income. Planting trees in lower income communities can support environmental equity.	Consider areas where there is below average UTC and a high percentage of residents living below the poverty level.
Vulnerable Populations	Trees can help improve air quality by reducing air temperature and removing pollutants from the air.	Consider areas where there is below average UTC and a high percentage of people below 18 years of age and above 65.

Air Quality

Trees absorb, trap, offset, and hold pollutants such as particulates, ozone, sulfur dioxide, carbon monoxide, and CO_2. Street right-of-way corridors typically have higher concentrations of particulate matter. Officials should partner to target canopy increases in street ROW as an air pollution mitigation strategy while increasing walkability, retail, and biking.

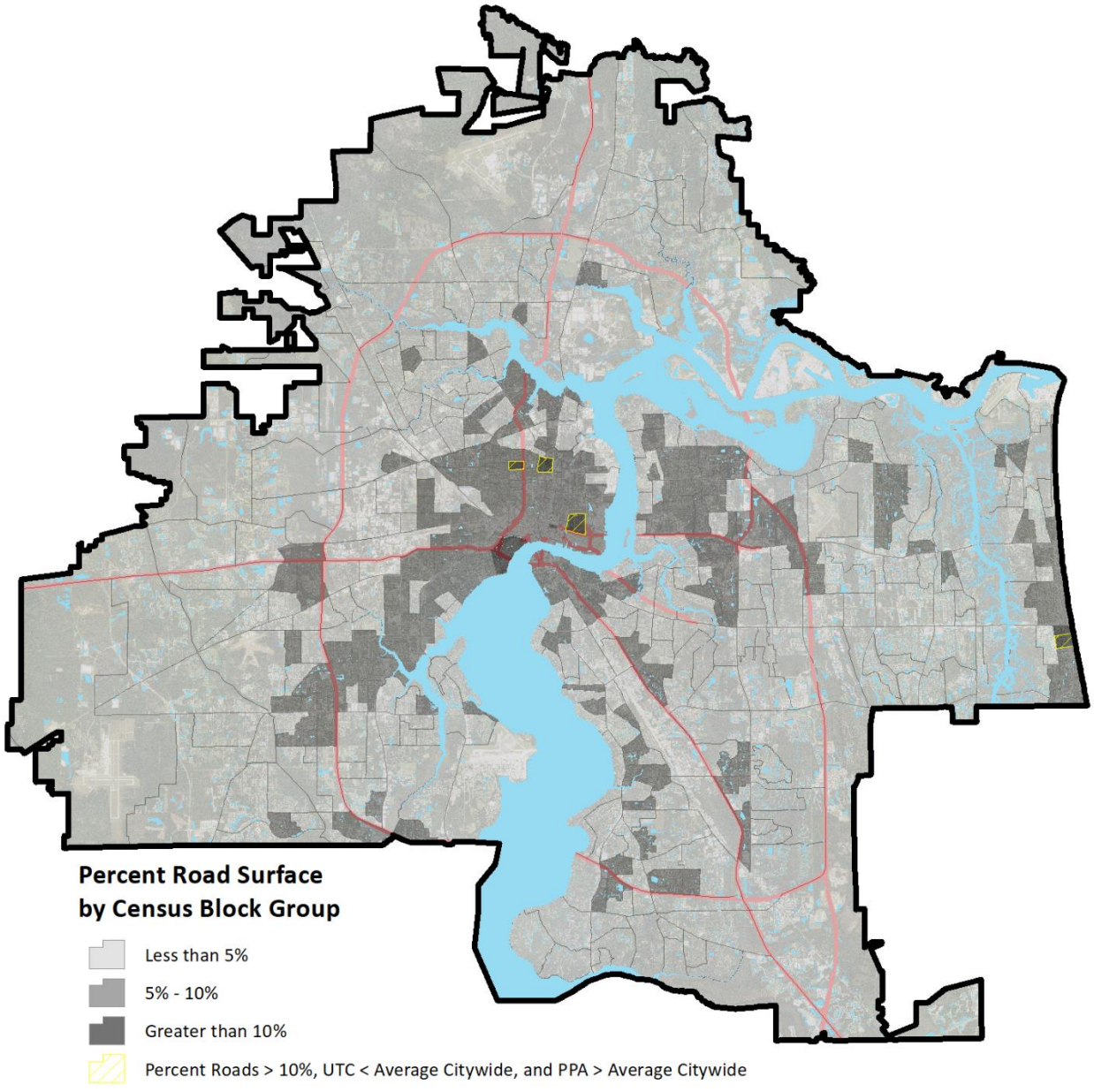

Figure 16: Priority planting areas based on air quality criteria

Energy Conservation

Trees provide a reduction in energy use in the summer by providing shade, and in the winter by reducing wind. By strategically planting trees in residential areas where the urban tree canopy is low, heating and cooling costs may be reduced, and the amount of energy required to achieve desired home temperatures will also be reduced.

