URBAN TREE CANOPY

ASSESSMENT

BENTONVILLE,
ARKANSAS
APRIL | 2021

THE CITY OF BENTONVILLE

PLANIT GEO™
mapping a greener future

AN ASSESSMENT OF
URBAN TREE CANOPY

BENTONVILLE, ARKANSAS

> **Someone is sitting in the shade today because someone planted a tree a long time ago.**
> **-Warren Buffet**

PREPARED BY
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PREPARED FOR
The City of Bentonville, Arkansas

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5,366
ACRES OF CANOPY

25%
OF BENTONVILLE WAS COVERED BY TREE CANOPY IN 2019

EXECUTIVE SUMMARY

The urban forest in Bentonville is a valuable asset providing residents and visitors with many environmental, social and economic benefits. This assessment analyzed urban tree canopy (UTC), possible planting area (PPA), and areas unsuitable for planting and how they are distributed throughout the City's complete boundary, riparian areas, voting wards, zoning types, and parcels.

The results, based on the most recently available source imagery from the USDA's National Agriculture Imagery Program (NAIP) collected in 2019, provides an update to the previous assessment data produced using 2013 imagery and will allow the city to revise and develop existing and new strategies to protect and expand tree canopy. In 2019, Bentonville had 24.8% urban tree canopy cover and 45.3% possible planting area. The maps and data help to concentrate efforts in areas where needs are greatest, tree planting space is available, and benefits can be realized.

Prior to assessing Bentonville's canopy and canopy change since 2013, a land cover assessment was conducted by PlanIT Geo, LLC (www.planitgeo.com). This assessment is funded by and prepared for the Bentonville Parks Conservancy and the City of Bentonville, Arkansas (2020).

In 2019, tree canopy constituted 25% of Bentonville's land cover; non-canopy vegetation was 45%; soil/dry vegetation was 3%; impervious was 26% (of which 7% are buildings and 19% are "other impervious" surfaces such as roads, sidewalks, and parking lots); and water is 1%.

Next, tree canopy data were analyzed for several geographies, including Bentonville's zoning types, to determine the distribution of existing and potential urban tree canopy throughout the city. Downtown Neighborhood areas had the highest canopy coverage at 39%, although Residential areas contained the most canopy overall, containing 2,287 acres or 45% of all canopy in the City. Residential areas also contain the greatest potential for canopy expansion, offering over 3,166 acres (42 percent PPA by area and 61 percent of the City's total plantable space).

Urban tree canopy change was also evaluated since it was last assessed in 2013. Bentonville had a small decrease in canopy of 0.2% although there is a larger decrease in mature canopy cover which is offset by the new plantings of smaller trees. This is evident within the included assessment geographies.

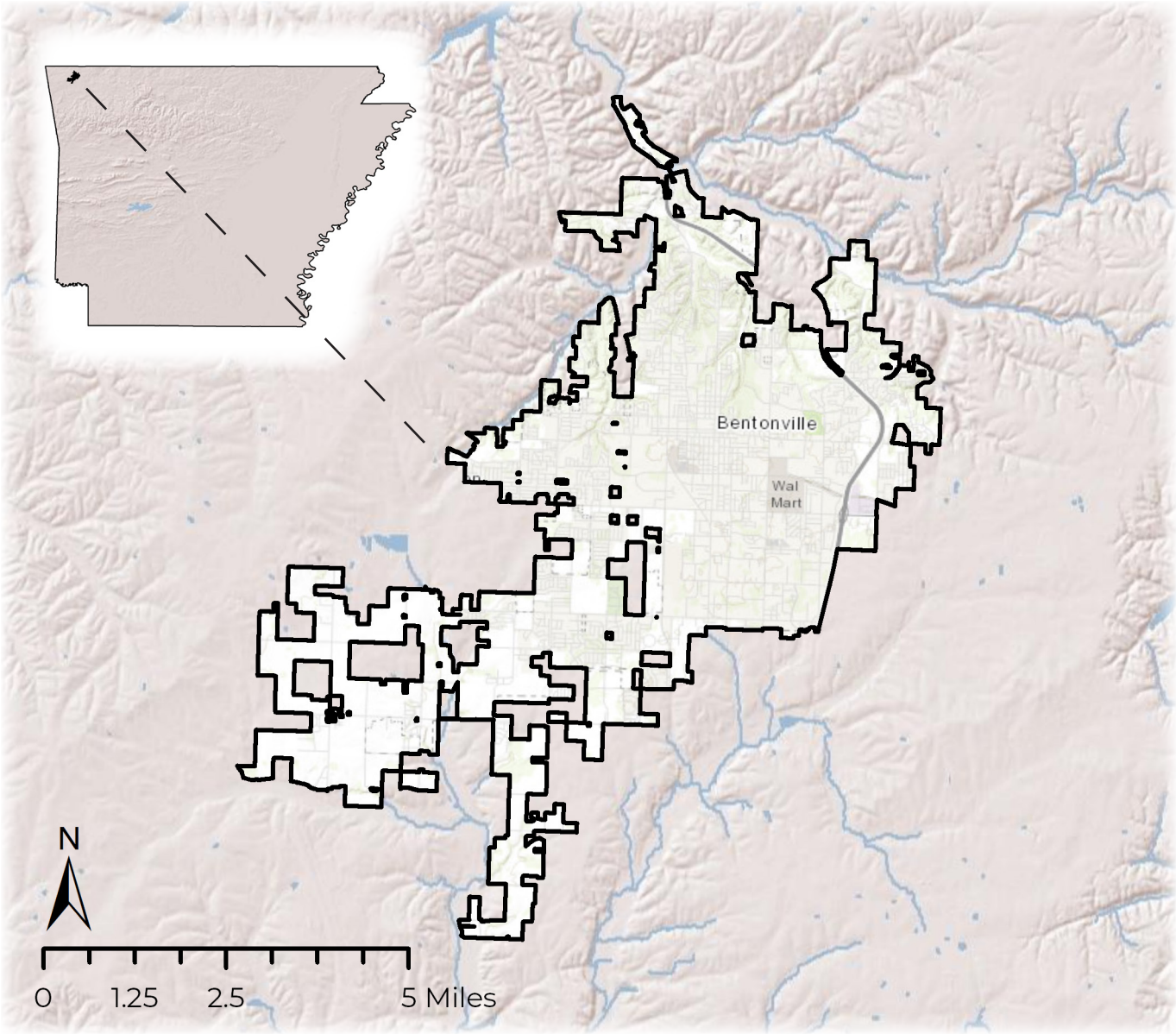

Figure 1. | Bentonville occupies approximately 34 square miles in Benton County, Arkansas.

25% URBAN TREE CANOPY

45% POSSIBLE PLANTING AREA

26% IMPERVIOUS SURFACE

Figure 2. | Based on an analysis of 2019 high-resolution imagery, Bentonville contains 25% tree canopy, 45% areas that could support canopy in the future, and 26% total impervious areas.

PROJECT METHODOLOGY

Land cover, urban tree canopy, and possible planting areas were mapped using the sources and methods described below. These datasets provide the foundation for the metrics reported at the selected geographic assessment scales.

DATA SOURCES

This assessment utilized high-resolution (1-meter) multispectral imagery from the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP) collected in 2019 to derive the land cover dataset. The NAIP imagery was used to classify all types of land cover. Additional GIS layers provided by the City of Bentonville were also incorporated into the analysis.

MAPPING LAND COVER

An initial land cover dataset was to be created prior to mapping tree canopy. The land cover data set is the most fundamental component of an urban tree canopy assessment. An object-based image analysis (OBIA) software program called Feature Analyst was used to classify features through an iterative approach. In this process, objects' spectral signatures across four bands (blue, green, red, and near-infrared), textures, and pattern relationships were considered. This remote sensing process used the NAIP imagery to derive four initial land cover classes. Additionally, tree canopy data from the EarthDefine US Tree Map (link: https://www.earthdefine.com/treemap/) were incorporated to create a five class land cover dataset. The US Tree Map is produced using a modern machine learning technique to extract tree canopy cover from the same 2019 NAIP imagery but at a more detailed 60-centimeter resolution.These five classes are shown in Figure 3 and described in the Glossary on page 20.

After manual classification improvement and quality control were performed on the remote sensing products, additional data layers from the city (buildings and water bodies) were utilized to capture finer feature detail and further categorize the land cover dataset.

Figure 3. | Five (5) distinct land cover classes were identified in the 2019 tree canopy assessment: urban tree canopy, other non-canopy vegetation, bare soil and dry vegetation, impervious (paved) surfaces, and water.

IDENTIFYING POSSIBLE PLANTING AREAS AND UNSUITABLE AREAS FOR PLANTING

In addition to quantifying Bentonville's existing tree canopy cover, another metric of interest in this assessment was the area where tree canopy could be expanded. To assess this, all land area in Bentonville that was not existing tree canopy coverage was classified as either possible planting area (PPA) or unsuitable for planting. Possible planting areas were derived from the non-canopy vegetation layer. Unsuitable areas, or areas where it was not feasible to plant trees due to biophysical or land use restraints (e.g. golf course playing areas, recreation fields, airports, agricultural areas, etc.), were manually delineated and overlaid with the existing land cover data set (Figure 4). The final results were reported as PPA Vegetation, Unsuitable Vegetation, Unsuitable Impervious, Unsuitable Soil, and Total Unsuitable.

