Auburn

TREES TO OFFSET STORMWATER

Case Study 11: City of Auburn, Alabama

Alabama Forestry Commission · Forest Service, U.S. Department of Agriculture · City of Auburn · Green Infrastructure Center

April 1, 2019

The Green Infrastructure Center Inc. is the technical services consultant for this project and the case study author. Illustrations in the report are by the Green Infrastructure Center Inc. (GIC).

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PROJECT OVERVIEW

This project, Trees to Offset Stormwater, is a study of Auburn's tree canopy and its role in taking up, storing and releasing water. This study was undertaken to assist Auburn in evaluating how to better integrate trees into their stormwater management programs. More specifically, the study covers the role that trees play in stormwater management and shows how the city can benefit from tree conservation and replanting. It also evaluates ways for the city to improve forest management as the city grows.

PROJECT FUNDERS AND PARTNERS

The project was developed by the nonprofit Green Infrastructure Center Inc. (GIC) in partnership with the states of Virginia, North Carolina, South Carolina, Georgia, Florida and Alabama. The GIC created the data and analysis for the project and published this report. This study is one of 12 pilot projects evaluating a new approach to estimate the role of trees in stormwater uptake.
The USDA Forest Service provided the funding for Alabama to determine how trees can be utilized to meet municipal goals for stormwater management. The Alabama Forestry Commission (AFC) administered the pilot studies in Alabama and selected Auburn to be the test case

The project was spurred by the on-going decline in forest cover throughout the southern United States. Causes for this decline arise from multiple sources including land conversion for development, storm damages, lack of tree replacement as older trees die, and for coastal cities, inundation from Sea Level Rise. Many localities have not evaluated their current tree canopy, which makes it difficult to track trends, assess losses or set goals to retain or restore canopy. In fact, Alabama has a high rate of tree loss. In a study of the biggest tree cover losses over a five-year period based on individual states, the greatest losses were seen in Alabama, Rhode Island, Georgia, Nebraska, and the District of Columbia (Nowak and Greenfield, 2018).

As a result of this project, Auburn now has baseline data against which to monitor canopy protection progress, measurements of the stormwater and water quality benefits provided by its urban forest, and locations for prioritizing canopy replanting.

Trees in the city's parks account for significant canopy in the city.

OUTCOMES

This report includes findings and recommendations from tree canopy cover mapping and analysis, the process to model stormwater uptake by trees, a review of relevant city codes and ordinances, and citizen input and recommendations for the future of Auburn's urban forest. More specifically, the following deliverables were included in the pilot study:

- Analysis of the current extent of the urban forest through high resolution tree canopy mapping,
- Possible Planting Area analysis to determine where additional trees could be planted,
- A method to calculate stormwater uptake by the city's tree canopy,
- A review of existing codes, ordinances, guidance documents, programs and staff capabilities related to trees and stormwater management, and recommendations for improvement,
- Two community meetings to provide outreach and education,
- Presentation about the project at regional and national conferences, and
- A case book and presentation detailing the study methods, lessons learned and best practices.

The project began in December 2017 and Auburn staff members have participated in project review, analysis and evaluation. The following city and university divisions were involved in the project planning and review as the Technical Review Committee (TRC) –City of Auburn; Departments of Parks and Recreation, Planning, Information Technology, Water Resource Management – Watershed's Division, and Engineering Services - Engineering Division: Auburn University's Office of Sustainability, Crop, Soil and Environmental Sciences Department and School of Forestry and Wildlife Sciences: and the Alabama Forestry Commission.

COMMUNITY ENGAGEMENT

Two community meetings were held. The first meeting held in June 2018 provided an overview of the project and opportunities to comment on the maps. The second meeting, held in January 2019, provided recommendations (listed below). Comments from both meetings were provided to the city. The GIC also presented the project to the City of Auburn's Tree Commission.

At the first meeting, residents learned about the project and offered suggestions to improve tree management and canopy coverage. At the second meeting, they learned about the project's findings, provided their opinions and made additional suggestions to conserve the city's canopy. Participants also considered whether trees could be required as part of a development's 'green infrastructure.'

Citizen studies possible planting areas

In addition, at the second meeting GIC presented specific code/ordinance or practice changes recommended for adoption by the city. Meeting attendees were asked to choose the top changes they felt would most benefit the urban forest and reduce runoff. The top policy or code changes are listed below. Additional recommendations are found in this report under the Codes, Ordinances and Practice Review section.

1. Work with developers to shrink the development footprint.
2. Approve trees as stormwater management practices in Auburn.
3. Increase education about the benefits of trees for private citizens.
4. Accommodate large trees in urban areas by providing adequate soil volume.

Participants discuss tree planting potential.

Evaluating policy priorities

City staff recieve citizen input.

Auburn can use this report and its associated products to:

- *Set canopy goals by watershed and develop management plans for retaining or expanding its tree canopy.*
- *Improve management practices so trees will be well-planted and well-managed.*
- *Educate developers about the importance of tree retention and replacement.*
- *Motivate private landowners (residential, commercial, and institutional) to plant trees.*
- *Support grant applications for tree conservation projects.*

SUMMARY OF FINDINGS

Satellite imagery was used to classify the types of land cover in Auburn (for more on methods see page 18). This shows the city those areas where vegetative cover helps to uptake water and those areas where impervious land cover is more likely to result in stormwater runoff. High-resolution tree canopy mapping provides a baseline that is used to assess current tree cover and to evaluate future progress in tree preservation and planting. An ArcGIS geodatabase with all GIS data from the study was provided to Auburn.

The goal of this study was to identify ways in which stormwater entering the city's municipal separate storm sewer system (MS4) could be reduced by using trees to intercept and soak up stormwater runoff. Tree canopy serves as 'green infrastructure' that can extend the capacity of the city's grey infrastructure (i.e. stormwater drainage systems) by intercepting, absorbing, and/or evaporating excess precipitation before it is converted into runoff. The stormwater model created for this project shows how the city can reduce potential pollution of its surface waters, which can help attain load allocations prescribed in Total Maximum Daily Loads (TMDL), help meet other water quality objectives, and fulfill a variety of goals and objectives of local watershed plans.

The detailed land cover analysis created for the project was used to model how much water is taken up by the city's trees in various scenarios. This new approach allows for more detailed assessment of stormwater uptake based on the landscape conditions of the city's forests. It distinguishes whether the trees are growing in a more natural setting (e.g. a cluster of trees in an urban forest), a lawn setting, or over pavement, such as streets or sidewalks. The amount of open space and the condition of surface soils affect the infiltration of water.

As city trees are evaluated, it's important to remember that trees within a cluster provide more value than individual trees alone because they also tend to have a more natural ground cover, more leaf litter (as they are not managed or mowed under) and less compacted soils. Thus, there is more stormwater retention for trees found in a natural setting than a tree over a lawn or over pavement. Trees clustered together also shelter one another from wind damages and are less likely to fall. As cities develop and lose forest, trees planted in isolation do not provide equivalent value as the same number of trees found clustered together. Therefore, when counting total trees in a city, managers should also consider the setting in which those trees are found and they should protect intact forested clusters of trees as often as possible.

One mature tree can absorb thousands of gallons of water per year.

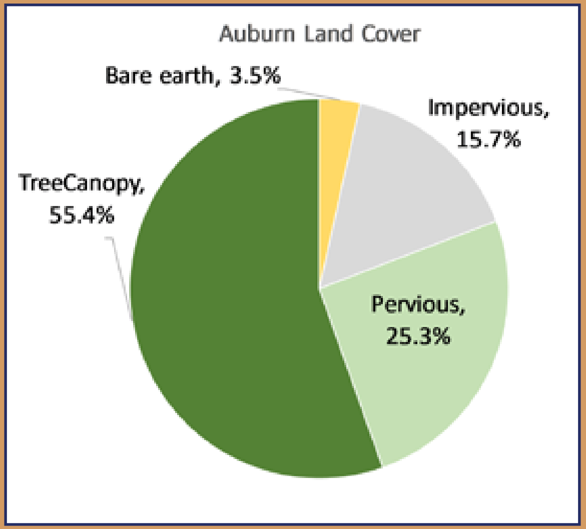
During an average high volume rainfall event in Auburn (a 10-year storm), over 24 hours the city's trees take up an average of 297.5 million gallons of water.

That's 450 Olympic swimming pools of water!

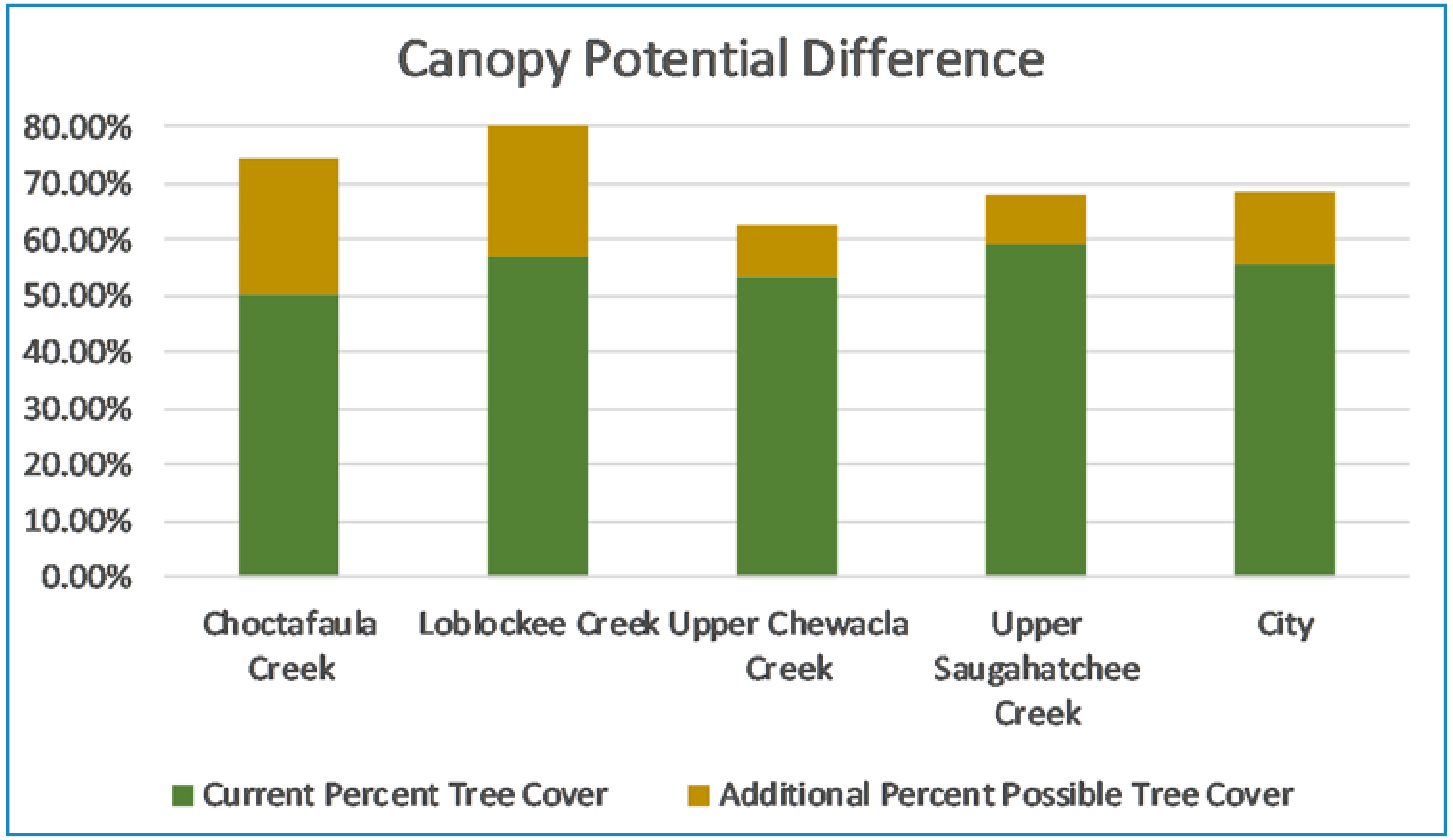
Auburn: Fast Facts & Key Stats

- Located on the Fall Line splitting the Piedmont Upland and East Gulf Coastal Plain in central eastern Alabama.
- 2017 U.S. Census
  Population Estimate: ...... 63,973 people
- City Area From Land Cover
  - Total area: .... 59.85 sq. mi.
  - Land: .... 58.83 sq. mi.
  - Water: .... 1.02 sq. mi.
  - Streams: .... 112.45 miles*
  - Tree Canopy: .... 21,067 acres (55%)