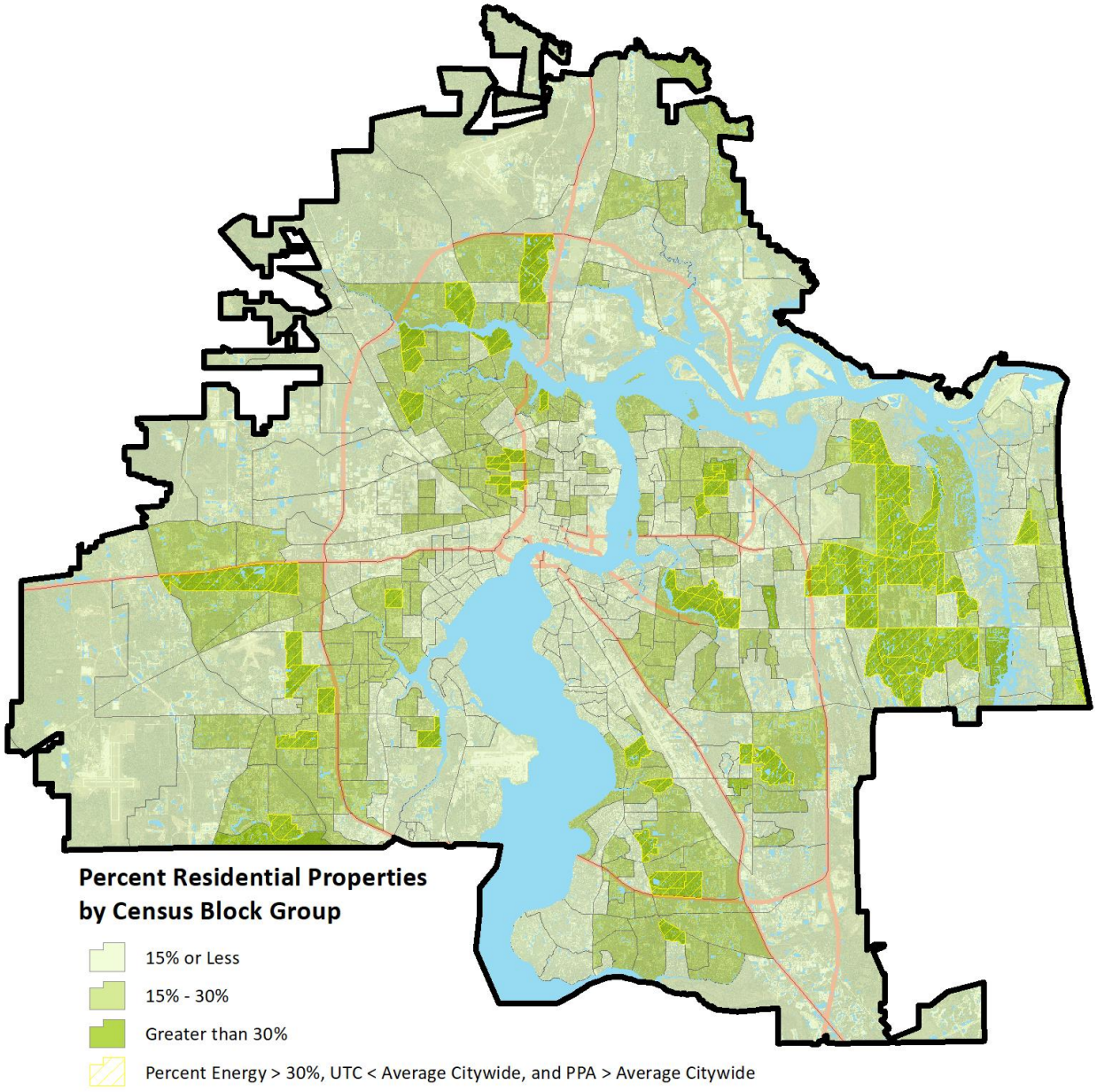

Figure 17: Priority planting areas based on energy conservation criteria

Stormwater Reduction

Tree canopy in urban areas helps to mitigate flooding and stormwater issues. The increased amounts of impervious areas due to parking lots, roads, sidewalks, and more lead to less rainwater infiltrating into the soil profile. Urban canopy helps to intercept some of the rainfall, mitigate flooding, regulate water quality, and influence the timing of peak runoff values (Dunne & Leopold, 1978).