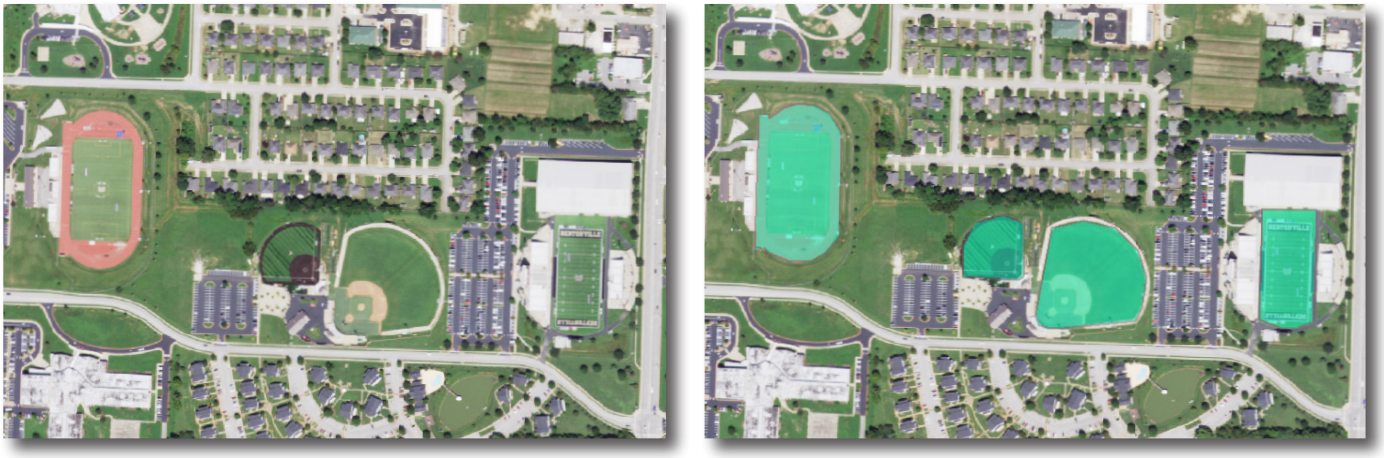

Figure 4. | Vegetated areas where it would be biophysically feasible for tree plantings but undesirable based on their current usage (left) were delineated in the data as "Unsuitable" (right). These areas included recreational sports fields, golf courses, and other open space.

DEFINING ASSESSMENT LEVELS

In order to best inform the City Council and Bentonville's various stakeholders, urban tree canopy and other associated metrics were tabulated across a variety of geographic boundaries (Figure 5). These boundaries include the city boundary, riparian corridors, voting wards, zoning, and parcels.

- The City of Bentonville **citywide boundary** is the one (1) main area of interest over which all metrics are summarized.
- The **riparian corridors** in Bentonville were assessed as one (1) area. This boundary was created by placing a 100-foot buffer around the streams in Bentonville.
- Tree canopy was analyzed for the four (4) **voting wards**, which cover Bentonville, 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.
- Twenty-four (24) unique **zoning** types were assessed to provide detail on tree canopy within the current human uses of land throughout Bentonville.
- Lastly, over seventeen thousand (17,000) individual **parcels** of land were assessed to provide information at the smallest geographic scale possible.

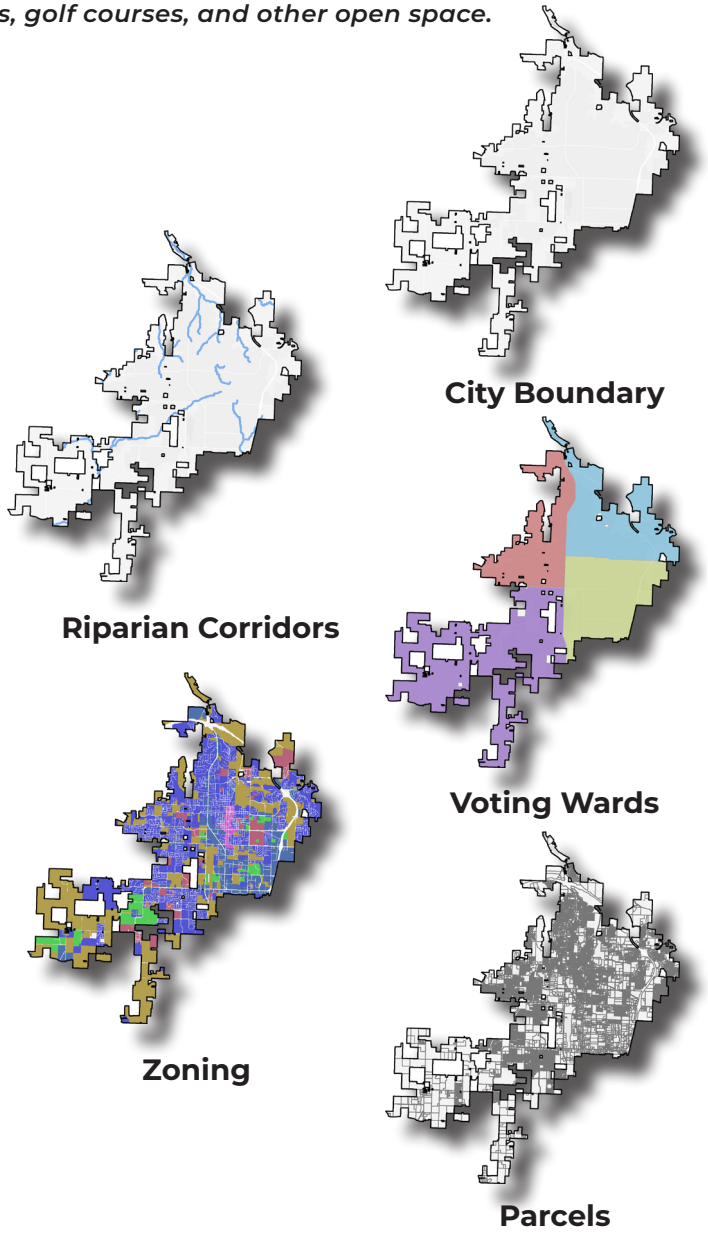

Figure 5. | Five (5) distinct geographic boundaries were explored in this analysis: the full city boundary, riparian corridors, voting wards, zoning, and parcels.

STATE OF THE CANOPY AND KEY FINDINGS

The results and key findings of this study, including the land cover map and canopy analysis results, are presented below. These results can be used to design a strategic approach to identifying existing canopy and future planting areas. Land cover percentages are based on the total area of interest while urban tree canopy, possible planting area, and unsuitable percentages are based on land area. Water bodies are excluded from land area because they are typically unsuitable for planting new trees without significant modification.

Table 1. | Land cover classes in acres and percent in the City of Bentonville.

City of Bentonville	Acres	% of Total
City Boundary	21,780	100%
Tree Canopy	5,366	25%
Non-Canopy Vegetation	9,897	45%
Impervious Surfaces	5,684	26%
Soil & Dry Vegetation	677	3%
Water	155	1%

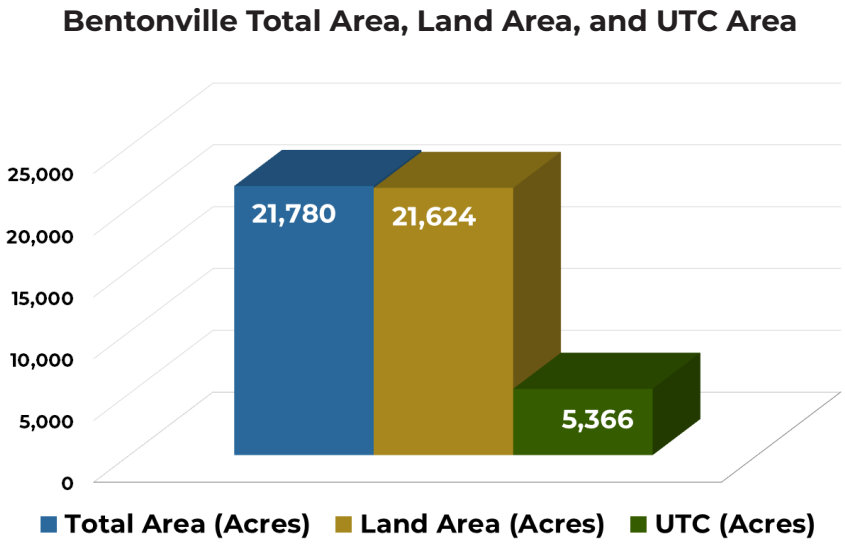

Figure 6. | Urban tree canopy compared to total area and land area, in acres, in the City of Bentonville.

CITYWIDE LAND COVER

In 2019, tree canopy constituted 25% of Bentonville's land cover; non-canopy vegetation was 45%; soil/dry vegetation was 3%; impervious was 26%; and water was 1%. These generalized land cover results are presented in Table 1 on the previous page. The impervious land cover class was then subdivided into more specific classifications. Approximately 7% of Bentonville was buildings and 19% was "other impervious" surfaces such as roads, sidewalks, and parking lots. The detailed land cover results, including impervious classifications, are presented in Figure 7 below.