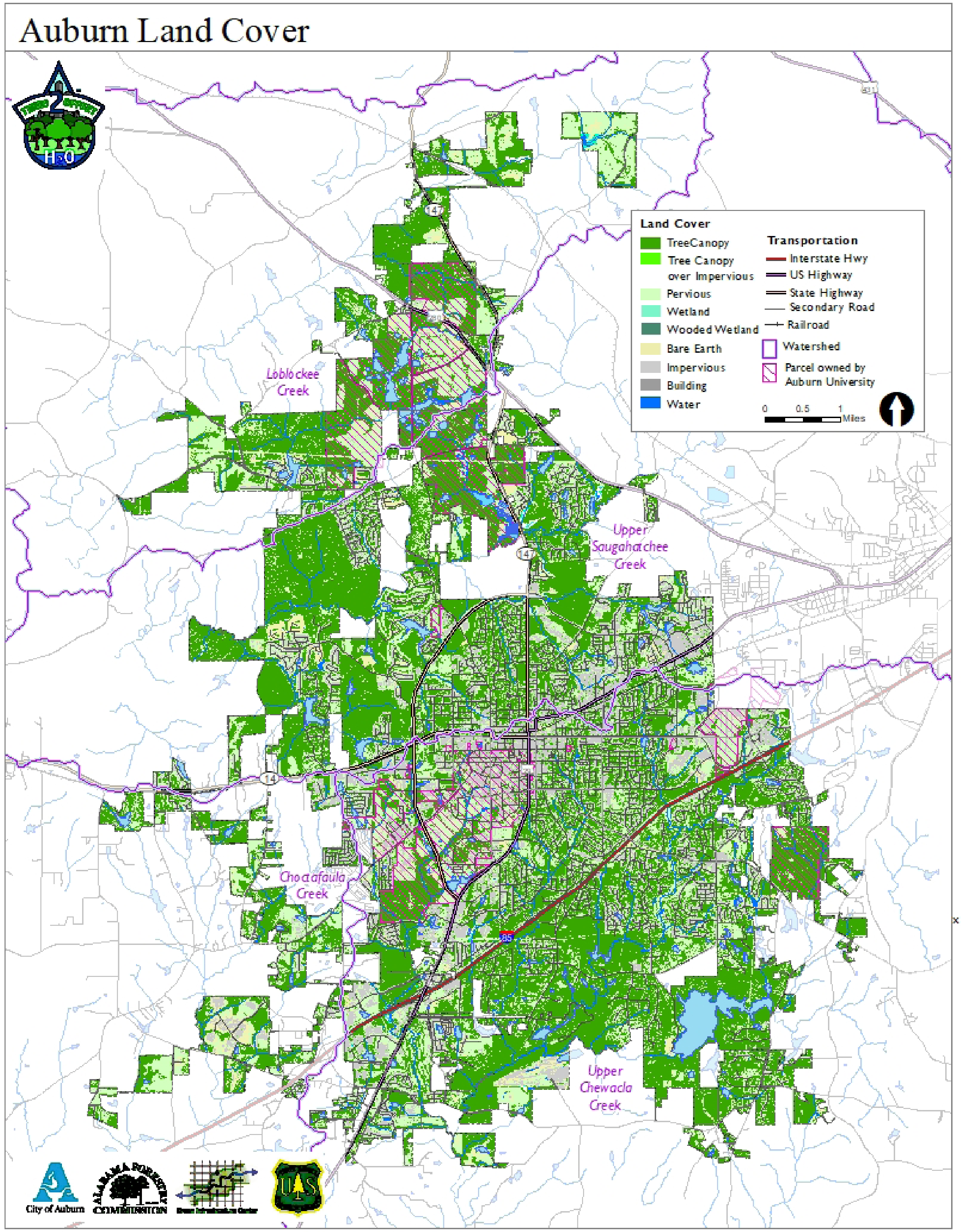
*Source: US Geological Survey



Citywide tree canopy is 55.4 percent.



Percent Tree Cover and Possible Planting Area by Watershed



This map shows the tree canopy of the city which covers 55.4 percent of the area.

WHY PROTECT OUR URBAN FORESTS?

Today, municipalities are losing their trees at an alarming rate, estimated at four million trees annually nationwide (Nowak 2010). This is due, in large part, to population growth. This growth has brought pressures for land conversion to accommodate both commercial and residential development. Cities are also losing older, established trees from the cumulative impacts of land development, storms, diseases, old age and other factors (Nowak and Greenfield 2012). The statistics for tree canopy include all lands within the city boundaries, regardless of ownership or land use. At 55.4 percent canopy (roughly half of the city), Auburn has very good tree canopy coverage for a developed area. This is comparable to the coverage for the university which is 54.1 percent tree covered. Of the total city canopy of 55.4 percent, the university's canopy comprises 7.6 percent of that canopy (within city boundaries). Canopy varies widely. For example, downtown canopy is 25.5 percent while in a more rural area west of downtown it is 81 percent.

Despite its relatively high canopy, Auburn has lost natural forest cover as the city has grown. The city may see losses in the future if replanting rates decline. As older trees die (or before they die), younger trees need to be planted to restore the canopy. For recommendations on how the city can better protect and manage its urban forests, see the Codes and Ordinances section of this report.

The purpose of this report is not to seek a limit on the city's development, but to help the city better utilize its tree canopy to manage stormwater. Additional benefits of improved canopy include:

- cleaner air
- aesthetic values
- reduced heating and cooling costs
- decreased urban heat island effects
- buffering structures from wind damage
- increased bird and pollinator habitat
- enhanced walkability and multimodal transportation and
- increased revenue from tourism and retail sales

According to the U.S. Environmental Protection Agency (EPA), excessive stormwater runoff accounts for more than half of the pollution in the nation's surface waters and causes increased flooding and property damages, as well as public safety hazards from standing water. The EPA recommends a number of ways to use trees to manage stormwater in the book *Stormwater to Street Trees*.

As their urban forest canopies have declined across the south, municipalities have seen increased stormwater runoff. Unfortunately, many cities do not have a baseline analysis of their urban forests or strategies to replace lost trees. In considering runoff, the amount of imperviousness is one

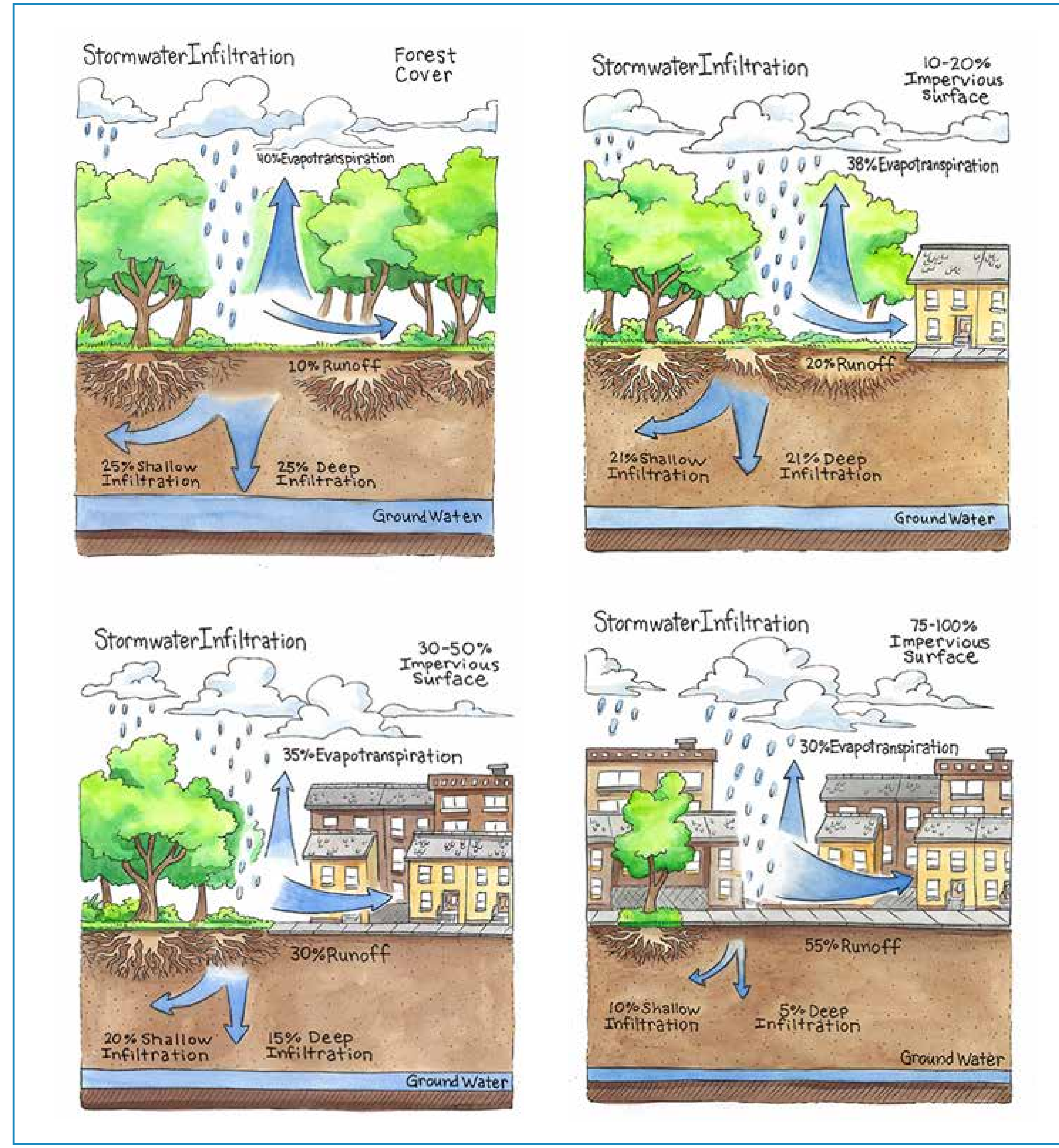
The city's creeks depend on forested buffers and citywide tree cover to reduce runoff and pollution that can harm aquatic life.

consideration; the other is the degree and type of forested land cover, since vegetation helps absorb stormwater and reduces the harmful effects of runoff.

When forested land is converted to impervious surfaces, stormwater runoff increases. This increase in stormwater causes temperature spikes in receiving waters, increased potential for pollution of surface and ground waters and greater potential for flooding. When underground aquifers are not replenished, land subsides.

Another cause of canopy decline is the many recent powerful storms that have affected the Southeastern United States. This study was funded to address canopy decline by helping municipalities monitor, manage and replant their urban forests and to encourage cities to enact better policies and practices to reduce stormwater runoff and improve water quality.

Assessment and inventory of trees is key to ensuring a healthy forest.



Runoff increases as land is developed. Information source: U.S. EPA

It is not just development and storms that contribute to tree loss. Millions of trees are also lost as they reach the end of their life cycle through natural causes. On average, for every 100 street trees planted, only 50 will survive 13-20 years (Roman et al 2014). Even in older developed areas with a well-established tree canopy, redevelopment projects may remove trees. Choosing the wrong tree for a site or climate, planting it incorrectly, or caring for it poorly can all lead to tree canopy loss. It is also important to realize that an older, well-treed neighborhood of today may not have good coverage in the future unless young trees – the next generation – are planted.