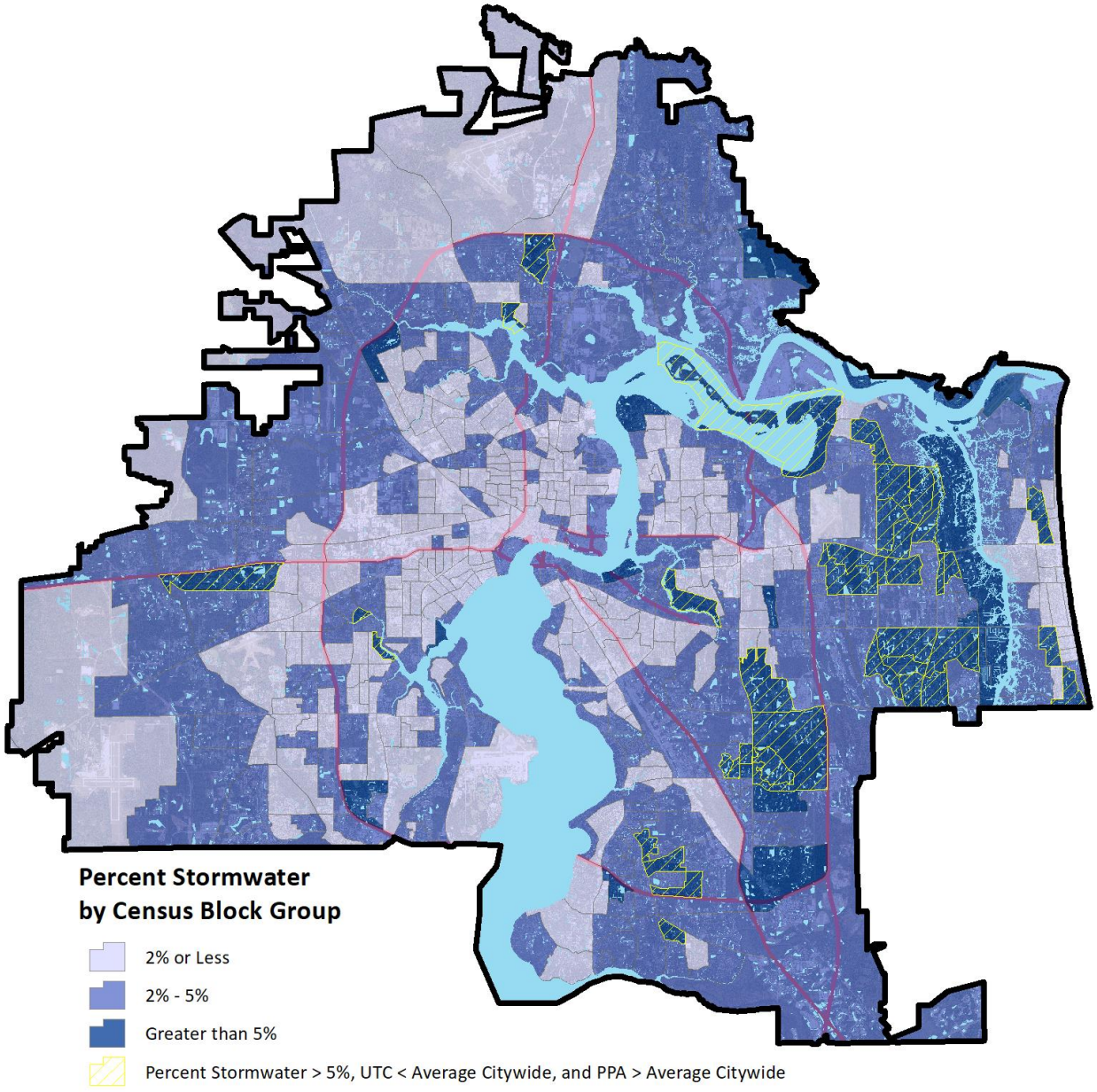

Figure 18: Priority planting areas based on stormwater reduction criteria

Urban Heat Island

Development and urbanization is often an indicator of a healthy economy. One consequence of urban development is the increase of paved surfaces which also include deleterious environmental impacts such as increased storm water runoff, flooding, and increased temperatures experienced through the Urban Heat Island effect (UHI). Mitigating the impacts of urbanization through targeted tree planting and canopy growth can be a cost-effective strategy for government agencies to improve public health for all Jacksonville residents.