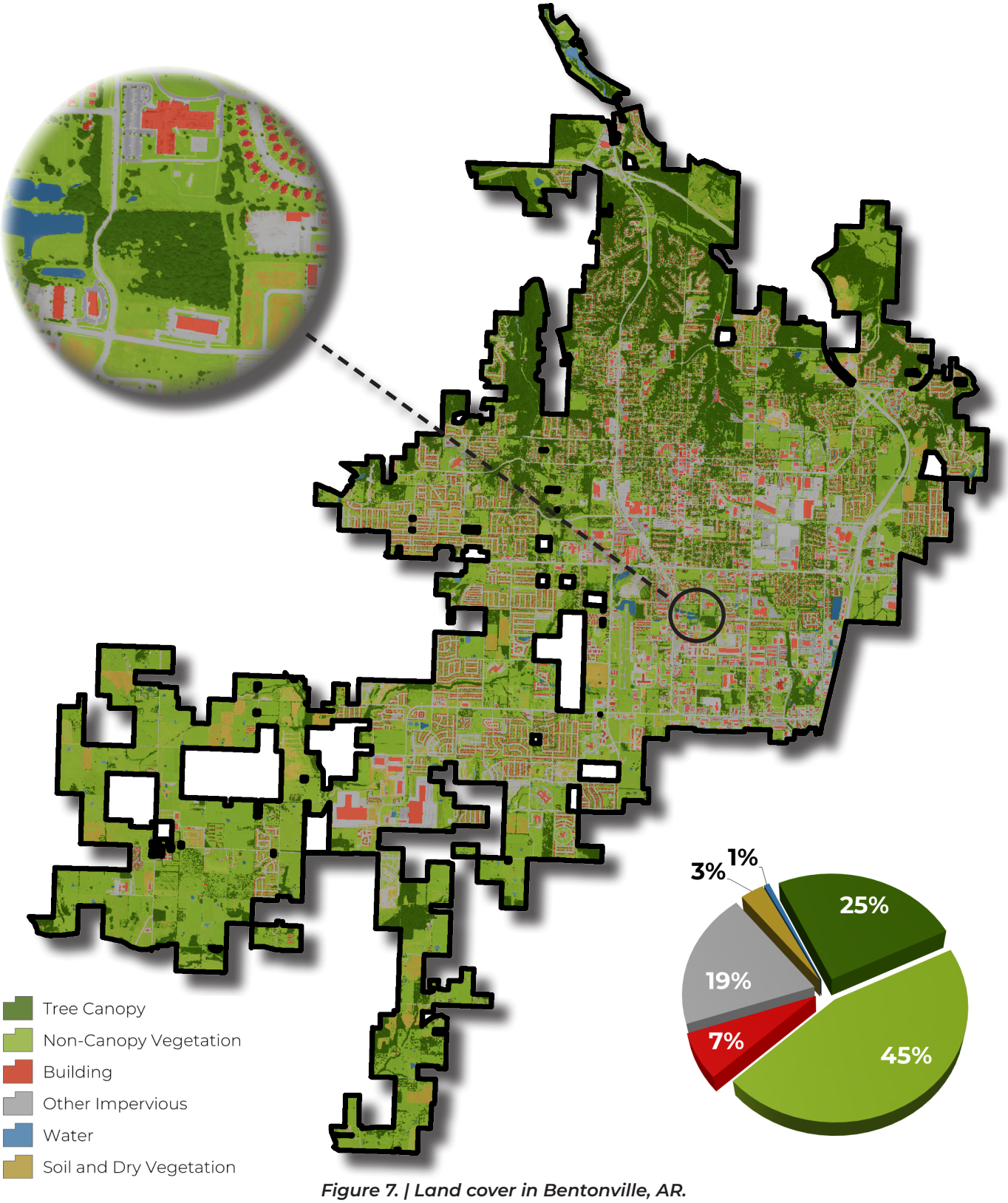

Figure 7. | Land cover in Bentonville, AR.

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 incorporated into the analysis. Note that the results of this study are based on land area, which excludes water bodies, as opposed to total area, which includes water bodies (note the difference between Total Acres and Land Acres in Table 2).

Results of this study indicate that within the City of Bentonville, 5,366 acres are covered with urban tree canopy, making up 25% of the City's 21,624 land acres; 9,791 acres are covered with other vegetation where it would be possible to plant trees (PPA), making up 45% of the City; and the other 6,468 acres were considered unsuitable for tree planting, making up 30% of the City. The unsuitable areas include recreational sports fields, golf course playing areas, impervious surfaces, and agricultural areas..

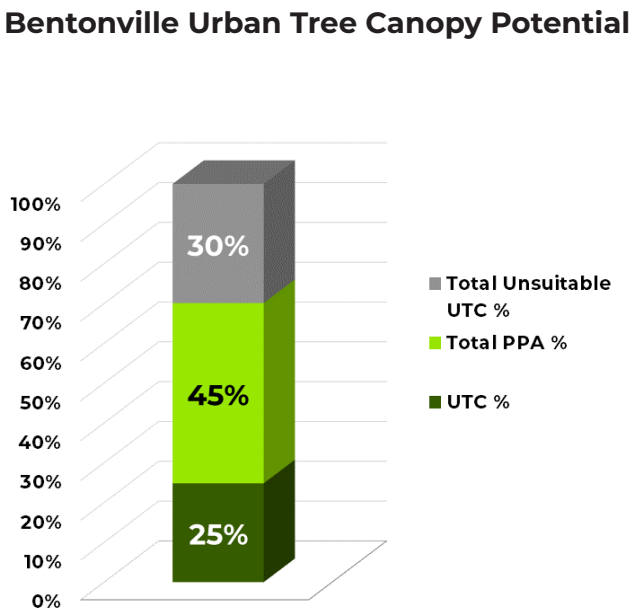

Figure 8. | Urban tree canopy, possible planting area, and area unsuitable for UTC in the City of Bentonville.

Table 2. | Urban tree canopy assessment results by acres and percent. (Percentages based on land acres.)

City of Bentonville	Acres	%
Total Area	21,780	100%
Land Area	21,624	99%
Urban Tree Canopy	5,366	25%
Total Possible Planting Area	9,791	45%
Unsuitable Vegetation	106	0%
Unsuitable Impervious	5,684	26%
Unsuitable Soil	678	3%
Total Unsuitable Area	6,468	30%

URBAN TREE CANOPY BY RIPARIAN CORRIDORS

UTC and PPA were assessed in Bentonville's riparian corridors, or the areas found within a 100-foot buffer along the City's streams, comprising a total of 640 land acres. Canopy cover was much higher in this area at 61% (392 acres) compared to the 25% citywide average. Bentonville's riparian corridors also included 188 acres of PPA (29%) and 60 acres of unsuitable areas (9%).

Table 3. | Urban tree canopy assessment results by riparian corridors. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the City's total UTC or PPA within the riparian corridor.

Riparian Corridors	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Riparian Corridors	640	3%	392	61%	7%	188	29%	2%
Citywide	**21,624**	**100%**	**5,366**	**25%**	**100%**	**9,791**	**45%**	**2%**

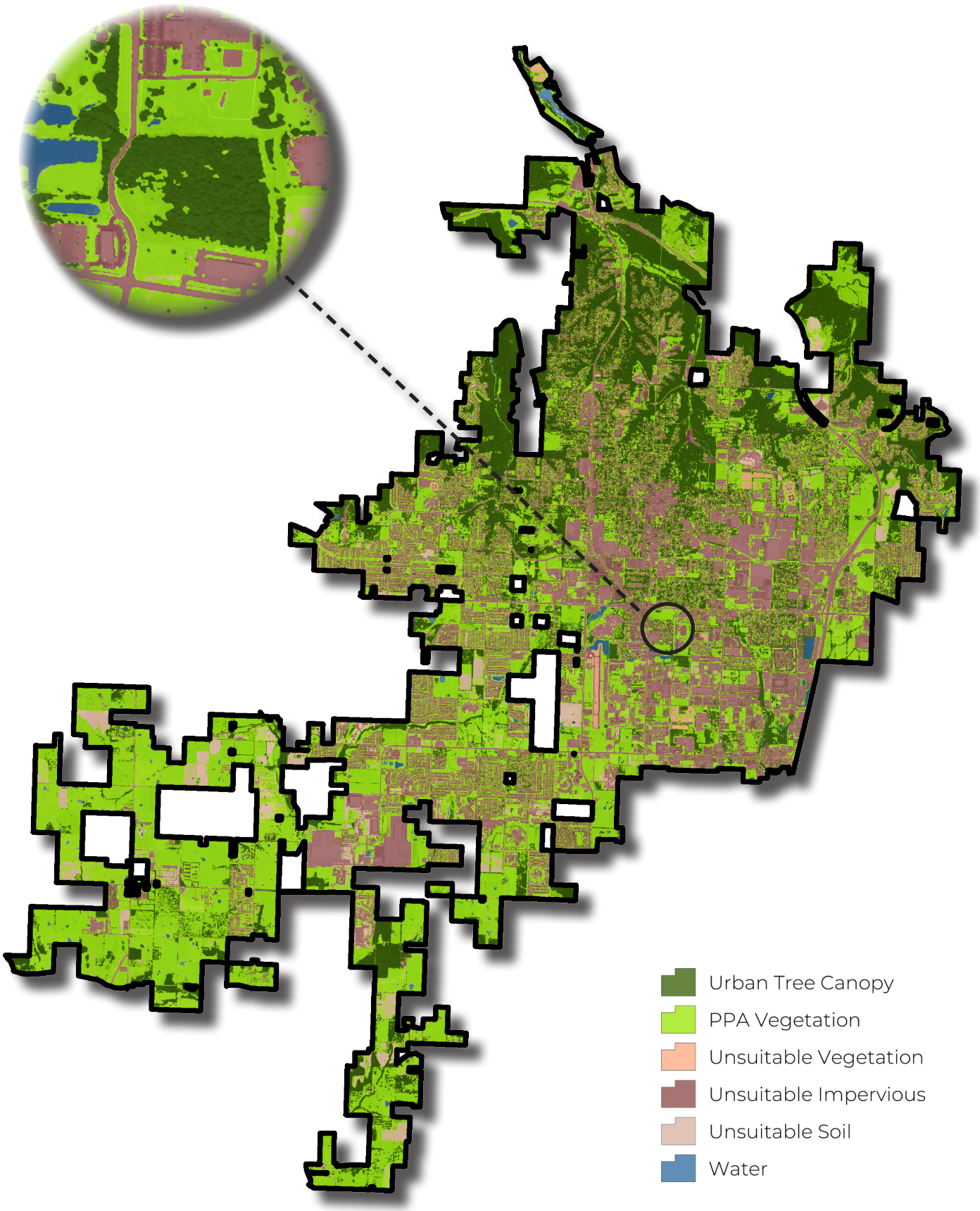

Figure 9. | Land cover in Bentonville, AR.