Tree Give Away

Excess impervious areas cause hot temperatures and runoff. Some older paved areas predate regulations requiring stormwater management.

Urbanizing counties and cities are beginning to recognize the importance of their urban trees because trees provide tremendous dividends. For example, urban canopy can reduce stormwater runoff anywhere from two to seven percent (Fazio 2010). According to Penn State Extension, during a one-inch rainfall event, one acre of forest will release 750 gallons of runoff, while a parking lot will release 27,000 gallons! This could mean an impact of millions of gallons of water during a major precipitation event. While stormwater ponds and other management features are designed to attenuate these events, they cannot fully replicate the pre-development hydrologic regime. In addition, as an older city, parts of Auburn may lack stormwater management practices that are now required for new developments.

Trees filter stormwater and reduce overall runoff volume. So, planting and managing trees is a natural way to mitigate stormwater. Estimates from Dayton, Ohio study found a seven percent reduction in stormwater runoff due to existing tree canopy coverage and a potential increase to 12 percent runoff reduction as a result of a modest increase in tree canopy coverage (Dwyer et al 1992). Conserving forested landscapes, urban forests, and individual trees allows localities to spend less money treating water through the municipal storm systems and also reduces flooding.

Each tree plays an important role in stormwater management. For example, based on the GIC's review of multiple studies of canopy rainfall interception, a typical street tree's crown can intercept between 760 gallons to 3000 gallons per tree per year, depending on the species and age. If a community were to plant an additional 5,000 such trees, annual stormwater runoff could be reduced by millions of gallons. This means less flooded neighborhoods and reduced stress on storm drainage pipes and decreased runoff into the city's creeks.

Another compelling fiscal reason for planning to conserve trees and forests as a part of a green infrastructure strategy is minimizing the impacts and costs of natural disasters. Not only do trees reduce the likelihood of extensive flooding, they also serve as a buffer against storm damages from wind.

In urban areas, Geographic Information Systems (GIS) software is used to map the extent of the current canopy as well as to estimate how many new trees might be fitted into an urban landscape. A Possible Planting Area (PPA) map estimates areas that may be feasible to plant trees. A PPA map helps communities set realistic goals for what they could plant (this is discussed further on in the Methods Appendix).

Trees in residential yards also help to soak up rainfall.

Newly planted tree at Auburn Univeristy

ADDITIONAL URBAN FOREST BENEFITS

Quality of Life Benefits

During Alabama's hot summers, more shade is always appreciated. Tree cover shades streets, sidewalks, parking lots, and homes, making southern urban locations cooler, and more pleasant for walking or biking. Trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Shaded pavement has a longer lifespan thereby reducing maintenance costs associated with repairing or replacing roadways and sidewalks (McPherson and Muchnick 2005).

Trees shelter homes from sun and save on energy costs.

Large neighborhood trees provide shade and stormwater interception and uptake.

Communities with greener landscapes benefit children by reducing both asthma and ADHD symptoms.

Children who suffer from Attention Deficit Hyperactivity Disorder (ADHD) benefit from living near forests and other natural areas. One study showed that children who moved closer to green areas have the highest level of improved cognitive function after the move, regardless of level of affluence (Wells 2000). Thus, communities with greener landscapes benefit children and reduce ADHD symptoms. Trees also cause people to walk more and walk farther. This is because when trees are not present, distances are perceived to be longer and destinations farther away, making people less inclined to walk than if streets and walkways are well treed (Tilt, Unfried and Roca 2007).

Well treed areas encourage people to walk.

Economic Benefits

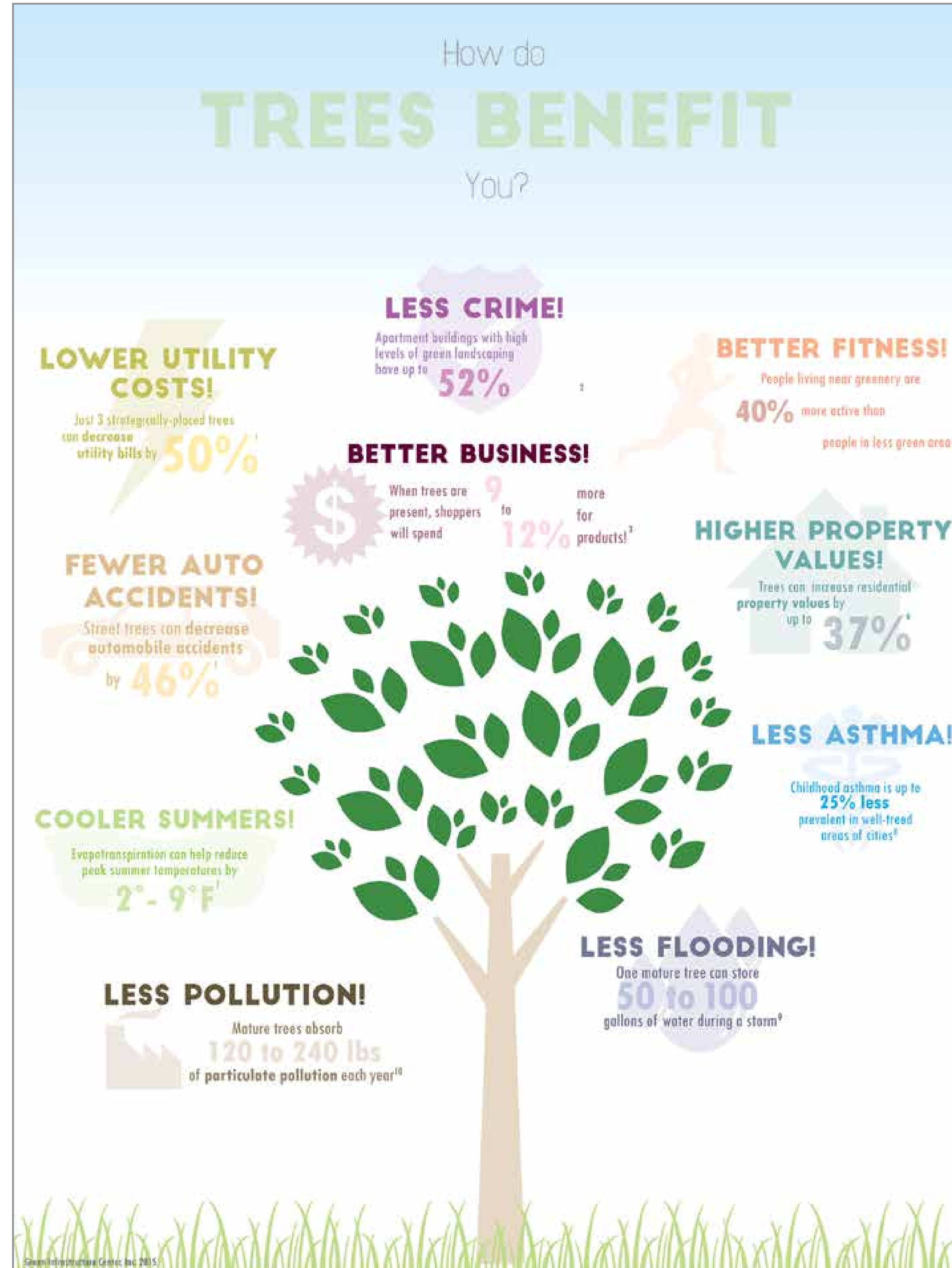
Developments that include green space or natural areas in their plans sell homes faster and for higher profits than those that take the more traditional approach of building over an entire area without providing for community green space (Benedict and McMahon 2006). This desire for green space is supported by a National Association of Realtors study which found that 57 percent of voters surveyed were more likely to purchase a home near green space and 50 percent were willing to pay 10 percent more for a home located near a park or other protected area. A similar study found that homes adjacent to a greenbelt were valued 32 percent higher than those 3,200 feet away (Correll et al. 1978).

Meeting Regulatory Requirements

Trees also help meet the requirements of the Clean Water Act. The Clean Water Act requires Alabama to have standards for water quality. When waters are impaired they may require establishment of a Total Maximum Daily Load (TMDL) standard and a clean-up plan (i.e., Best Management Action Plan) to meet water quality standards. Since a forested landscape produces higher water quality by cleaning stormwater runoff (Booth et al 2002), increasing forest cover results in less pollutants reaching the city's surface and ground waters.

Homes adjacent to a greenbelt were valued 32% higher

There are many places where trees can be added for shade and beauty, such as the commercial area above and the residential area below.



NATURAL ECOLOGY IN CHANGING LANDSCAPES

Natural history, even of an urbanized location, informs planting and other land-management decisions. The Köppen climate classification lists the city's climate as humid subtropical. Auburn's location in western Lee County gives rise to a complex geology. It sits on the Fall Line where the piedmont plateau and the coastal plain join. Portions of Auburn also include the southernmost exposure of rocks showing evidence of the Appalachian orogeny (mountain building) and the 'last foothill' of the Appalachian Mountains is found in Chewacla State Park in southern Auburn.

The city's elevation ranges from 386 ft. above sea level where Chewacla Creek crosses Sand Hill Road to 845 ft. above sea level in northern Auburn near the Chambers County line. Rolling plains and savannahs characterize the southwest and western regions of the city on the plateau. South of this area lies the coastal plain, comprised primarily of sandy soil and pine forests. The northern areas of Auburn have more rugged terrain and denser forests. In the south of the city which surrounds Chewacla Park, there are distinct peaks and steep elevation drops at the fall line where the Appalachians meet the coastal plain. For more on the complex geography of Auburn see http://www.netstate.com/states/geography/al_geography.htm

HISTORIC LAND COVER

Alterations to the landscape began with its original inhabitants and accelerated most dramatically with urbanization in the latter half of the 20th century. Originally settled by the Native American Creek (also known as the Muscogee) tribes, the area was opened to non-indigenous settlement by the Treaty of Cussetta in 1832 which ceded all tribal claims to lands east of the Mississippi. Judge John J. Harper led a group to settle the town as a religious and educational center and the Town of Auburn was formally incorporated in 1839. Establishment of Methodist and Baptist churches, along with educational academies drew more people to the area, resulting in 1,000 residents by 1858. In 1859, the state chartered the East Alabama Male College which later became Auburn University. Today, Auburn University comprises more than 30,000 students spread over a campus of 1,875 acres.

Although the landscape of the City of Auburn is highly altered, today the city's vegetation and tree canopy support birds, bees and other pollinators while providing shade and cooling for the city and water quality benefits.

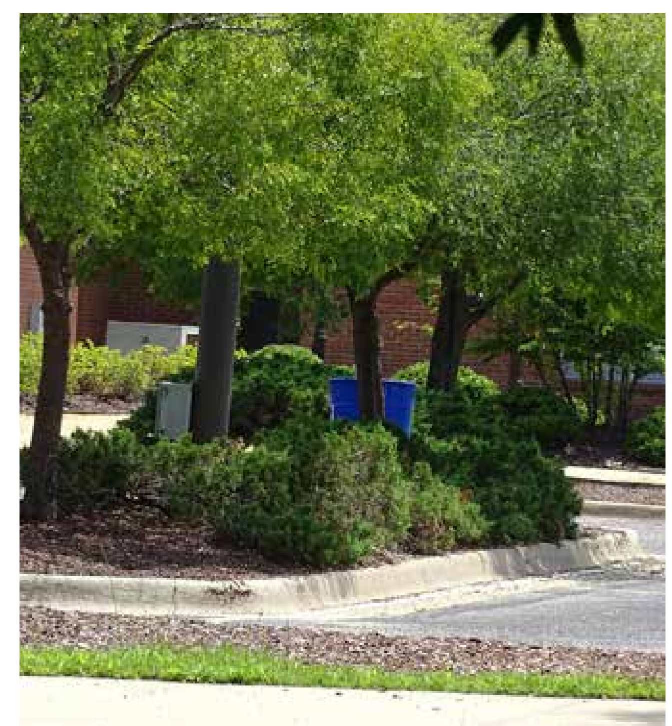
The Auburn University campus covers 1,875 acres.