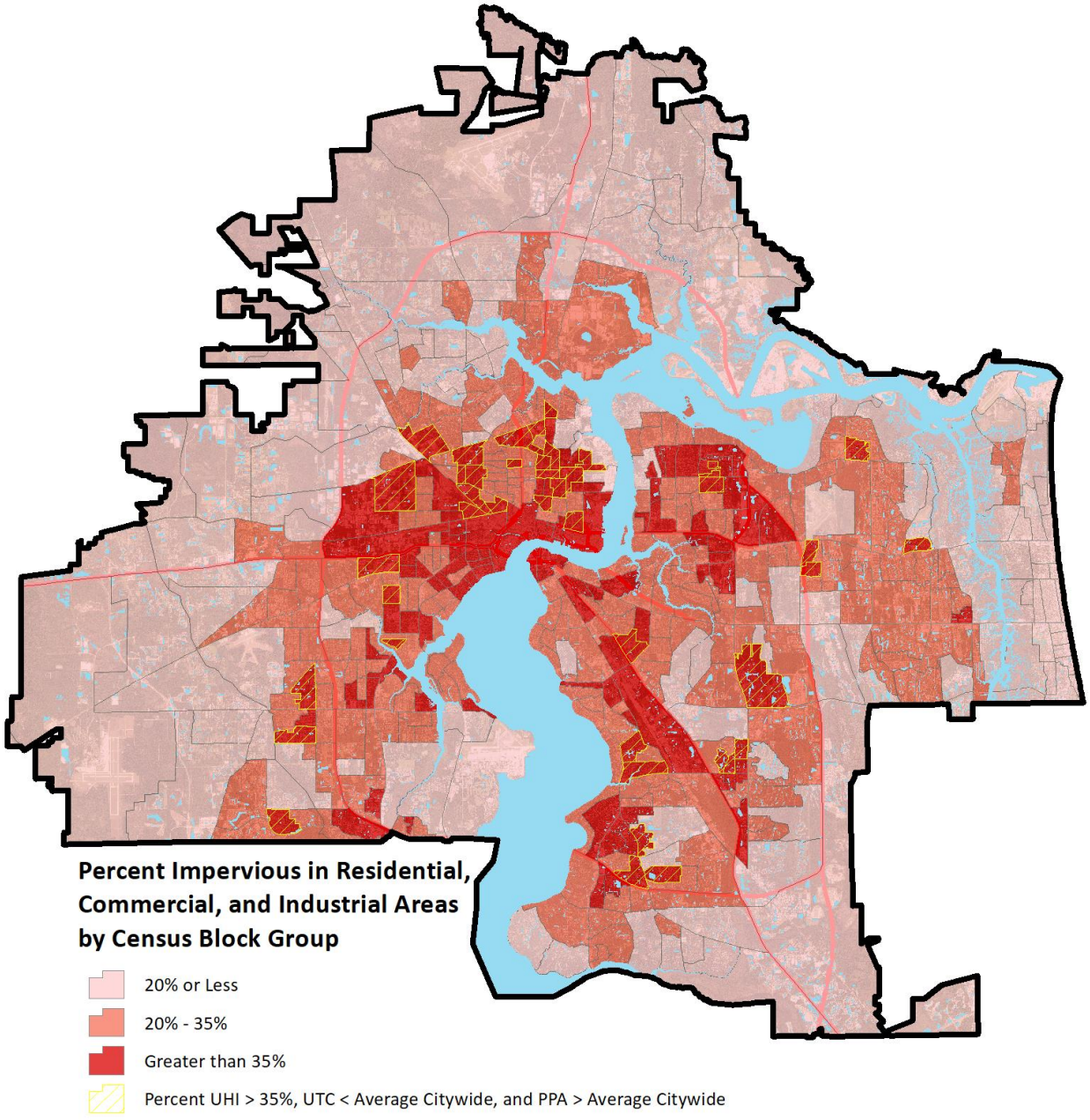

Figure 19: Priority planting areas based on urban heat island criteria

Wildlife Connectivity

Planting new trees adjacent to large tracts of existing canopy will help expand the greater canopy and fill in gaps over time. This is important for promoting wildlife migration and wildlife diversity supported by canopy connectivity.

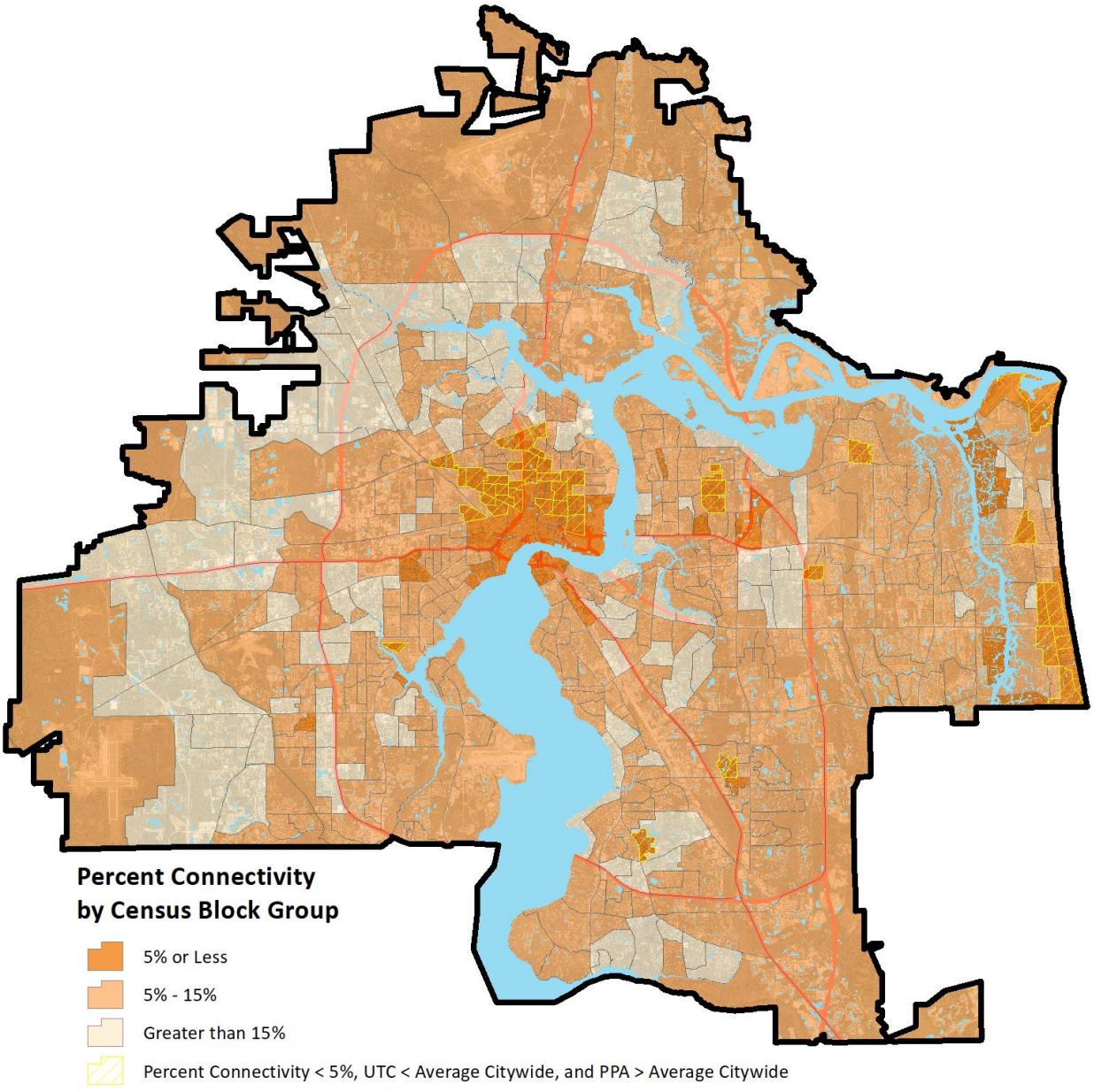

Figure 20: Priority planting areas based on wildlife connectivity criteria

Minority Populations

Tree canopy is negatively correlated with the percentage of minority residents. Planting trees in communities with higher percentages of minority residents can support environmental equity.