URBAN TREE CANOPY BY VOTING WARDS

UTC and PPA were assessed in Bentonville's four voting wards. UTC varied significantly across the wards. Ward 1 had the highest UTC at 44%, followed by Ward 2 at 39%. The voting wards with the lowest UTC were Ward 3 and Ward 4, with 13% and 15% UTC, respectively. PPA was more consistent across wards, with Wards 1, 2, and 4 all containing 33-36% PPA. The greatest opportunity for future canopy expansion was found in Ward 3, the voting ward with the greatest distribution of the City's land area and lowest existing UTC %. It contained 5,068 acres of PPA or 52% of all plantable space in Bentonville.

Table 4. | Urban tree canopy assessment results by voting wards. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the City's total UTC or PPA within each voting ward.

Voting Ward	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Ward 1	4,791	22%	2,120	44%	40%	1,587	33%	16%
Ward 2	3,820	18%	1,471	39%	28%	1,338	35%	14%
Ward 3	8,138	38%	1,033	13%	19%	5,068	62%	52%
Ward 4	4,768	22%	719	15%	13%	1,724	36%	18%
Citywide	**21,516**	**100%**	**5,344**	**25%**	**100%**	**9,716**	**45%**	**100%**

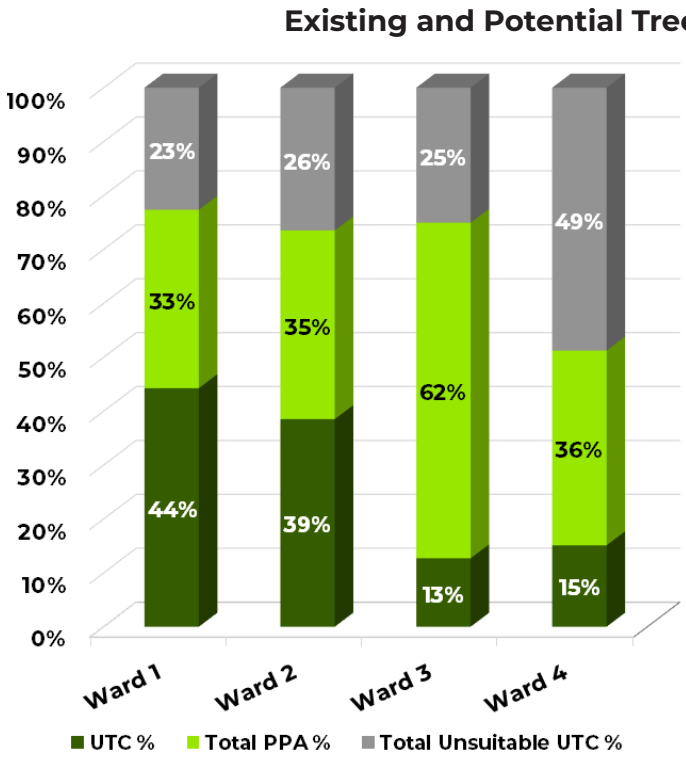

Figure 10. | Urban tree canopy, possible planting areas, and unsuitable areas in Bentonville by voting wards.

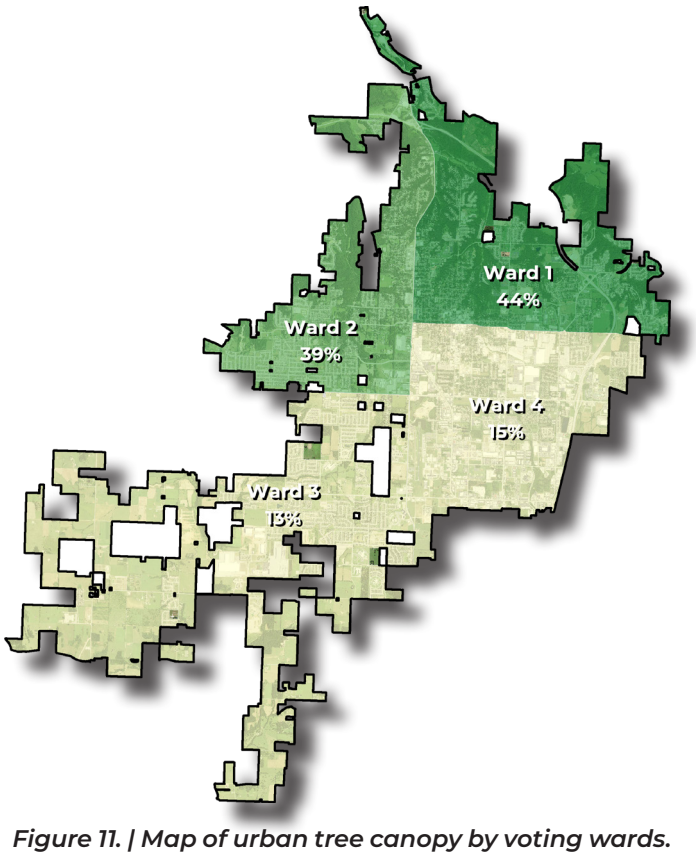

Figure 11. | Map of urban tree canopy by voting wards.

URBAN TREE CANOPY BY PARCELS

UTC and PPA were assessed for each unique parcel of land in Bentonville which is the smallest unit of analysis in this assessment. UTC and PPA varied amongst parcels from 0 to 100%.

However, the majority of the City's parcels fell within the 0-10% UTC range (48% of all parcels) and the 50-100% PPA range (29% of all parcels).

This parcel-level UTC analysis can be used to identify specific areas where canopy loss has occurred in order to prioritize planting spaces where canopy can be replanted.

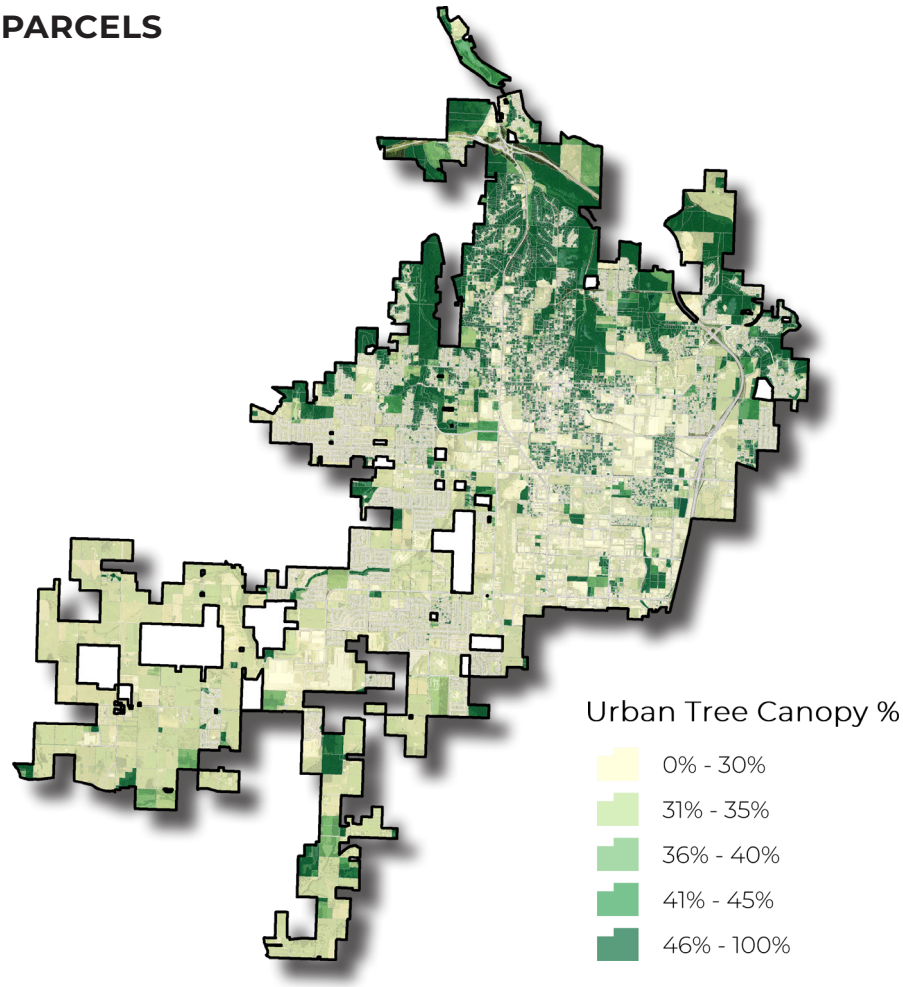

Figure 12. | Urban tree canopy in Bentonville by parcels.