Recently planted trees will eventually become shade trees in the historic downtown.

GROWTH AND DEVELOPMENT CHALLENGES

The city suffered setbacks during the Civil War when the university was forced to close and it entered a prolonged depression following the war. In the 1860s and 1870 a series of fires gutted the downtown. By 1910, the city's population had rebounded. However, the collapse of cotton prices in the 1920s followed by the Great Depression led to business closures and poverty and state support for the college disappeared for a time. Finances rebounded during World War II as the college served as a training center for technical specialists and after the war when GIs flocked to the college to obtain delayed educations. In the 1980s, the town's over-reliance on the University for its economic stability became an issue, and city began to actively recruit industry to locate there. Today the city has a strong industrial base of small to mid-sized technology and manufacturing firms.

The city's population has increased 19.8 percent since the 2010 census (U.S. Census Bureau), making it the 8th fastest growing city in the state of Alabama https://www.homesnacks.net/fastest-growing-cities-in-alabama-127063/. As the city has grown, demands for space to meet the needs for housing, commercial, business, and transportation uses put strains on both the city's grey and green infrastructure. However, the city is endeavoring to grow in a way that supports a greener city and has undertaken a study for how to add more constructed green infrastructure into the city (e.g. bioswales).



Planting understory shrubs and other vegetation will help soak up rainwater and are better than lawns for reducing runoff.

All city land was mapped including the Univeristy.

The city's past contributes to its charming character today. The university's location in the heart of downtown, gives rise to a strong pedestrian and bicycle culture. The area around the university is a 14.5-acre National Register Historic District with buildings originating from 1846 to 1951. Many of the historic buildings have been repurposed as shops, condos and restaurants. The city also boasts an impressive park and greenspace network and is ranked as one of 150 'Bike Friendly Communities' by the League of American Bicyclists with 44 miles of bike paths. Of the city's 11 parks, Kiesel Park is the city's largest with 157 acres crossed by nature trails and gardens. Town Creek Park offers a historic tree trail and the Donald E. Davis Arboretum on the university's grounds boasts 150 native tree species that serve as teaching tools for university research and education. All of these factors generally contribute to the city's consistently high livability rankings such as in Southern Living for the South's 7th best small town in 2017!

As Auburn grows, demands for green space increase. The city can use current park and school sites to help ensure tree cover is maintained and to plant more trees on public lands and right of way areas..

Parks enhance the city's livability and soak up rainfall.

DEVELOPMENT AND STORMWATER

The requirements set forth by the Clean Water Act of 1972 for the National Pollution Discharge Elimination System (NPDES) permitting program, and subsequent amendments in 1987 regulating nonpoint source pollution, form the foundation for the city's stormwater management program. However, as an older city, established in 1839, many areas of Auburn were developed prior to the 1987 Clean Water Act Amendments requiring treatment of stormwater runoff.

Adding stormwater treatment for older areas is achieved by either retrofitting stormwater best management practices into the landscape, or adding them as properties are re-developed. Auburn is retrofitting existing roads and other infrastructure to include 'green infrastructure.' For example, the city has invested in permeable pavement and trees supported with silva cells to allow for water infiltration and healthful tree growth and retention downtown. The City of Auburn has also recently completed a Green Infrastructure Master Plan, with strategic goals and objectives for the integration of green infrastructure.

Adding more trees is a best management practice that provides other benefits beyond stormwater uptake, such as shade, air cleansing and aesthetic values. Recommendations for improvements to better utilize trees to manage stormwater and to reduce imperviousness are found in the Codes, Policies and Practices section of this report.

Permeable pavers and suspended pavement support this tree's health by allowing more water to reach the tree's roots, providing additional structural support as the tree grows, while reducing runoff.

Stormwater should be captured to reduce the volume of water reaching storm drains and inlets.

This municipal parking lot next to city hall has a bioswale — a recessed bed planted with a tree to capture and clean stormwater before it reaches the city drainage system.

Reducing imperviousness and increasing vegetation are one way to ease the frequency of flooding because this limits the amount of water that needs to be drained by the storm drainage system. Vegetation reduces water entering the system by intercepting, capturing and transpiring that water.

Auburn Tree Commission

Tree Give Away—residents can make a difference in runoff by planting trees and other vegetation to soak up runoff.

ANALYSIS PERFORMED

This project evaluated options for how to best model stormwater runoff and uptake by the city's tree canopy. Its original intended use was for planning at the watershed scale for tree conservation. An example is provided on page 17. However, new tools created for the project allow the stormwater benefits of tree conservation or additions to be calculated at the large site scale as well.

As noted, trees intercept, take up and slow the rate of stormwater runoff. Canopy interception varies from 100 percent at the beginning of a rainfall event to about three percent at the maximum rain intensity. Trees take up more water early on during storm events and less water as storm events proceed and the ground becomes saturated (Xiao et al. 2000). Many forestry scientists, as well as civil engineers, have recognized that trees have important stormwater benefits (Kuehler 2017, 2016). See diagram of tree water flow below.

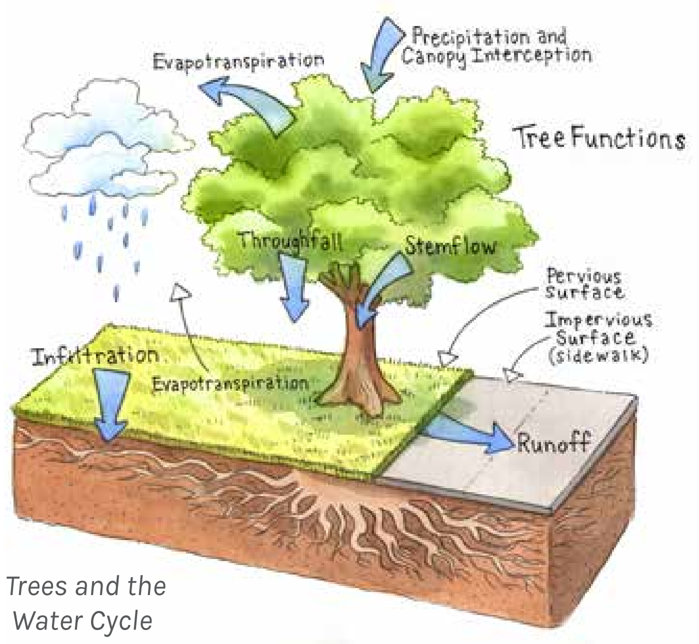
METHOD TO DETERMINE WATER INTERCEPTION, UPTAKE AND INFILTRATION

This project provides a tool for setting goals at the watershed scale for planting trees and for evaluating consequences of tree loss as it pertains to stormwater runoff. The chart shows the canopy breakdown by watersheds.

Watersheds in Auburn	Percent Tree Canopy
Choctafaula Creek	50.38%
Loblockee Creek	57.35%
Upper Chewacla Creek	53.15%
Upper Saugahatchee Creek	59.38%
Citywide	55.40%

Currently, most cities use TR-55 curve numbers developed by the Natural Resources Conservation Service (NRCS) to model expected runoff amounts. This study used modified TR-55 curve numbers to calculate stormwater uptake for different land covers, since they are widely recognized and understood by stormwater engineers and are used for site plans to calculate stormwater runoff and capture. The equation used to calculate runoff includes a factor for canopy interception of stormwater.

Curve numbers produced by this study can be utilized in the city's modeling and design reviews. The project's spreadsheet calculator tool makes it very easy for the city to change the curve numbers if they so choose. The input to the calculator comes from the GIS land cover maps. When those maps are updated in the future (GIC recommends updates every 5 years) then new data can be input into the spreadsheet. A canopy interception factor is added to account for the role trees play in interception of rainfall based on location and planting condition (e.g. trees over pavement versus trees over a lawn or in a forest).



Trees and the Water Cycle

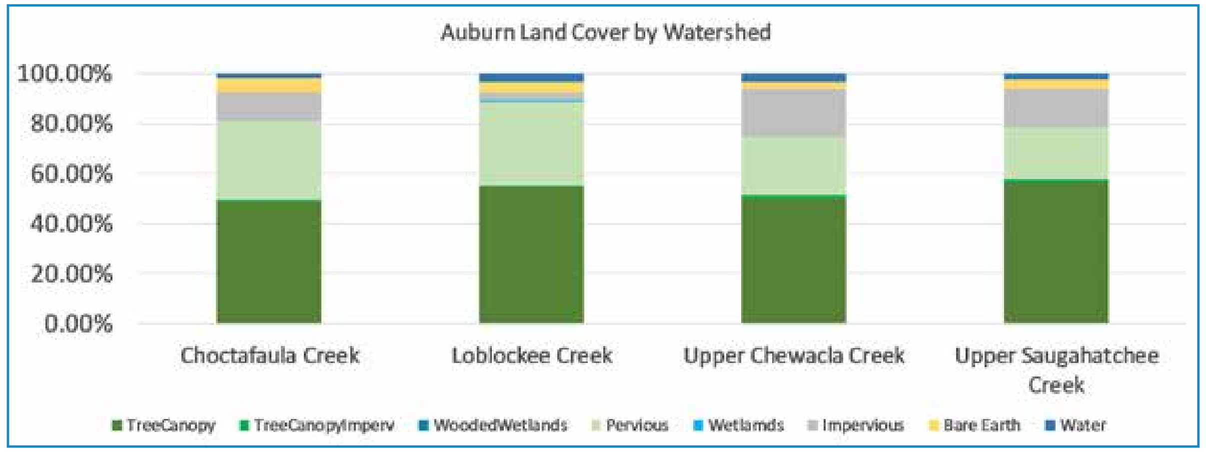
Tree canopy reduces the proportion of precipitation that becomes stream and surface flow, also known as water yield. In a study, Hynicka and Divers (2016) modified the water yield equation of the NRCS model by adding a canopy interception term (Ci) to account for the role that canopy plays in capturing stormwater, resulting in:

$$R = \frac{(P - C_i - I_a)^2}{(P - C_i - I_a) + S}$$

Where R is runoff, P is precipitation, Ia is the initial abstraction for captured water, which is the fraction of the storm depth after which runoff begins, and S is the potential maximum retention after runoff begins for the subject land cover (S = 1000/CN – 10).