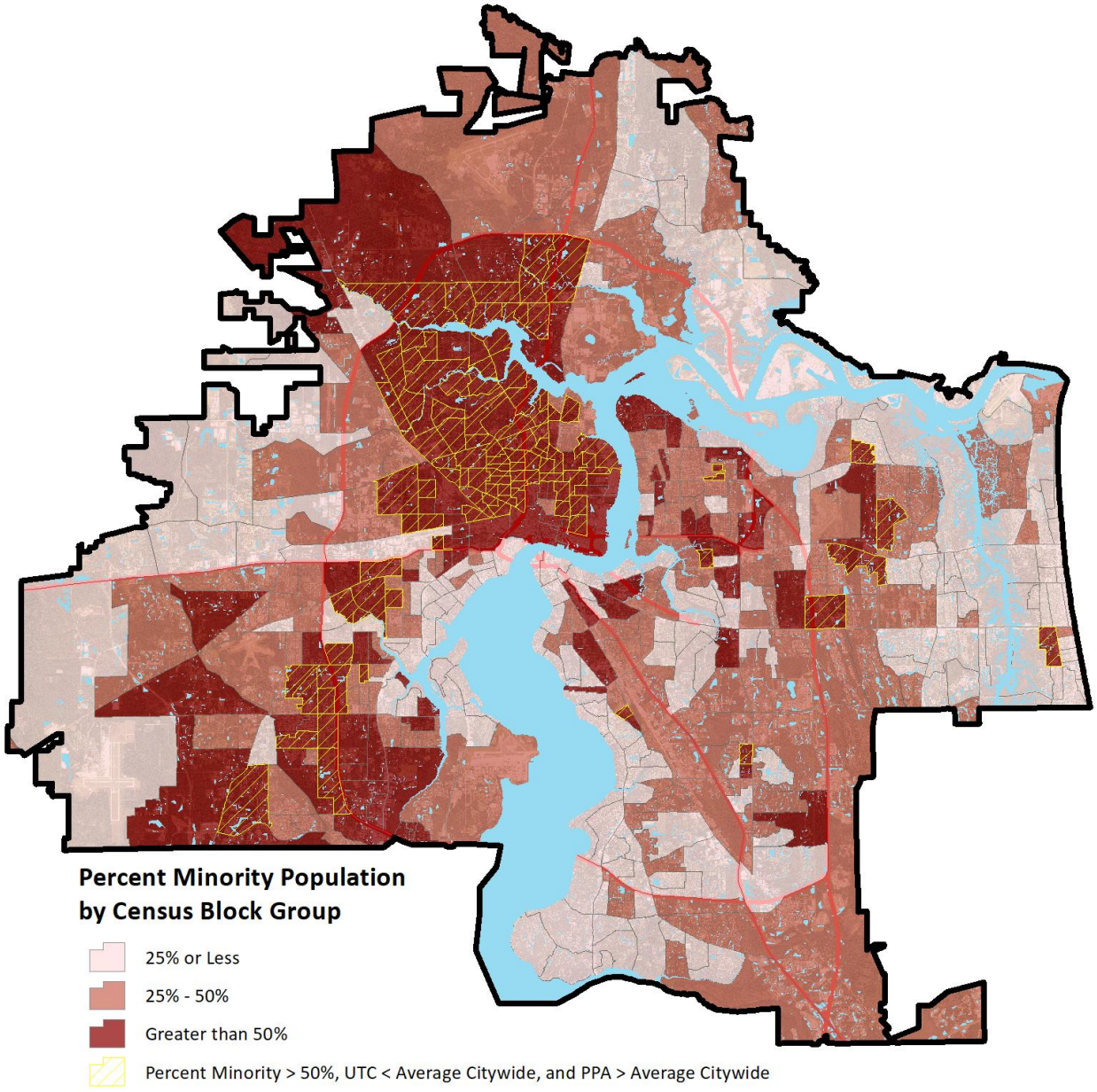

Figure 21: Priority planting areas based on minority populations criteria

Underserved Populations

Tree canopy is positively correlated with higher median income. Planting trees in lower income communities can support environmental equity. This indicator shows the percentage of residents living below the poverty level.