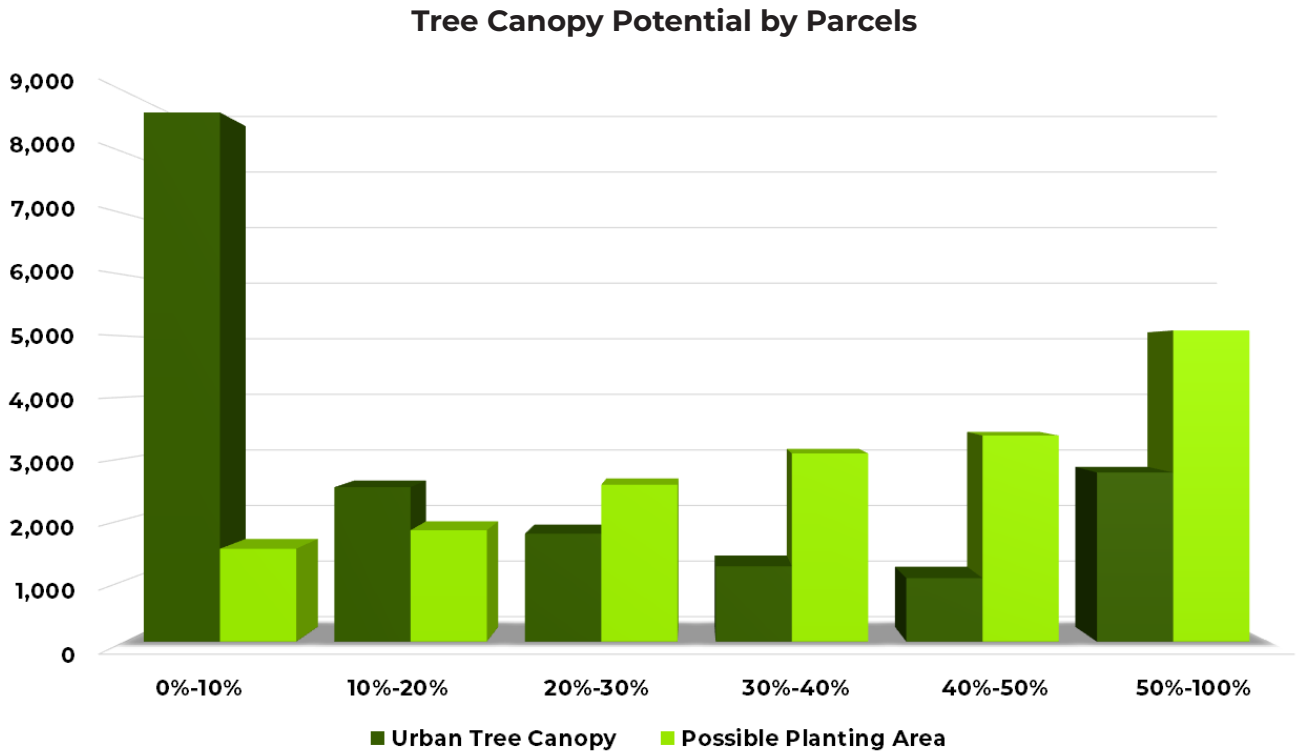

Figure 13. | Urban tree canopy and possible planting area in Bentonville by parcels (number of parcels within range).

URBAN TREE CANOPY BY ZONING

UTC and PPA were assessed for the 24 unique zoning types found within Bentonville. UTC varied across the different zoning types The highest UTC was 52% found in the residential zone R-MHP, while the lowest UTC was 7% found in the commercial and industrial zones C-3 and I-2. PPA ranged from 25% in zone D-E to 60% in zone R-E. 39% of all canopy cover in Bentonville was found in zone A-1, and another 38% was found in zone R-1. Those two zones also contained the greatest opportunities for potential canopy expansion with zone A-1 containing over 4,000 acres of PPA (44% of all PPA in the City) and zone R-1 containing another ~2,400 acres (26% of citywide PPA).

Zoning types were also aggregated into seven broader categories by type. Bentonville's Downtown Neighborhood had the highest UTC at 39 percent, yet this zoning occupies a relatively small area in total (31 acres). The majority of Bentonville's canopy was found in residential areas, which contain over 2,280 acres of canopy and constitute 45 percent of all UTC in the City.

In terms of tree canopy potential, agricultural areas had the greatest proportion of PPA (areas of other non-canopy vegetation that could support trees) at 58 percent or 44 percent of all PPA in Bentonville; however, due to the uses of these areas, they should not be considered for potential urban canopy expansion for purposes other than agriculture.

When agricultural areas were removed from this calculation, total PPA decreased from 9,174 to 5,165 acres (48 to 27 percent), and residential areas became home to the greatest potential for canopy expansion, offering over 3,166 acres (42 percent PPA by area and 61 percent of the City's total plantable space).

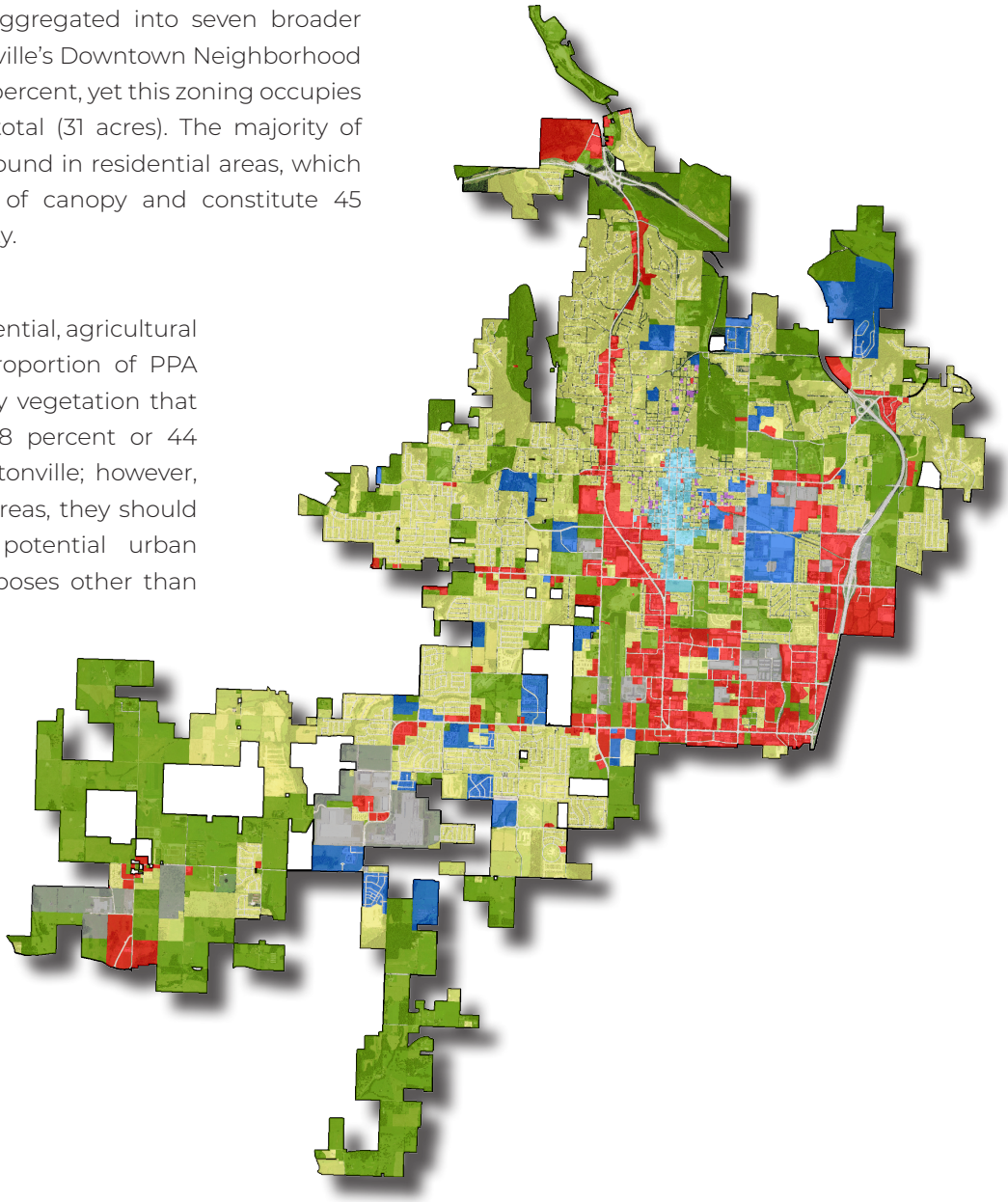

Figure 14. | Urban tree canopy in Bentonville by zoning.

Table 4. | Urban tree canopy assessment results by zoning. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the City's total UTC or PPA within each aggregated zoning type.