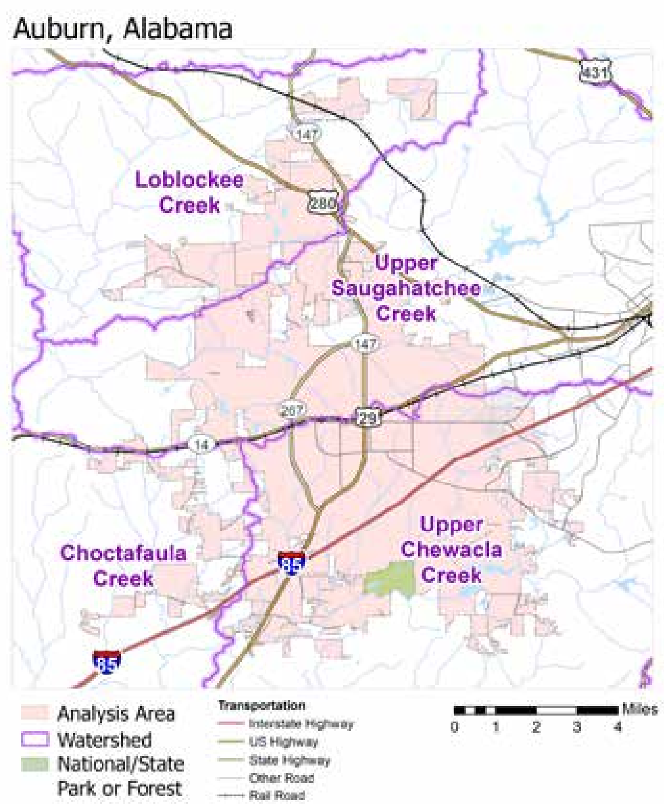
Major factors in determining Curve Numbers (CN) are:

- The hydrologic soil group (defined by surface infiltration rates and transmission rates of water through the soil profile, when thoroughly wetted)
- Land cover types
- Hydrologic condition – density of vegetative cover, surface texture, seasonal variations
- Treatment – design or management practices that affect runoff

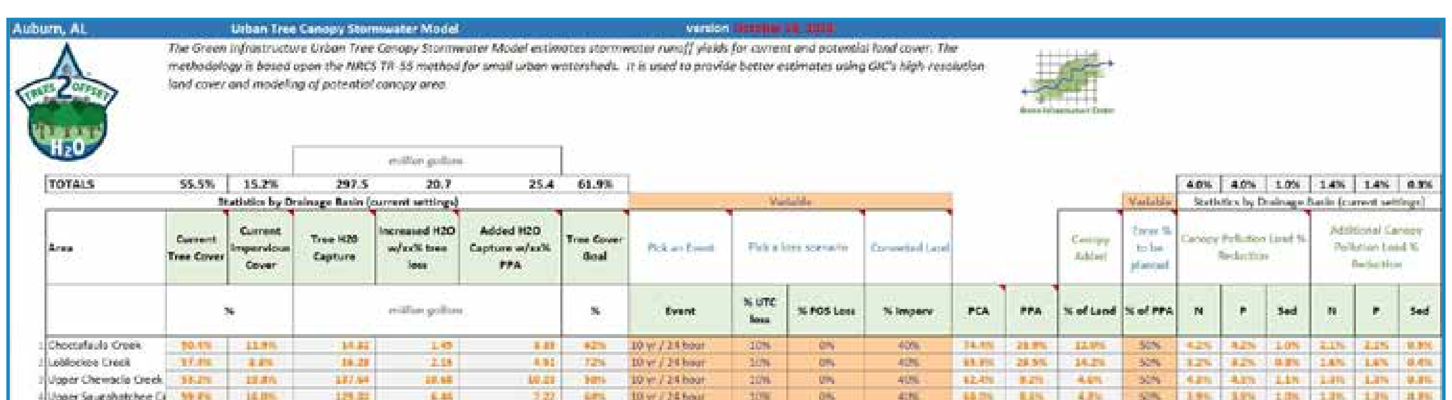


What is new about the calculator tool is that the curve numbers relate to the real land cover conditions in which the trees are found. In order to use the equation and model scenarios for future tree canopy and water uptake, the GIC first developed a highly detailed land cover analysis and an estimation of potential future planting areas, as described following. These new land cover analyses can be used for many other projects, such as looking at urban cooling, walkability (see map of street tree coverage on following pages), trail planning and for updating the comprehensive plan.

An example of how this modeling tool can be used for watershed-scale forest planning is shown below. The stormwater model spreadsheet was provided to Auburn. It links to the land cover statistics for each type of planting area. It also allows the city to hypothetically add or reduce tree canopy to see what are the effects for stormwater capture or runoff. The key finding from this work is that removal of mature trees generates the greatest impacts for stormwater runoff. As more land is developed and re-developed in Auburn, the city should maximize tree conservation to maintain surface water quality and groundwater recharge. This will also benefit the city's quality of life by fostering clean air, walkability, and attractive residential and commercial districts. Several studies have shown that higher tree canopy percentage is associated with lower overall hospitalization numbers and also with lower hospital visits from asthma.



Several watersheds make up the city's drainage and extend outside of the city's boundaries.



The calculator tool developed for this project allows the city to see the water uptake by existing canopy and model impacts from changes, whether positive (adding trees) or negative (removing trees).

The stormwater runoff model provides estimates of precipitation capture by tree canopy and the resulting reductions in runoff yield. It takes into account the interaction of land cover and soil hydrologic conditions. It can also be used to run 'what-if' scenarios, specifically losses of tree canopy from development and increases in tree canopy from tree planting programs.

The trees and stormwater model can be used to estimate the impact of the current canopy, possible losses to that canopy, and potential for increasing that canopy. As shown below, for a 10-year,* 24-hour storm, a loss of 10% of the urban tree canopy would increase runoff by 20.7 million gallons, while increasing canopy coverage from the current 56 to 62 percent will decrease runoff by almost 25.4 million gallons for that storm event.

This new approach allows for more detailed assessments of stormwater uptake based on the landscape conditions of the city's forests. It distinguishes whether the trees are within a tree cluster, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. Tree setting is considered because the conditions in which the tree is living affect the amount of water the tree can intercept. The amount of open space and the condition of surface soils affect the infiltration of water. In order to determine these conditions, a detailed land cover assessment was performed as described following. The analysis can be used to create plans for where adding trees or better protecting them can reduce stormwater runoff impacts and improve water quality.

* A 10-year storm refers to the average recurrence interval, or a 10 percent chance of that level of rainfall occurring.

Small creeks depend on trees to filter and clean runoff.

People walk longer and father on tree lined streets and paths.

Fishing on Lake Ogeltree. Trees protect the lake's water quality and fishery by filtering land runoff. The lake supplies Auburn with drinking water.

LAND COVER, POSSIBLE PLANTING AREA, POSSIBLE CANOPY AREA ANALYSIS

The land cover data were created using 2017 leaf-on imagery from the National Agriculture Imagery Program (NAIP) distributed by the USDA Farm Service Agency. These data are from aerial images that are flown every two years by the USDA. Ancillary data for roads (from Auburn government), and hydrology (from National Wetlands Inventory and National Hydrography Dataset) were used to determine:

1) Tree cover over impervious surfaces, which otherwise could not be seen due to these features being covered by tree canopy; and
2) Wetlands not distinguishable using spectral/feature-based image classification tools.

In cities studied for this project, forested open space was identified as areas of compact, continuous tree canopy greater than one acre, not intersected by buildings or paved surfaces.

The final classification of land cover consists of six classes listed below. The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees. (i.e., areas where the growth of a tree will not affect or be affected by existing infrastructure.) Of the six land cover classes, only pervious (grass and scrub vegetation) is considered for PPA.

- Tree canopy
- Tree canopy over impervious
- Pervious
- Impervious
- Bare earth
- Water

Next, these eligible planting areas are limited based on their proximity to features that might either interfere with a tree's natural growth (such as buildings) or places a tree might affect the feature itself, such as power lines, sidewalks or roads. Playing

Adding more canopy can help alleviate flooding such as this high water on East University Drive in Auburn.

This shows what is currently treed (green) and areas where trees could be added (orange).

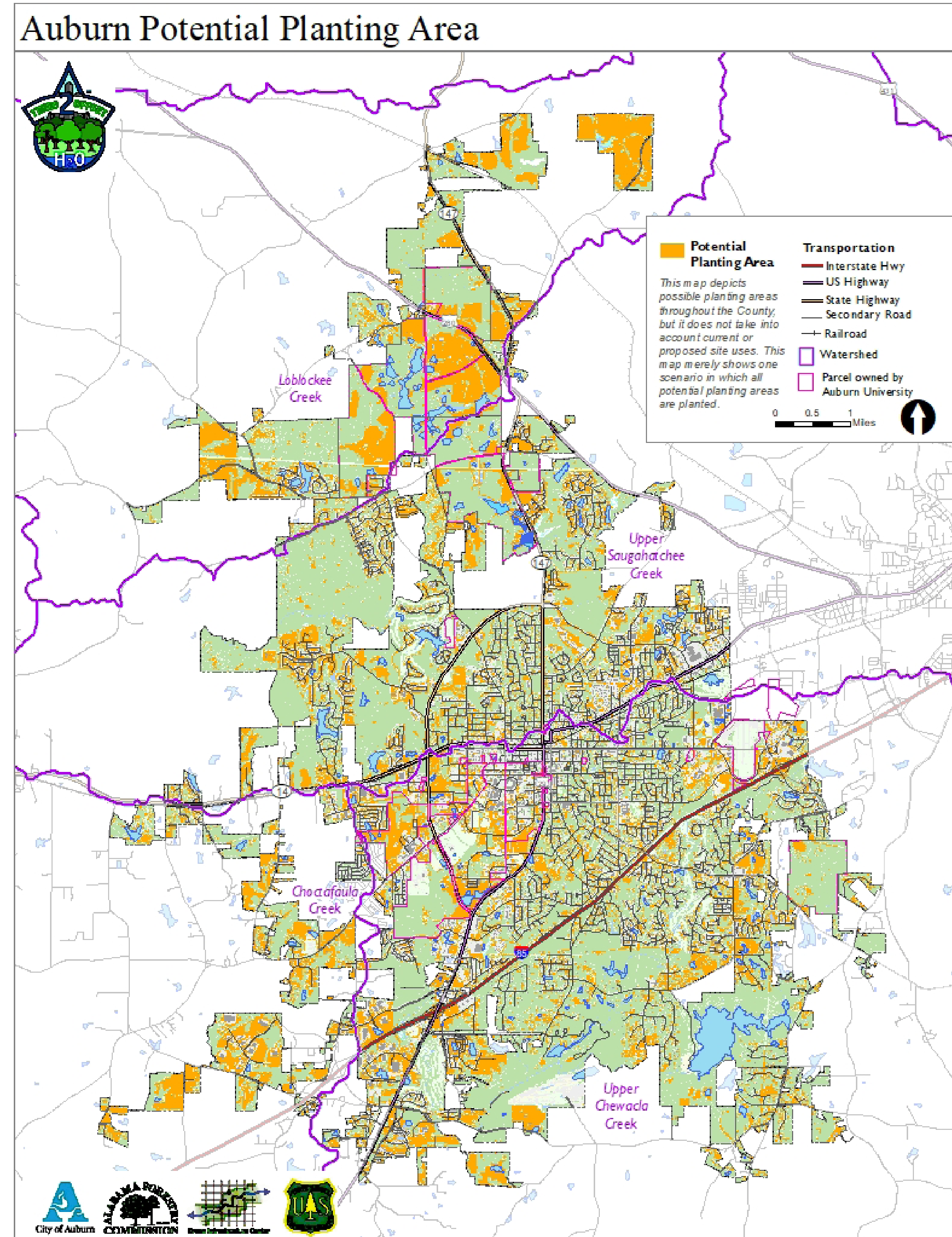
fields and other known land uses that would not be appropriate for tree cover are also avoided. However, there may be some existing land uses (e.g. golf courses) that are unlikely to be used for tree planting areas but that may not have been excluded from the PPA. In addition, the analysis did not take into account proposed future developments (e.g., planned developments) that would not likely be fully planted with trees. Therefore, the resulting PPA represents the maximum potential places trees can be planted and grow to full size. A good rule is to assume about half the available PPA space could actually be planted with trees.