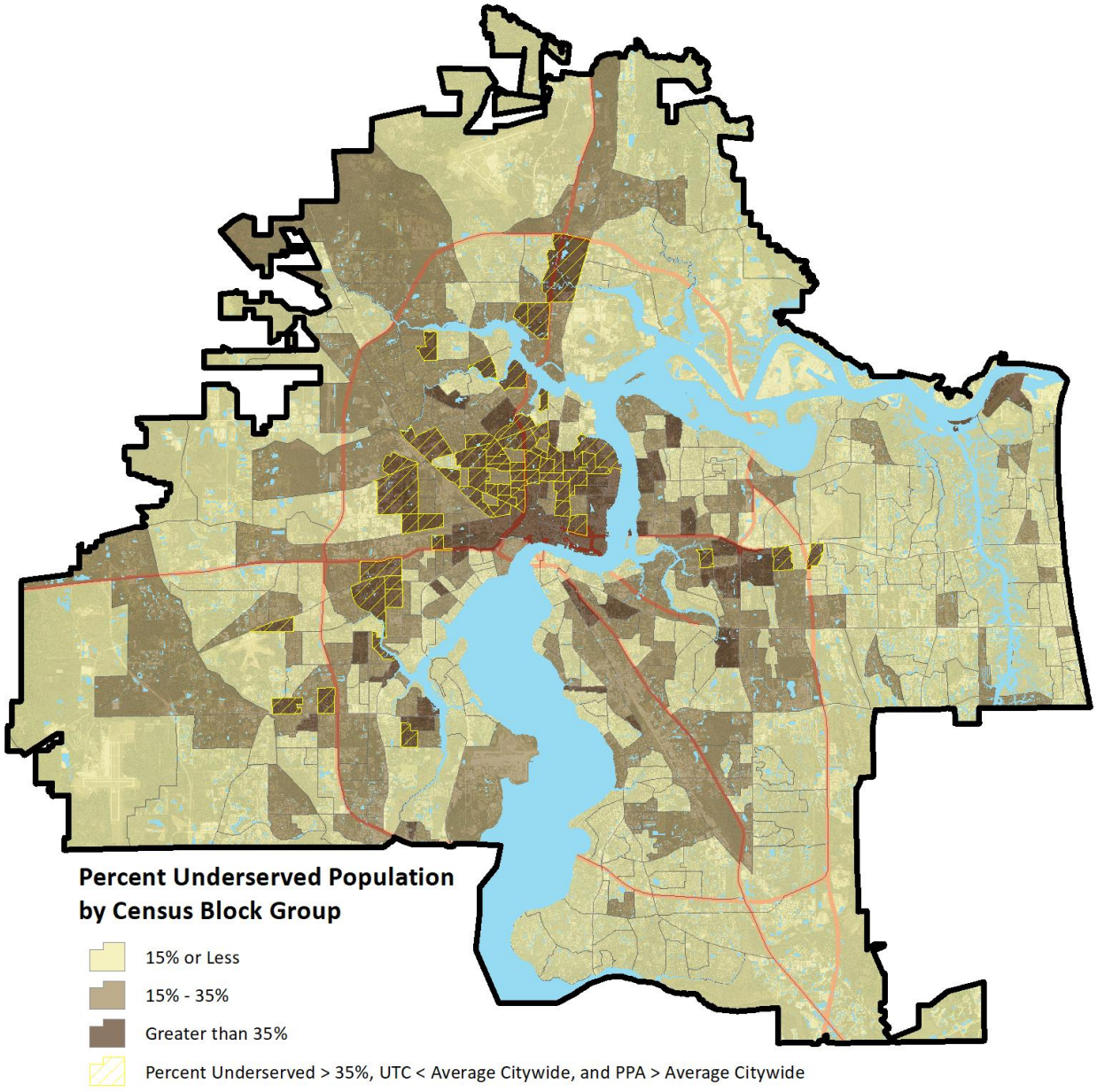

Figure 22: Priority planting areas based on underserved populations criteria

Vulnerable Populations

Trees provide many environmental and health benefits. This indicator shows the percentage of vulnerable residents who are under the age of 18 or over the age of 65.

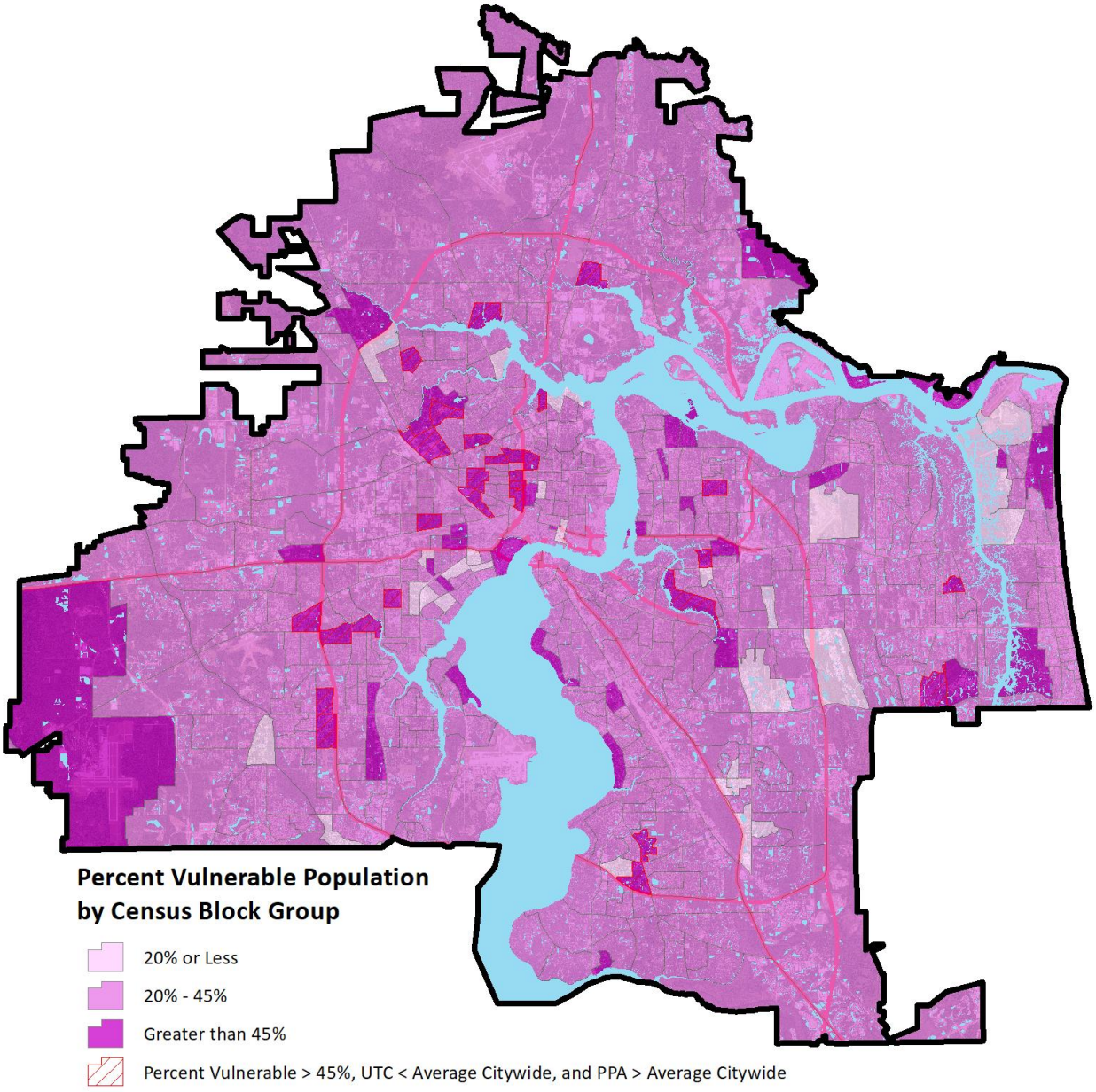

Figure 23: Priority planting areas based on vulnerable populations criteria

Overall

The overall planting prioritization considers all other prioritization criteria: air quality, energy conservation, stormwater reduction, urban heat island, wildlife connectivity, minority populations, underserved populations, and vulnerable populations as well as areas with low existing tree canopy and high possible planting area. Ranks represent low planting priority areas, medium planting priority areas, and high planting priority areas.