Zoning	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Agricultural · A-1 Agricultural	6,886	36%	1,993	29%	39%	0	0%	0%
Commercial · C-1: Neighborhood Commercial · C-2: General Commercial · C-3: Central Commercial	2,395	12%	356	15%	7%	928	39%	18%
Downtown · D-C: Downtown Core · D-E: Downtown Edge	200	1%	40	20%	1%	56	28%	1%
Downtown Neighborhood · DN-1: Downtown Low-Density Residential · DN-2: Downtown Medium-Density Residential · DN-3: Downtown High-Density Residential · DN-4: Downtown Mixed-Use Residential	31	0%	12	39%	0%	11	34%	0%
Industrial · I-1: Light Industrial · I-2: Heavy Industrial	1,039	5%	82	8%	2%	485	47%	9%
Planned Development · PRD: Planned Residential Development · PUD: Planned Unit Development	1,256	7%	314	25%	6%	519	41%	10%
Residential · R-1: Single Family Residential · R-2: Duplex and Patio Home Residential · R-3: Medium Density Residential · R-4: High Density Residential · RC-2: Central Residential - Moderate Density · RC-3: Central Residential - High Density · R-E: Residential Estate · R-MHP: Manufactured Home Residential · R-O: Residential Office · R-ZL: Zero Lot Line	7,486	39%	2,287	31%	45%	3,166	42%	61%
Totals	**19,293**	**100%**	**5,083**	**26%**	**100%**	**5,165**	**27%**	**100%**

URBAN TREE CANOPY CHANGE ANALYSIS

Tree canopy change between 2013 and 2019 was also analyzed across the same geographic assessment boundaries described in the previous section. The previous assessment was performed by PlanIT Geo in 2014 using 2013 imagery. Although the exact methods used to map land cover varied slightly between the 2013 and 2019 studies, the resulting land cover data are comparable. Both studies used leaf-on, high-resolution aerial imagery from the USDA's National Agriculture Imagery Program (NAIP) as their primary source. However, the current 2019 study used a higher resolution 60-centimeter image and machine learning techniques to capture tree canopy. Both studies also utilized Feature Analyst remote sensing software and an object-based image analysis (OBIA) as their primary method of mapping other land cover types.. To ensure an even comparison, the 2013 land cover data were reanalyzed using the current boundaries of the city, riparian corridors, zoning, etc., and changes since 2013 were assessed at the same geographic assessment scales. Similar to the UTC and PPA assessment, the urban tree canopy change percentages are based on land area only.

CITYWIDE URBAN TREE CANOPY CHANGE

There was a small decrease in Bentonville's tree canopy over the six-year study period from 2013-2019. Throughout the city, the average canopy cover decreased from 25.0 percent in 2013 to 24.8 percent in 2019. Tree canopy decreased by approximately 49 acres citywide, yielding a 0.2% raw decrease (-0.9% relative to 2013 acreage) since 2013. Although the overall change in canopy was small, an additional analysis of *where* canopy existed in 2013 and 2019 revealed that approximately 1,020 acres of existing canopy had been lost or removed and 962 acres had been gained during the six-year time period. These results indicate that while the City's existing tree canopy has been well preserved, amidst change and development and many new trees have been planted, canopy expansion did not occur. New development throughout the city appears to be the cause of a majority of the losses in tree canopy. Current levels of urban tree canopy in Bentonville can be maintained as long as future development does not call for the removal of established trees with large crown coverage and with careful planning and planting efforts derived from the tree planting scenarios section of this report. Bentonville's mature trees, which may eventually succumb to old age, stress, and other environmental factors, may also cause a decline in canopy cover over the next 20 year period if planting efforts are insufficient.

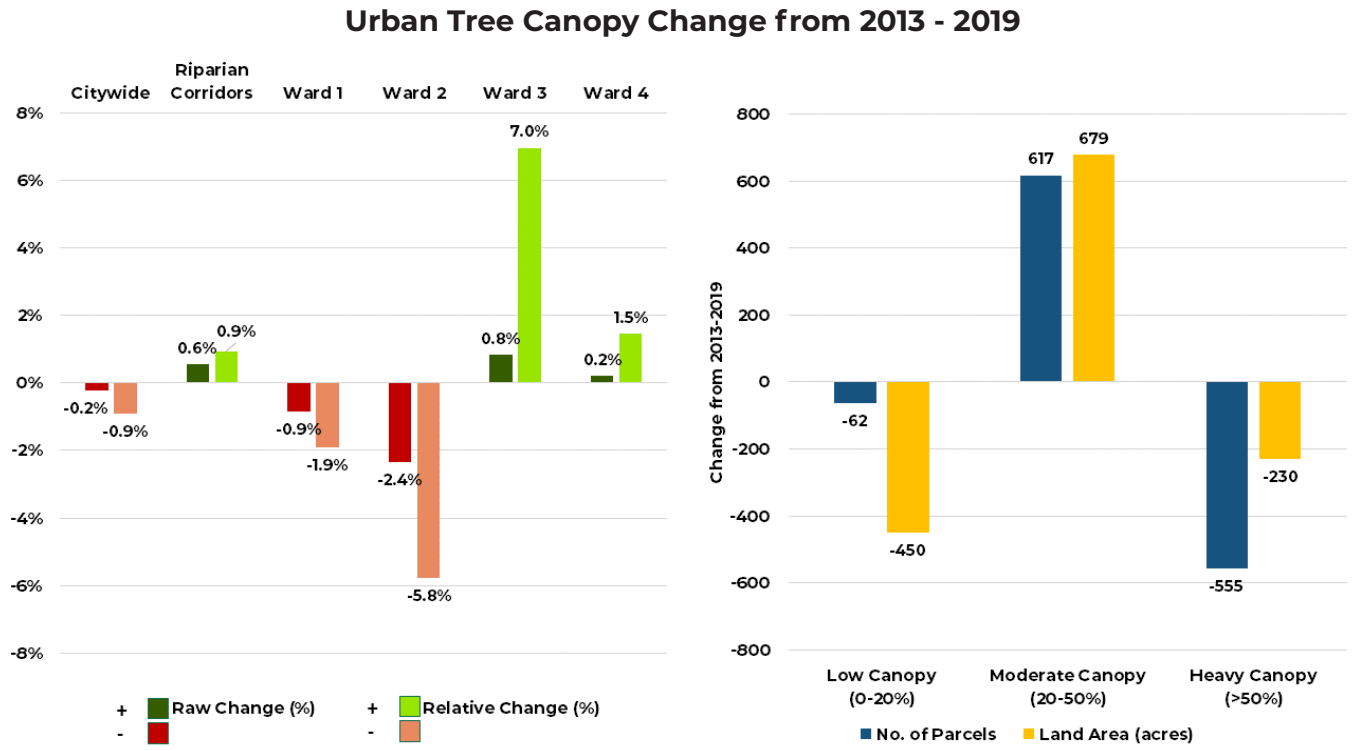

Figure 14. | Urban tree canopy change from 2013-2019 in Bentonville by selected geographies (citywide, riparian corridors, and voting wards), left, and canopy cover type change by parcels, right.

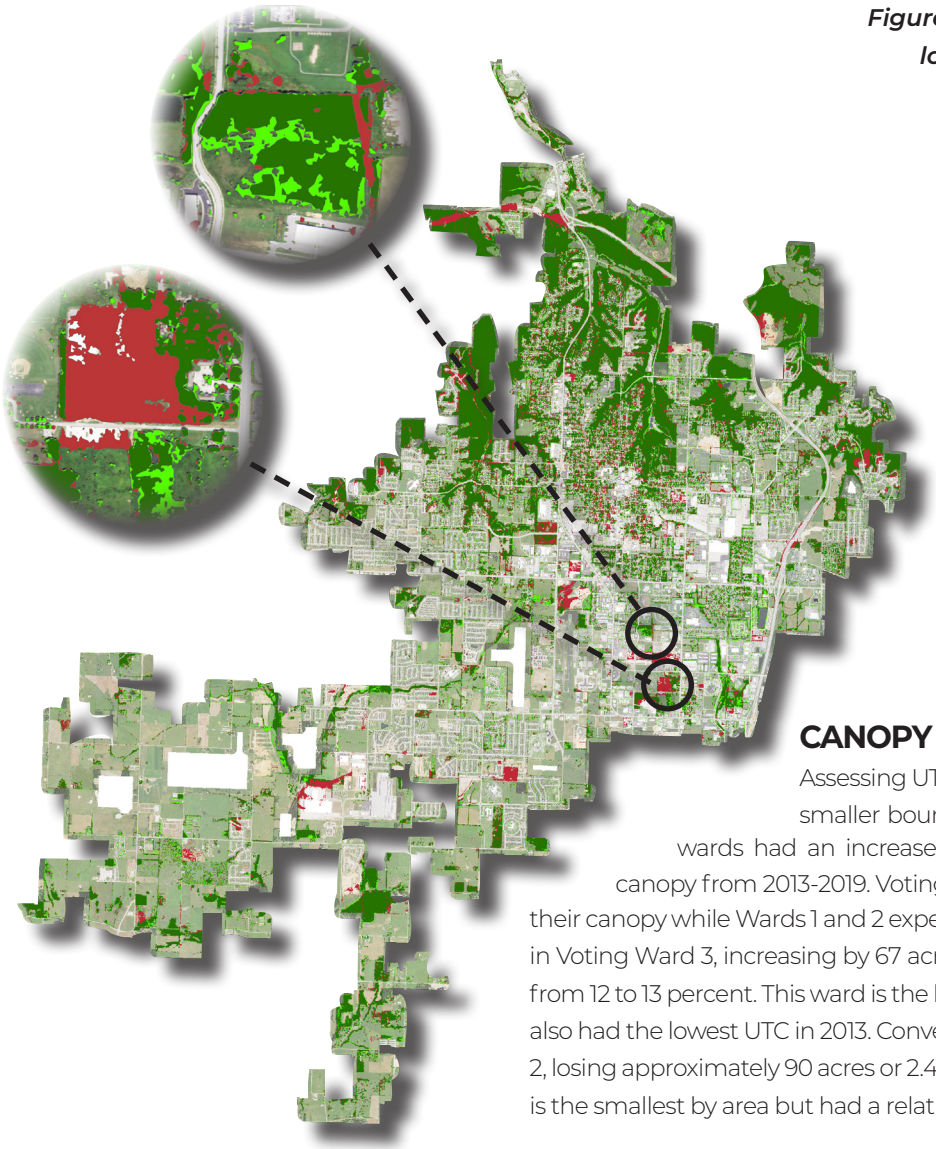

Figure 15. | Urban tree canopy gains and losses (2013-2019) in Bentonville.