Tree over street

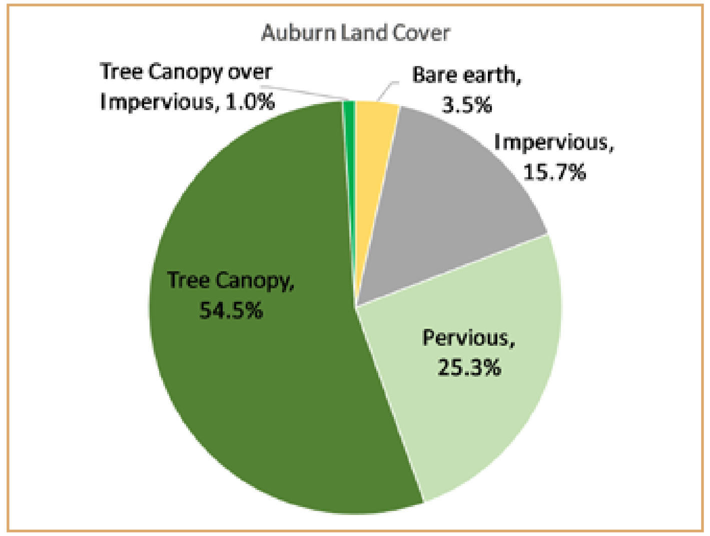
Trees over forest

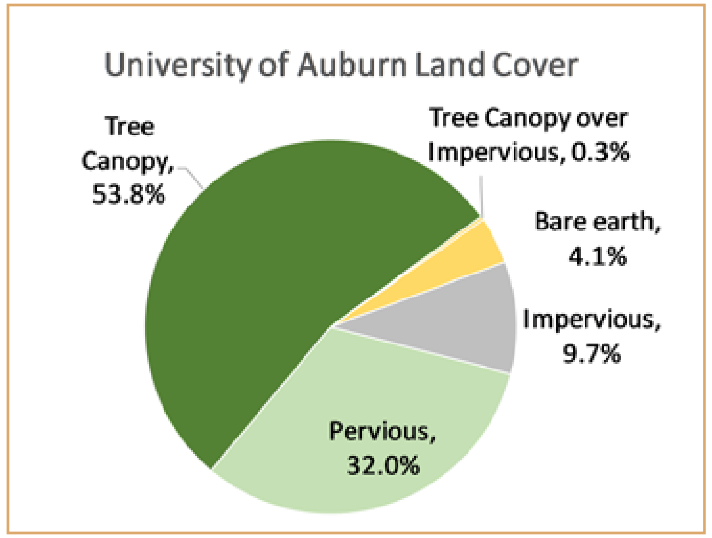
Tree over lawn

Tree over parking lot



Potential Planting Area (PPA) shown in orange depicts areas where it may be possible to plant trees. All sites would need to be confirmed in the field and may be on private or public lands.





Potential Planting Spots (PPS)

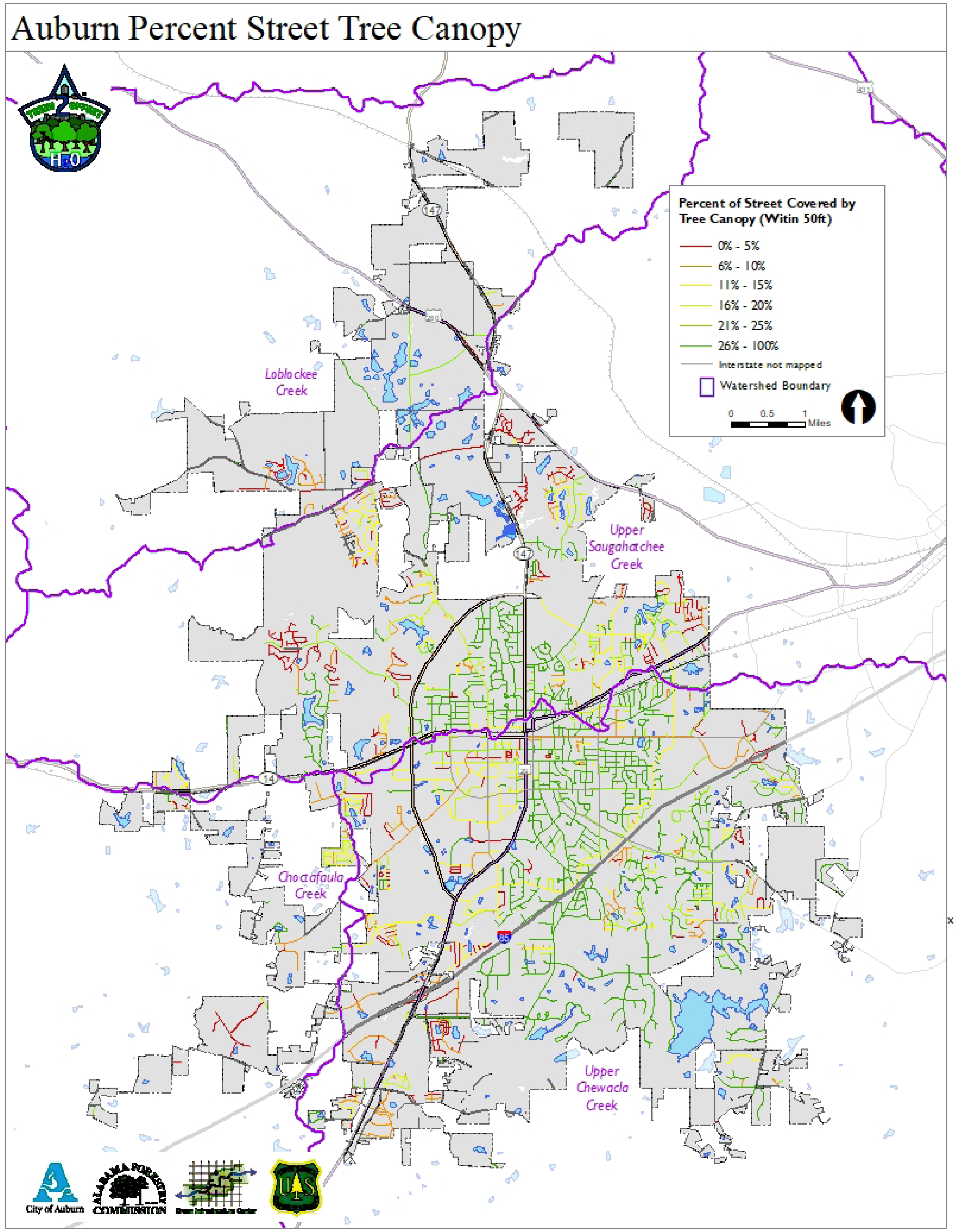
Potential Canopy Area (PCA)

The Potential Planting Spots (PPS) are created from the PPA. The PPA is run through a GIS model that selects those spots where a tree can be planted depending on the size of trees desired. For this analysis, expected sizes of both 20 ft. and 40 ft. diameter of individual mature tree canopy were used with priority given to 40 ft. diameter trees (larger trees have more benefits). It is expected that 30 percent overlap will occur as these trees reach maturity. The result demonstrates a scenario where, if planted today, once the trees are mature, their full canopy will cover the potential planting area and overlap adjacent features, such as roads and sidewalks.

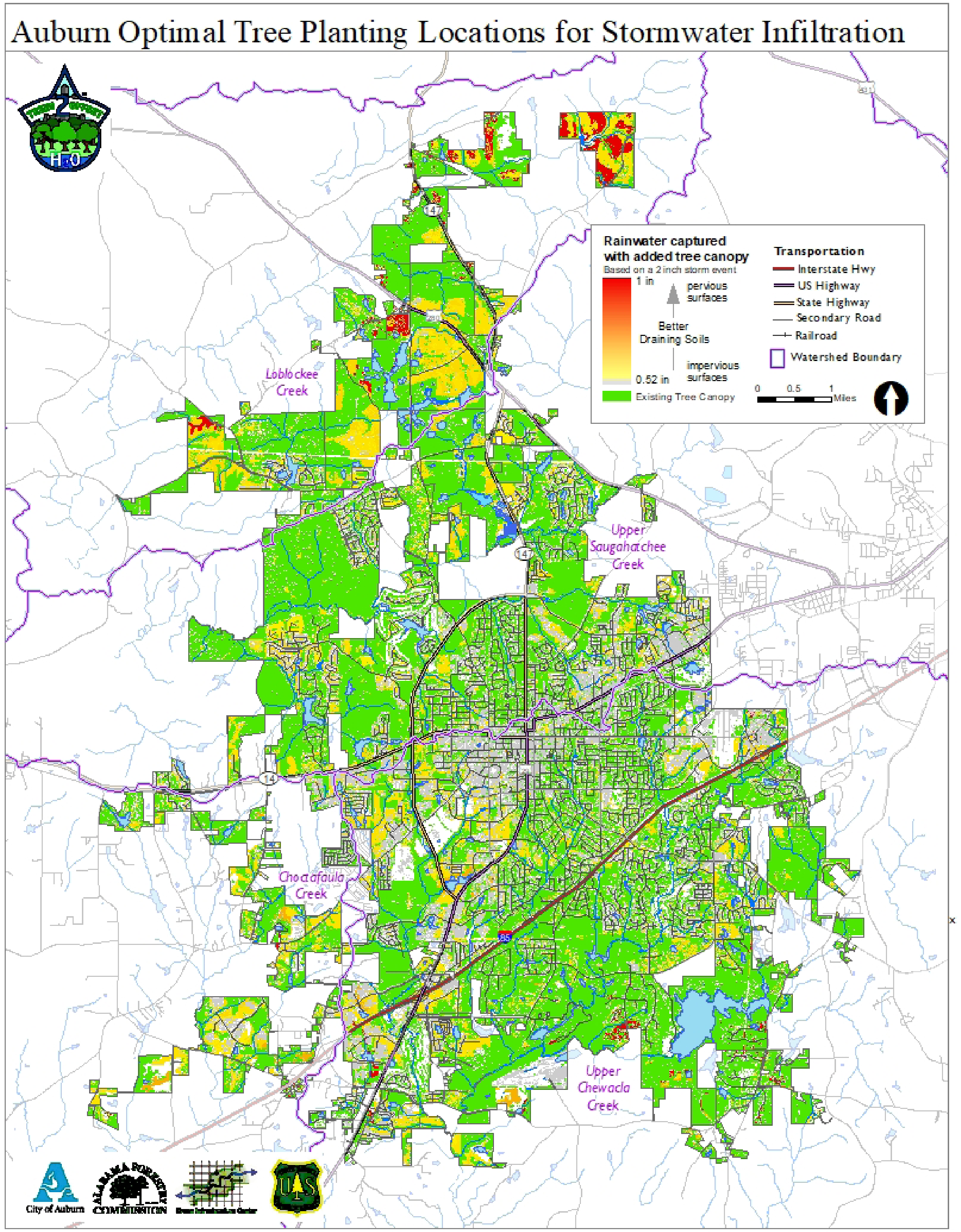
Trees shade pathways for walkers and soak up stormwater too!

The The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are selected, a buffer around each point that represents a tree's mature canopy is created. Similarly, the tree buffer radius is 20 ft. or 40 ft. diameter canopy for each tree. These individual tree canopies are then dissolved together to form the potential overall canopy area.

Percent Street Trees is calculated using the Land Cover Tree Canopy and road centerlines, which are buffered to 50 ft. from each road segment's centerline. The percent value represented is the percentage of tree cover within that 50 ft. buffer.



The street trees map shows which streets have the most canopy (dark green) and which have the least (red). Streets lacking good coverage can be targeted for planting to facilitate uses, such as safe routes to school or beautifying a shopping district.



This map shows where tree planting will yield the greatest benefits for stormwater infiltration (darkest orange).

See Methods Appendix for more details on mapping methodology.

CODES, ORDINANCES AND PRACTICES REVIEW

This review is designed to determine which practices make the city more impervious (e.g. too much parking required) and which make it more pervious (e.g. conserving trees or requiring open spaces). Documents reviewed during the codes, ordinances and practices analysis for the project include relevant sections of the city's current code that influence runoff or infiltration. Data were gathered through analysis of city codes and policies, as well as interviews with city staff, whose input was incorporated directly on the spreadsheet summary prepared by the GIC. The spreadsheet provided to the city lists all the codes reviewed, interviews held and relevant findings. A more detailed memo submitted to the city by GIC provides additional ideas for improvement.

EVALUATION AND RECOMMENDATIONS

Points were assigned to indicate what percentage of urban forestry and planning best practices have been adopted to date by the city. The spreadsheet tool created for city codes can also serve as a tracking tool and to determine other practices or policies the city may want to adopt in the future to strengthen the urban forestry program or to reduce impervious land cover. A final report comparing all studied localities will be issued by GIC in 2019.