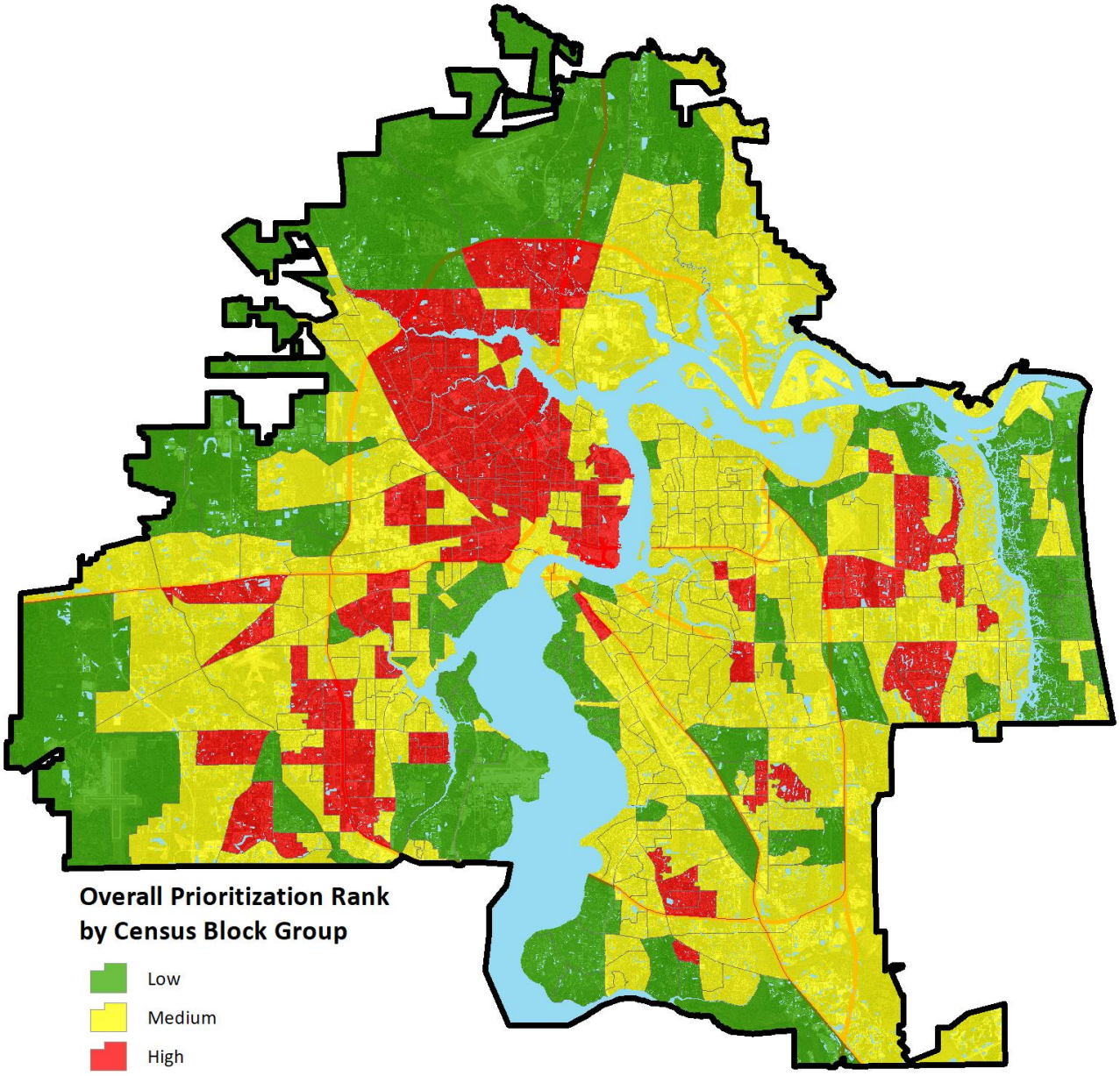

Figure 24: Priority planting areas based on all planting prioritization criteria

RECOMMENDATIONS

It is clear that the City values its natural resources and wants to maintain a healthy and sustainable urban environment. As such, the City should use these suggestions, along with the key findings in this report, as a starting point for an interdisciplinary goal-setting process and determination of priorities and strategies.

Recommendation 1: Utilize assessment results to preserve and promote urban tree canopy.

The results of this assessment can and should be used to encourage investment in forest monitoring, maintenance, and management, and to develop targeted presentations for city leaders, planners, engineers, resource managers, and the public on the functional benefits of trees in addressing environmental issues. The land cover data should be disseminated to diverse partners for urban forestry and other applications while the data is current and most useful for decision-making and implementation planning. The City should also utilize the additional tools provided, including the Canopy Planner and Tree Plotter web application to inform decisions and engage stakeholders. Canopy Planner allows stakeholders to visualize existing land cover and create custom weighted priority planting maps, while Tree Plotter allows the city to track tree planting without intensive training or GIS skills. The online mapping application incorporates individual tree inventory data gathered over time and landscape-scale data produced by this assessment. The application also provides users with the tools to map, inventory, search, update, and quantify environmental/economic benefits based on i-Tree research. Users can report on individual tree planting locations and existing trees so that the survey will continue to reflect the current status of the canopy for years to come.