CANOPY CHANGE BY RIPARIAN CORRIDORS

UTC change in Bentonville's riparian corridors, which have a higher canopy cover than the citywide average, was also small. Only 4 acres, or 0.6 percent of canopy in these areas, were lost from 2013-2019, keeping UTC along waterways at 61 percent cover.

CANOPY CHANGE BY VOTING WARDS

Assessing UTC change over the six-year period within smaller boundaries tells a different story. Two voting wards had an increase and the other two had a decrease in canopy from 2013-2019. Voting Wards 3 and 4 both had an increase in their canopy while Wards 1 and 2 experienced a loss. The greatest increase was in Voting Ward 3, increasing by 67 acres of canopy or approximately 1 percent from 12 to 13 percent. This ward is the largest by land area of the four wards but also had the lowest UTC in 2013. Conversely, the greatest loss was seen in Ward 2, losing approximately 90 acres or 2.4 percent from 41 to 39 percent. This ward is the smallest by area but had a relatively high UTC in 2013.

CANOPY CHANGE BY ZONING

UTC change since 2013 was assessed in Bentonville's seven aggregated zoning classes, and the results varied from a 16 percent loss to a 2 percent gain. The greatest proportional losses of canopy were seen in the Downtown, Downtown Neighborhood, and Industrial classes, which lost 5, 8, and 23 acres of canopy, respectively. This equates to losses of 16 percent total canopy (or 30 percent relative to the previous UTC), 4 percent (16 percent relative) and 2 percent (22 percent relative), respectively. Residential areas, which contain the majority of Bentonville's land area and existing canopy, had a loss of approximately 12 acres or 0.2%. Commercial areas had the greatest increase in canopy, gaining 39 acres of UTC between 2013-2019 or an increase of nearly 2%.

CANOPY CHANGE BY COVER TYPE AND PARCELS

In addition to changes in urban tree canopy by acres and raw or relative percent, changes in Bentonville's urban forest in terms of types of canopy cover was also assessed using the UTC by parcels data. First, parcels were categorized as Low Canopy (0-20%), Moderate Canopy (20-50%), or Heavy Canopy (>50%) in both 2013 and 2019. Next, change was assessed by parcel, and lastly, the land areas of the parcels were summed to determine changes in amounts of canopy type by land area. Bentonville experienced a slight 1% decline in heavy tree canopy between 2013-2019. Heavy tree cover in the City of Bentonville's 21,624 land acres declined by 230 acres from 4,063 to 3,833 acres. During this same time period, the City saw a 3% increase in moderate tree cover of approximately 679 acres, bringing the total from 3,712 to 4,025 acres. The category with the most cover, low tree canopy (areas with less than 20% tree cover and urban areas) decreased by 2% or 450 acres, from 11,645 acres to 11,195. A decrease in heavy tree cover is an indicator of ecological change resulting from urban development, whereas a decrease in low canopy indicates that newly-planted trees are maturing and aging into the moderate or heavy classes.

TREE PLANTING PRIORITIZATION

Urban tree canopy provides a multitude of direct and indirect benefits. Six planting prioritization criteria were created using the land cover dataset to identify areas where specific benefits provided by tree canopy are needed most. These areas represent possible planting areas as determined by remote sensing classification. Areas have not been evaluated for conflicts between overhead or underground utilities and should be visited to determine sitesuitability prior to planting.

Air Quality – Street rights-of-way corridors typically have higher concentrations of particulate matter due to automobile traffic. In addition to higher concentrations of road surfaces, the right-of-way is typically comprised of land under the city's influence. Trees can be planted along roads to absorb vehicle exhaust and reduce pollution. This criteria indicates plantable space within the right-of-way.

Energy Conservation – Trees provide a reduction in energy use in the summer by providing shade and in the winter by reducing wind. This indicator identifies plantable space within 50 feet of all buildings.

Riparian – The area immediately surrounding rivers and creeks constitutes a vital habitat for local wildlife. This indicator identifies plantable space within riparian corridors.

Table 6. | Citywide planting area prioritization.

Prioritization Criteria	Acres of Plantable Space
Air Quality	617
Energy Conservation	2,085
Riparian	188
Stormwater	7,678
Urban Heat Island	355
Wildlife Habitat Connectivity	3,020
Citywide Total	**9,791**

Stormwater Runoff Prevention – Trees can be integrated to help manage stormwater, specifically when targeting impervious surfaces. This indicator uses available planting area adjacent to impervious surfaces and surface water bodies.

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. Parking lots comprise a large amount of impervious surfaces within urban areas of a city. This indicator identifies plantable space within 25 feet of parking lot edge lines.

Wildlife Habitat Connectivity - Large tracts of connected canopy cover can improve habitat for local wildlife. This indicator identifies available planting areas within 100' of large canopy tracts (1 acre in size or larger).

Table 7. | Tree planting prioritization by voting wards. Each value represents the percent of each ward that is suitable for planting to address each criterion.

	Ward 1	Ward 2	Ward 3	Ward 4
Criteria	% of Ward Area	% of Ward Area	% of Ward Area	% of Ward Area
Air Quality	29%	26%	10%	59%
Energy Conservation	9%	14%	7%	9%
Riparian	1.0%	0.5%	0.9%	0.9%
Stormwater Reduction	25%	29%	33%	29%
Urban Head Island Mitigation	1.4%	1.0%	0.6%	4%
Wildlife Habitat Connectivity	15%	15%	9%	9%

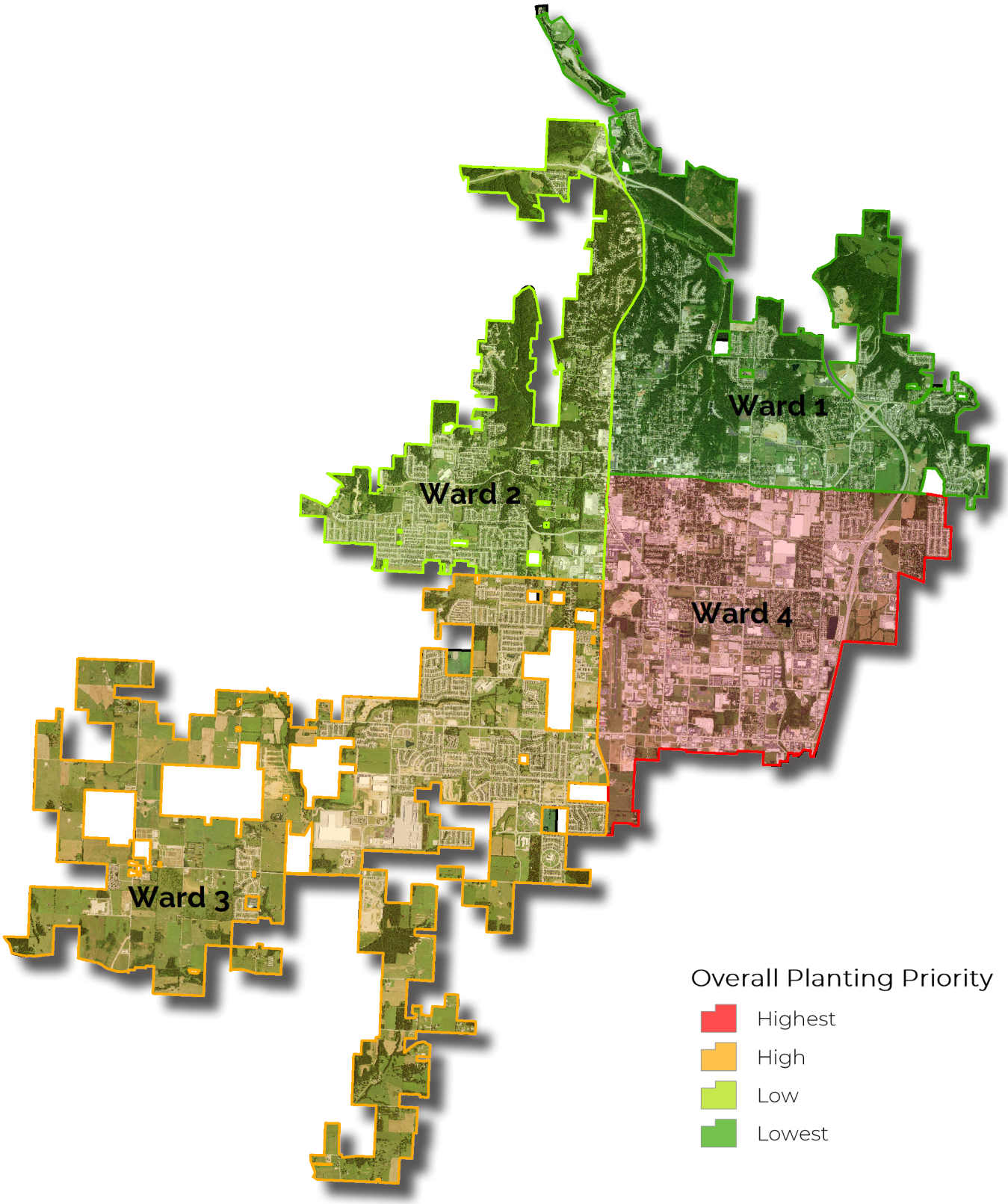

Figure 16. | Overall planting priority by voting wards.