Auburn is one of the first cities in Alabama to be certified as a 'Tree City USA', with 35 years of designation by the Arbor Day Foundation.

Auburn invests staff time and funds to manage its urban forest. The city was one of the first In Alabama to be recognized as a 'Tree City USA' by the Arbor Day Foundation, which means that it spends adequate funds per capita on tree care, it has a tree ordinance, and it practices tree management. In fact, the City of Auburn celebrated 35 years as a tree city in 2018. The city has one arborist on staff. Auburn University is also designated as a "Tree Campus USA University" for its dedication to campus and forestry management and environmental stewardship.

The city has one of the higher canopies for communities evaluated under this project. To ensure that the canopy is maintained, the GIC recommends the following strategies to increase the protections for, and maintain the size of, the forest in Auburn. As noted earlier, the city's canopy is 55.4 percent, but it is not distributed equally citywide. The University's canopy is similar at about 54 percent. Even just maintaining this level of coverage requires new plantings each year. Auburn is one of 12 localities in a six-state area of the Southeastern U.S. to be studied and the 11th to be completed. As other places are studied, they will be compared to the city, and vice versa.

Photo by the Auburn Reporter

Arbor Day, celebrated annually, includes tree planting and community education.

Photo by the Sun Journal

Preparing the next generation of tree stewards!

Top recommendations to improve forest care and coverage in Auburn listed in priority order include the following:

1. **Require a tree inventory of all hardwood trees 18" DBH and over, softwood trees 24" DBH and over, and understory species 8" DBH and over on concept and final site plan submittal for both publicly and privately owned properties.** Tree protection begins with tree inventory. A tree inventory contains information about the type, age, and caliper of existing trees on a site. The city should impose tree inventory requirements for lands proposed for development.

2. **Require tree protection mechanisms on both public and privately owned properties.** Trees are often lost during construction due to damage from construction equipment, soil compaction, root loss etc. Enforcing best management practices during construction includes requiring a standard tree protection zone of 1.5' per 1" tree DBH for trees designated for protection on the site plan, using root pruning where appropriate, and using root matting to protect pore spaces in soil can all help save more trees during the development process. More post-development trees on a site translates to higher property values, quicker sales and lower vacancy rates.

3. **Work with developers to shrink the development footprint to minimize impervious surface.** Holding a pre-development conference allows all parties to explore ideas for tree conservation before extensive funds are spent on land planning. For example, parking lots can be reduced in size depending on the permitted land uses and buildings can be built higher, rather than wider. Variable space sizing is another way to shrink surface parking lots while still meeting demand.

4. **Hold inter-departmental meetings about proposed projects to discuss and minimize site conflicts resulting in excess tree loss and retain healthy tree clusters whenever possible.** Often, requirements such as curb/gutter, sidewalks, driveways, parking pads, etc. require tree removals. Many of these requirements are managed by city departments such as Planning and Public Works. As requirements are managed by more than one department, inter-departmental communication is a critical component of achieving site designs which minimize tree canopy coverage loss and maximize livability and connectivity of habitats.

5. **Conduct a land cover assessment every four years to determine current canopy coverage and allow for comparison of tree canopy coverage change over time.** Keeping tree canopy coverages at levels that promote public health, walkability, and groundwater recharge is vital for livability and meeting state water quality standards. Regular updates to land cover maps allow for this analysis and planning to take place.

6. **Allow interdepartmental access to urban forestry data and train staff in use of the urban forestry data collection software.** Urban forestry data are currently collected about Auburn's urban forest. However, not all staff are trained in accessing and using the data so it is difficult to utilize the information for decision making. The city should provide data access and train staff in utilizing the data to make informed urban forestry decisions across departments and incorporate the data into city GIS systems.

7. **Use the GIC's stormwater uptake calculator to determine the benefits of maintaining or increasing tree canopy goals by watershed and set urban forestry goals.** The calculator provided to Auburn allows the city to determine the stormwater benefits or detriments (changes in runoff) from adding or losing trees and calculates the pollution loading reductions for nitrogen, phosphorus, and sediment.

8. **Require 600, 1,000 and 1,500 cubic feet soil volume planting requirements for small, medium, and large trees respectively for all tree plantings.** At a minimum, canopy trees require 1000 cubic feet of soil volume to thrive as recommended by the Environmental Protection Agency (Stormwater to Street Trees, 2013). The City of Auburn currently does not require a minimum root zone volume. Instead, areas of pervious surface around trees are specified. For canopy trees this is 325 square feet and for understory trees this is 90 square feet. Lacking a minimum root zone requirement can lead to inadequate soil volume for newly planted trees contributing to suboptimal growth and health.

9. **Perform tree risk assessments. Increase assessment intervals in densely populated portions of the city.** Tree risk assessments help proactively manage the urban forest. Diseased or damaged trees can be pruned, treated or, if necessary, removed to ensure public safety even before a citizen tree risk report is filed. The city should perform visual (Level 1) tree risk assessments on all publicly owned trees annually, especially for public lands and in densely populated areas of the city.

10. **Modify the steam buffer ordinance to base buffer size on stream type and feasibility instead of by watershed size.** Stream buffer ordinances protect perennial, intermittent, and ephemeral streams in a community. The City of Auburn has a stream buffer ordinance, however the buffer zones depend on watershed size. The smallest buffer required is 35'. The city should revise the stream buffer ordinance to provide a minimum of a 50' buffer on perennial, intermittent, and ephemeral streams to expand the buffer to include wetlands, steep slopes, and floodplains when they are adjacent. The city also could conduct a GIS analysis to determine how large a buffer would be practical for more developed urban zones and have variable widths depending on the reality on the ground.

This tree has been damaged by a storm and should be removed.

11. **Allow variable space sizing for parking and reduce overall imperviousness in the city.** Residents of Auburn drive a variety of car sizes and models. Some people drive smaller cars. As such, some parking spaces should be designated and designed for smaller cars. Making some spaces smaller means there is less total impervious surface in Auburn. Auburn's codes do not allow compact car spaces. This creates more impervious surface, effectively creating more stormwater runoff. The city should allow compact spaces as a component of parking lot design to shrink the overall footprint.

12. **Adopt a complete green streets policy.** Complete green streets allow for integration of stormwater management and aesthetic goals. By incorporating vegetation as an integral part of the design, green streets create and connect habitat, reduce urban heat island effect, help remove air pollutants, and promote walking and biking. The city should develop a green streets policy that includes the following elements: green infrastructure (trees and other vegetation), pedestrian space, bicycle lanes, and stormwater management.

13. **Include tree plantings as an approved stormwater Best Management Practice (BMPs) in Auburn.** A mature street tree can take up 1,000 gallons of stormwater. The City of Auburn identified several BMPs in the Water Resources Management Design and Construction Manual. However, tree plantings are not included in the list of BMPs. The city should add trees to the list of approved BMPs and take up more stormwater while preserving Auburn's urban forests..

14. **Use the urban forestry budget calculator to determine funds needed to reach planting goals.** Planting and maintaining more trees costs additional money, but is well worth the outcomes for ecosystem services provided by trees. The city should add trees to the list and determine the goal for its tree canopy coverage level and allocate funds to achieve it over time.

15. **Develop an Urban Forest Management Plan (UFMP) for the city.** A UFMP details a vision for urban tree canopy. The UFMP should align local government and community interests to proactively manage the urban canopy and provide long term benefits. The UFMP describes the condition of the urban forest, the current maintenance costs, the urban tree canopy coverage goals and how they can be achieved. It also includes maintenance costs, and options to achieve urban tree canopy coverage goals.

16. **Develop a Forestry Emergency Response Plan (FERP) for the city.** Forestry Emergency Response Plans (FERPs) are essential parts of any municipality's hazard mitigation and emergency management plans. Elements of FERPs should be given the same thought and attention paid to other aspects of emergency response management. FERPS should include the following sections: tree benefits, risk management and pre-disaster response, and post-disaster response and FEMA reimbursement.

17. **Link urban forestry to the city's stormwater infrastructure through program documentation.** This allows for reimbursement of expended funds through FEMA after storms. Urban forestry programs are only eligible for tree replanting funds following a storm event if the municipality has linked their urban forestry program to an infrastructure system such as stormwater management. The municipality also must treat the urban forest as a part of their essential infrastructure. The City of Auburn should link their urban forestry program to their stormwater program.

18. **Re-use urban waste wood.** Establishing an urban waste wood program is an excellent way to engage community members and re-use a valuable product and to have a plan for using storm damaged trees instead of sending them to landfill. Auburn should launch a city-wide campaign encouraging the re-use of waste wood and let citizens and businesses know how to participate. Proceeds from sale of urban waste wood can fund tree plantings. For more ideas see: https://www.vibrantcitieslab.com/research/waste-management/

BEST PRACTICES FOR CONSERVING TREES DURING DEVELOPMENT

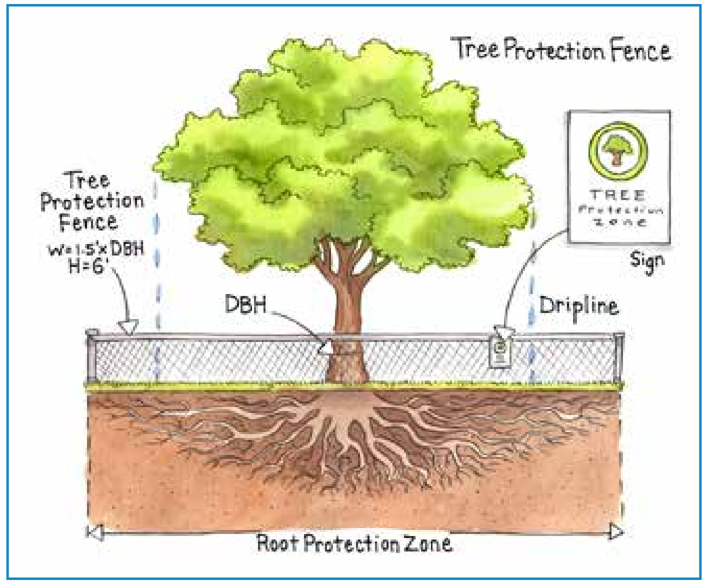
Tree planting or preservation opportunities can be realized throughout the development process. A first step is to engage in constructive collaboration with developers. The City of Auburn can hold planning concept reviews at the pre-development stage and should identify large trees on conceptual and final site plans. These meetings, tree reporting and additional funding for the city's urban forestry program could expand the options for conservation of the city's trees.

Encouraging Tree Conservation

It is also necessary to actively promote the implementation of development designs that minimize the loss of urban forest canopy and habitat. While the city encourages site layouts that conserve trees, developers may not always agree to implement staff suggestions. The GIC has found that economic arguments (real estate values for treed lots, access to open spaces, and rate of sales) are usually the most compelling way to motivate developers to take the extra effort and care to design sites and manage construction activities to promote tree conservation. This will facilitate site designs which save more trees and thereby require less constructed stormwater mitigation. Many developers are willing to cooperate in such ventures, as houses often sell for a higher premium in a well-treed development.

Tree Protection Fencing and Signage

Small roots at the radial extents of the tree root area, uptake water and absorb nutrients. Protection of these roots is critical for the optimal health of a tree. While protection at the dripline is an accepted practice, it does not adequately protect the roots. A value of 1.5 feet per DBH inch of trunk is a recommended practice and should be applied across all development projects.