Recommendation 2: Develop an urban forest management plan to provide a shared vision.

These assessment results should be used to encourage investment in forest monitoring, maintenance, management, and in preparing supportive information for local budget requests/grant applications. The information from this study can help establish canopy cover goals for the short and long term.

Recommendation 3: Relate urban forestry efforts to greater citywide initiatives and priorities.

The City of Jacksonville's urban forest green infrastructure is providing a great deal of benefits to the City that can be quantified. These benefits often relate back to greater community concerns and citywide initiatives and priorities. For example, air and water quality, stormwater management, and energy savings and all benefits that come from the urban forest. The City should use the USDA's i-Tree suite of software, along with the results of this study, to measure the value of its current urban tree canopy.

APPENDIX

Accuracy Assessment

Classification accuracy serves two main purposes: First, accuracy assessments provide information to technicians producing the classification about where processes need to be improved and where they are effective. Secondly, measures of accuracy provide information about how to use the classification and how well land cover classes are expected to estimate actual land cover on the ground. Even with high resolution imagery, very small differences in classification methodology and image quality can have a large impact on overall map area estimations. The classification accuracy error matrix illustrated in Figure 14 contains confidence intervals that report the high and low values that could be expected for any comparison between the classification data and what actual, on the ground land cover was in 2015. This accuracy assessment was completed using high resolution aerial imagery, with computer and manual verification. No field verification was completed.

The internal accuracy assessment was completed in five (5) steps

1. Approximately one thousand (1,500) sample points were randomly distributed across the study area and assigned a random numeric value.
2. Each sample point was then referenced using the NAIP imagery and assigned one of the five land cover classes ("Ref_ID") mentioned above.
3. In the event that the reference value could not be discerned from the imagery, the point was dropped from the accuracy analysis. In this case, no points were dropped.
4. An automated script was then used to assign values from the classification raster to each point ("Eval_ID"). The classification supervisor provides unbiased feedback to quality control technicians regarding the types of corrections required. Misclassified points (where reference ID does not equal evaluation ID) and corresponding land cover are inspected for necessary corrections to the land cover[1].

Accuracy is re-evaluated (repeat steps 3 & 4) until an acceptable classification accuracy is achieved.

Sample Error Matrix Interpretation

Statistical relationships between the reference pixels (representing the true conditions on the ground) and the intersecting classified pixels are used to understand how closely the entire classified map represents the Jacksonville, FL landscape. The error matrix shown in Figure 14 represents the intersection of reference pixels manually identified by a human observer (columns) and classification category of pixels in the classified image (rows). The gray boxes along the diagonals of the matrix represent agreement between the two-pixel maps. Off-diagonal values represent the number pixels manually referenced to the column class that were classified as another category in the classification image. Overall accuracy is computed by dividing the total number of correct pixels by the total number of pixels reported in the matrix (597 + 307 + 286 + 18 + 189 = 1,397 / 1,500 = 93 percent), and the matrix can be used to calculate per class accuracy percent's. For example, 645 points were manually identified in the reference map as Tree Canopy, and 619 of those pixels were classified as Tree Canopy

[1] Note that by correcting locations associated with accuracy points, bias is introduced to the error matrix results. This means that matrix results based on a new set of randomly collected accuracy points may result in significantly different accuracy values.

in the classification map. This relationship is called the "Producer's Accuracy" and is calculated by dividing the agreement pixel total (diagonal) by the reference pixel total (column total). Therefore, the Producer's Accuracy for Tree Canopy is calculated as: (619/645 = .96), meaning that we can expect that ~96 percent of all tree canopy in the Jacksonville, FL study area were classified as Tree Canopy in the classification map.

Classification Data	Reference Data: Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	597	43	2	1	2	645
Vegetation	19	307	15	0	2	343
Impervious	3	5	286	0	1	295
Soil / Dry Veg.	0	6	1	18	0	25
Water	0	2	1	0	189	192
Total	619	363	305	19	194	1,500

Overall Accuracy = 93%

Producer's Accuracy	
Tree Canopy	96%
Veg. / Open Space	85%
Impervious	94%
Bare Ground / Soil	95%
Water	97%

User's Accuracy	
Tree Canopy	93%
Veg. / Open Space	90%
Impervious	97%
Bare Ground / Soil	72%
Water	98%

Figure 25: Error Matrix for Land Cover Classifications within Jacksonville, FL

Conversely, the "User's Accuracy" is calculated by dividing the total number of agreement pixels by the total number of classified pixels in the row category. For example, 597 classification pixels intersecting reference pixels were classified as Tree Canopy, but 43 pixels were identified as Vegetation, two pixels were identified as Impervious, one pixel was identified as soil/dry vegetation, and two pixels were identified as water in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (597/645 = 0.93), meaning that ~93 percent of the pixels classified as Tree Canopy in the classification were actual tree canopy. It is important to recognize the Producer's and User's accuracy percent values are based on a sample of the true ground cover, represented by the reference pixels at each sample point. Interpretation of the sample error matrix results indicates this land cover, and more importantly, tree canopy, were accurately mapped in Jacksonville, FL. The largest sources of classification confusion exist between tree canopy and vegetation.

Results

Interpretation of the sample error matrix results indicates this land cover (and more importantly, tree canopy) was accurately mapped in Jacksonville, FL. The largest sources of classification confusion exist between tree canopy and vegetation.