CONCLUSIONS AND RECOMMENDATIONS

The City of Bentonville has demonstrated that it values its natural resources and wants to maintain a healthy and sustainable urban environment. Recurring assessments of the City's tree canopy represent important steps in ensuring the long-term health of its urban forest. A greater percent of canopy cover can be achieved with proper planning, investment, and care of existing trees. The City should continue to monitor the health of the urban forest and implement the following recommendations to ensure the urban forest is considered during future city planning and development to sustain and enhance the benefits that trees provide to the community.

Target new tree plantings to provide air quality and stormwater reduction benefits

To preserve, protect, and maintain Bentonville's tree canopy, the City should have a tree canopy assessment performed on a regular interval. As the City changes, they will be able to use these data to ensure that their urban forest policies and management practices prioritize its maintenance, health, and growth. The City's urban forest provides Bentonville with a wealth of environmental, social, and even economic benefits which relate back to greater community interest in citywide initiatives and priorities. These results can be used to identify where existing tree canopy cover should be preserved, where there are opportunities to expand the City's canopy cover, and which areas would receive the greatest benefits from the investment of valuable time and resources into Bentonville's urban forest.

1. Leverage the results of this assessment to promote the urban forest

The results of this assessment should be used to encourage investment in urban forest monitoring, maintenance, and management; to prepare supportive information for local budget requests/grant applications; 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 and planting prioritization data should be disseminated to diverse partners for urban forestry and other applications while the data are current and most useful for decision-making and implementation planning. The information from this study can help establish canopy cover goals for the short- and long-term.

2. Use the planting site prioritization to identify plantable space within the right-of-way

The City and its various stakeholders can utilize the results of the UTC, PPA, and planting site prioritization analyses to identify the best locations on public land to focus future tree planting and canopy expansion efforts. Trees can play a large role in improving public health by improving air quality, reducing temperature, and improving public health. Planting trees near impervious surfaces can offset the urban heat island effect, stormwater runoff, and energy consumption. Plantable space in the right-of-way is often found close to high concentrations of impervious surfaces. Land cover analysis results revealed that 61% of all plantable space fell within residential areas, and another 18% is found in commercial and planned development areas each. The priority planting analysis should be used to identify planting opportunities adjacent to high concentrations of impervious surfaces in these areas, within the right-of-way, and on public lands throughout the City.

3. Develop outreach programs towards private landowners

In Bentonville, when agricultural areas are excluded, 61% of PPA is found in areas designated as Residential. The City should focus on community outreach and education programs to better inform citizens and private landholders of the environmental, health, social, and financial benefits that trees provide and consider other strategies to help preserve and grow the tree canopy in the nearly 3,200 acres of plantable space in residential areas. Tree giveaways and tree planting programs will continue to promote new tree plantings. Other incentives can be developed to further increase the tree canopy. In addition, the City should continue to conduct volunteer tree planting events to increase awareness levels in the community.

61% OF ALL PLANTABLE SPACE IN BENTONVILLE IS LOCATED IN RESIDENTIALLY-ZONED AREAS.

4. Focus new plantings in high priority areas

To maximize impact, see greater return on investment, and provide the greatest number of benefits to the community, we recommend that the City focus planting and management efforts in areas with high weighted priority rankings. Planting priority maps and data, such as the map on page 16, show the areas of highest priority for all planting prioritization criteria and land cover metrics. The City should also use the GIS data provided to create unique weighted scenarios to focus efforts in targeted areas that meet specific criteria. For instance, the City could find areas that have low UTC, high PPA, or would offer the greatest benefits to air quality, summertime temperature reduction, and energy conservation. Focusing urban forest management resources on expanding and maintaining tree canopy in this area will have positive impacts on multiple factors that the City has deemed important. Efforts should focus on outreach to the residents of these neighborhoods, as well as local business and land owners, in order to promote new tree plantings and continued maintenance of existing trees.

REPORT APPENDIX

ACCURACY ASSESSMENT

Classification accuracy serves two main purposes. Firstly, 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 Table A1 contain 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 2019. 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 THESE STEPS:

1. Seven hundred fifty (750) sample points, or approximately 20 points per square mile area in Bentonville (34 sq. miles), were randomly distributed across the study area and assigned a random numeric value.
2. Each sample point was then referenced using the NAIP aerial photo and assigned one of five generalized land cover classes (“Ref_ID”) mentioned above by a technician.
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]
5. 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 Bentonville’s landscape. The error matrix shown in Table A1 represent the intersection of reference pixels manually identified by a human observer (columns) and classification category of pixels in the classified image (rows). The blue boxes along the diagonals of the matrix represent agreement between the two-pixel maps. Off-diagonal values represent the number of 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 (131 + 258 + 264 + 67 + 10 = 730 / 750 = 97.33%), and the matrix can be used to calculate per class accuracy percentage’s. For example, 141 points were manually identified in the reference map as Tree Canopy, and 131 of those pixels were classified as Tree Canopy 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: (131/141 = .93), meaning that we can expect that ~93% of all 2019 tree canopy in the Bentonville, AR study area was classified as Tree Canopy in the 2019 classification map.

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, 134 classification pixels intersecting reference pixels were classified as Tree Canopy, but 3 pixels were identified as Vegetation in the reference map. Therefore, the User’s Accuracy for Tree Canopy is calculated as: (131/134 = 0.98), meaning that ~98% 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 Bentonville in 2019. The largest sources of classification confusion exist between tree canopy and vegetation.

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.

Table A1. | Error matrix for land cover classifications in Bentonville, AR (2019).

Classification Data	Reference Data: Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	131	3	0	0	0	134
Vegetation	9	258	0	0	0	267
Impervious	1	6	264	1	0	272
Soil / Dry Veg.	0	0	0	67	0	67
Water	0	0	0	0	10	10
Total	141	267	264	68	10	750

Overall Accuracy = 97%

Producer's Accuracy	
Tree Canopy	93%
Veg./ Open Space	97%
Impervious	100%
Bare Ground / Soil	99%
Water	100%

User's Accuracy	
Tree Canopy	98%
Veg./ Open Space	97%
Impervious	97%
Bare Ground / Soil	100%
Water	100%

ACCURACY ASSESSMENT RESULTS

Interpretation of the sample error matrix offers some important insights when evaluating Bentonville's urban tree canopy coverage and how well aligned the derived land cover data are with interpretations by the human eye. The high accuracy of the 2019 data indicates that regardless of how and when it was achieved, Bentonville's current tree canopy can be safely assumed to match the figures stated in this report (approximately 25%).

GLOSSARY/KEY TERMS

Land Acres: Total land area, in acres, of the assessment boundary (excludes water).

Non-Canopy Vegetation: Areas of grass and open space where tree canopy does not exist.

Possible Planting Area - Vegetation: Areas of grass and open space where tree canopy does not exist, and it is biophysically possible to plant trees.

Possible Planting Area - Total: The combination of PPA Vegetation area and PPA Impervious area. In this project no impervious areas were identifies as plantable.

Soil/Dry Vegetation: Areas of bare soil and/or dried, dead vegetation.

Total Acres: Total area, in acres, of the assessment boundary (includes water).

Unsuitable Impervious: Areas of impervious surfaces that are not suitable for tree planting. These include buildings and roads and all other types of impervious surfaces.

Unsuitable Planting Area: Areas where it is not feasible to plant trees. Airports, ball fields, golf courses, etc. were manually defined as unsuitable planting areas.

Unsuitable Soil: Areas of soil/dry vegetation considered unsuitable for tree planting. Irrigation and other modifiers may be required to keep a tree alive in these areas.

Unsuitable Vegetation: Areas of non-canopy vegetation that are not suitable for tree planting due to their land use.

Urban Tree Canopy (UTC): The "layer of leaves, branches and stems that cover the ground" (Raciti et al., 2006) when viewed from above; the metric used to quantify the extent, function, and value of the urban forest. Tree canopy was generally taller than 10-15 feet tall.

Water: Areas of open, surface water not including swimming pools.

APRIL 2021

URBAN TREE CANOPY

ASSESSMENT

BENTONVILLE, ARKANSAS

THE CITY OF BENTONVILLE

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