Tree Protection Fence and Signage

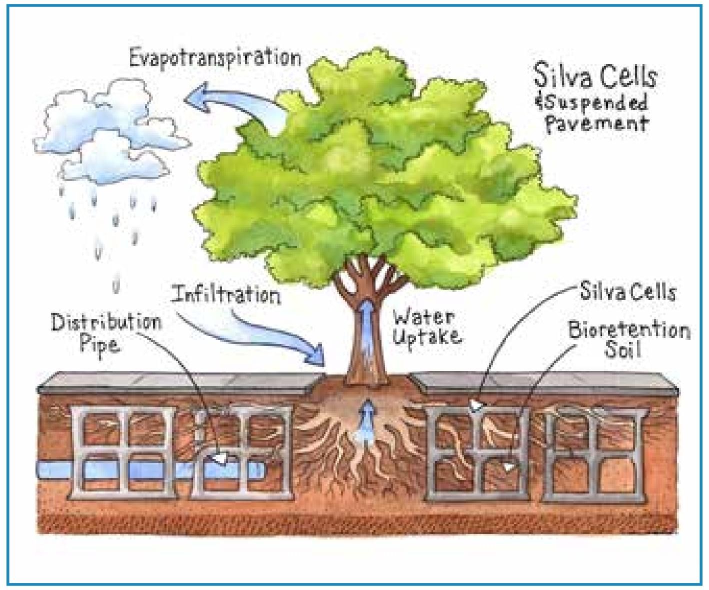
Trees slated for protection may still suffer development impacts such as root compaction and trunk damage. The most common form of tree protection during construction is tree protection fencing. It is a physical barrier that keeps people and machines out of trees' critical root zones during land disturbance.

Trees' protection signage communicates how work crews should understand and follow tree protection requirements. It also informs crews and citizens about the consequences of violating city code. The city does not have requirements for tree protection signage on development projects, unless it is a project on city-owned land. It is important that building materials are not placed in tree protection zones and that protective fences not be moved.

This tree is drought stressed as shown in the dead, leafless branches and will likely not survive. Post-planting care is critical to ensure required trees remain alive.

TREE PLANTING

In urban environments, many trees do not survive to their full potential life span. Factors such as lack of watering or insufficient soil volume and limited planting space put stresses on trees, stunt their growth and reduce their lifespans. For every 100 street trees planted, only 50 will survive 13-20 years (Roman et al 2014). This means that adequate tree well sizing standards are a critical factor in realizing the advantages of a healthy urban forest. At a minimum, canopy trees require 1000 cubic feet of soil volume to thrive. In areas where space is tighter or where heavy uses occur above roots, 'Silva cells' or other trade technologies can be used to stabilize and direct tree roots towards areas with less conflicts (e.g. away from pipes). The city has implemented demonstration projects downtown that have larger tree wells and other root structural supports.



Silva Cells and Suspended Pavement

Other challenges arise from invasive pests. The emerald ash borer has been found in Alabama and will likely continue to spread. As ash trees are lost, the city will need to replant a new species of tree that is not susceptible to known pest outbreaks.

The city can consider whether some large impervious surfaces on vacant lots might be converted to open space and planted to provide more canopy in less well treed areas of the city and to uptake more stormwater along with other tree benefits. Recessed planting wells (bioswales) can also be integrated into existing lots to capture more stormwater.

The city has an active Tree Commission that organizes tree give-aways. The commission also supports the Auburn Tree Trust which accepts tax deductible donations for tree planting. A gift to the Tree Trust supports tree planting on public property. A minimum donation of $100 is required to honor a specific

Emerald Ash Borer is an invasive beetle from northeast Asia that kills ash trees by boring and feeding under their bark, thereby disrupting the movement of water and nutrients through the tree.

This tree planted in memory of Chris Cochran provides a living memorial that provides benefits for the city's environmental health.

This tree at a commercial site is showing signs of drought damage as evidenced by dead upper branches and sun scalding. It did not receive proper post-planting care and may not survive.

person or event but the Tree Trust will take any donation for planting trees in Auburn. The city has also partnered with nonprofit groups, such as the Master Gardeners, to purchase and install trees in the city and plans to continue such partnerships. The key to maintaining city canopy is to engage even more residents and civic groups as partners in city tree care and in planting on both public and private property.

Tree planting will be most successful when trees are planted in the right locations. Large trees should not be planted where they may interfere with overhead transmission lines or underground utilities. They should also never be 'topped' by having the top branches removed. This may happen when trees are planted under power lines, which should be avoided. These and other practices, implemented to provide long term care, protection and best planting practices for the urban forest, will help ensure that investments in city trees pay dividends for reducing stormwater runoff, as well as cleaner air and water, lower energy bills, higher property values and natural beauty long into the future.

This is one of two oaks at Toomer's Corner that has been replaced several times when unruly opposing fans have poisoned, burned or otherwise tortured these revered trees at Auburn University.

CONCLUSION AND NEXT STEPS

Adapting codes, ordinances, and municipality practices to use trees and other native vegetation for enhanced stormwater management will allow Auburn to treat stormwater more effectively. Implementing these recommendations will significantly reduce the impact of stormwater sources (impervious cover) and benefit the local ecology by using native vegetation (trees and other vegetation) to uptake and clean stormwater. It will also lower costs of tree cleanup from storm damages, since proper pruning or removal of trees deemed to be 'at risk' can be done before storms occur.

The city will use the canopy data, analysis and recommendations and the stormwater calculator tool to continue to create a safer, cleaner, cost-effective and more attractive environment for all. Auburn can use the canopy map and updates to track change over time and to set goals for increasing or maintaining canopy by neighborhood. The city will use the canopy data to inform the future land use plan and to strategize where to plant new trees.

Auburn has created an urban tree canopy goal to maintain canopy coverage at 55%. This study was completed with imagery from 2017 and since then, the city has experienced significant development. So, just to achieve the 55% goal, the city will need to plant many additional trees annually to maintain its canopy. The city also does not have an accurate way to track tree removals. The best way to determine if the city is meeting its maintenance goal of 55% is by conducting a canopy update in 4 years, comparing results and taking appropriate action if the percentage has fallen below the goal. Prior to this study, the city did not have an established goal for tree canopy. So setting a goal is an excellent first step to ensure better planning for the urban forest and the health of the city's watersheds.

The city's trees are our green infrastructure!

Auburn's parks are well treed and offer a green oasis for city residents.

APPENDIXES

APPENDIX A: TECHNICAL DOCUMENTATION

This section provides technical documentation for the methodology and results of the land cover classification used to produce both the Land Cover Map and Potential Planting Scenarios for Auburn. Land cover classifications are an affordable method for using aerial or satellite images to obtain information about large geographic areas. Algorithms are trained to recognize various types of land cover based on color and shape. In this process, the pixels in the raw image are converted to one of several types of pre-selected land cover types. In this way, the raw data (i.e. the images) are turned into information about land cover types of interest, e.g. what is pavement, what is vegetation? This land cover information can be used to gain knowledge about certain issues; for example: What is the tree canopy percentage in a specific neighborhood?

Land Cover Classification

NAIP 2017 (acquired between Sept/Oct 2017) Leaf-on imagery (4 band, 1-meter resolution) was used for the land cover classification. The full set of NAIP data was acquired through the Earth Resources Observation and Science (EROS) Center of the U.S. Geological Survey. Additional inputs included in classification were LiDAR from various acquisition dates in 2017 and planimetric data such as road area, buildings and other impervious surfaces.

Pre-Processing

The NAIP image tiles were first re-projected into the coordinate system used by the city.

NAD_1983_StatePlane_Alabama_East_FIPS_0101_Feet
WKID: 102629 Authority: Esri

Projection: Transverse_Mercator
False_Easting: 656166.6666666665
False_Northing: 0.0
Central_Meridian: -85.83333333333333
Scale_Factor: 0.99996
Latitude_Of_Origin: 30.5
Linear Unit: Foot_US (0.3048006096012192

Geographic Coordinate System: GCS_North_American_1983
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_North_American_1983
Spheroid: GRS_1980
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314140356
Inverse Flattening: 298.257222101

Supervised Classification

The imagery was classified using an object based supervised classification approach. The ArcGIS extension Feature Analyst was used to perform the primary classification with a 'bull's eye' object recognition configuration was used to identify features based on their surrounding features. Feature Analyst software is an automated feature extraction extension that enables GIS analysts too rapidly and accurately collect vector feature data from high-resolution satellite and aerial imagery. Feature Analyst uses a model-based approach for extracting features based on their shape and spectral signature.

The NDVI image along with the source NAIP bands (primarily 4, 1 and 2) were used to identify various features where they visually matched the imagery most accurately. The Tree Canopy class was then verified and refined using a LiDAR Normalized Digital Surface Model (NDSM). To get the NDSM – first returns are subtracted from last return to get feature height.

Post-Processing

The raw classifications from Feature Analyst then went through a series of post-processing operations. Planimetric data were also used at this point to improve the classification. Roads, sidewalks, and trails were 'burned in' to the raw classification (converted vector data to raster data, which then replaced the values in the raw classification). The 'tree canopy' class was not affected by the burn-in process, however, because tree canopy can overhang streets. These data layers were also used to make logic-based assumptions to improve the accuracy of the classification. For example, if a pixel was classified as 'tree canopy,' but that pixel overlaps with the roads layer, then it was converted to 'Tree Cover over Impervious.' The final step was a manual check of the classification. Several ArcGIS tools were built to automate this process. For example, the ability to draw a circle on the map and have all pixels classified as "tree canopy" to 'non-tree vegetation,' which is a process usually requiring several steps, is now only a single step.

Potential Planting Area Dataset

The Potential Planting Area Dataset has three components. These three data layers are created using the land cover layer and relevant data in order to exclude unsuitable tree planting locations or where it would interfere with existing infrastructure.

1. Potential Planting Area (PPA)
2. Potential Planting Spots (PPS)
3. Potential Canopy Area (PCA)

The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees, then eliminating areas that would interfere with existing infrastructure.

- **Initial Inclusion** selected from GIC created land cover
  - Pervious surfaces
  - Bare earth
- **Excluded Land Cover Features**
  - Existing tree cover
  - Water
  - Wetlands
  - Impervious surfaces
  - Ball fields (i.e.: baseball, soccer, football) where visually identifiable from NAIP imagery. Digitized by GIC.
- **Exclusion Features:** (buffer distance)
  - Roads areas (10 ft.)
  - Unpaved roads (10 ft.)
  - Road areas (10ft)
  - Parking lots (10ft)
  - Sidewalks (10ft)
  - Railroads (10ft)
  - Structures (10ft)
  - Fire hydrants (10ft)
  - Pump stations (10ft)
  - Water/sewer mains (10ft)
  - Utility poles (10ft)
  - Power lines (10ft)

Potential Planting Spots

The Potential Planting Spots (PPS) are created from the PPA. The Potential Planting Areas (PPA) is run through a GIS model that selects spots a tree can be planted depending on the size tree's that are desired. Tree planting scenario was based on a 20 ft. and 40 ft. mature tree canopy with a 30 percent overlap.

Potential Canopy Area

The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are given a buffer around each point, this represents a tree's mature canopy. For this analysis, they are given a buffer radius of 10 or 20 ft. that results in 20 and 40 ft. tree canopy.

NAIP Image 2016

Potential Planting Area (PPA)

Potential Planting Spots (PPS)

Potential Canopy Area (PCA)

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APPENDIX C: COMMUNITY MEETING NOTES

The first community meeting provided an orientation to the project and opportunities to comment on/correct the data as well as ideas for the city to consider.
Map Fixes to Make (these were made by GIC).

Auburn Land Cover Map:

AA: Location AA this has been developed and is 'over cleared.' Great deal of tree removal. Check with current aerial – may need to delete some canopy here and not use as possible planting areas (PPA).

Streets Tree Canopy Map:

Note 1: This is a 'Performance Neighborhood" and there are not many trees along the street, partly because they conflict with utility locations (both roots and canopy).

PPA Map:

Livestock: Remove these areas from PPA. These locations are ag fields at Auburn University (cows, pigs, horses) + art center is being built in this area, so remove these designations as PPA.
Remove baseball fields (Note 1) and playing fields (Note 2) from maps.
Note 3 and 4: Pay close attention to the soils in these spots. It may be bedrock and next to impossible to plant trees in these spots.
Note 5: There are opportunities for tree plantings in this spot as re-development is planned/underway.

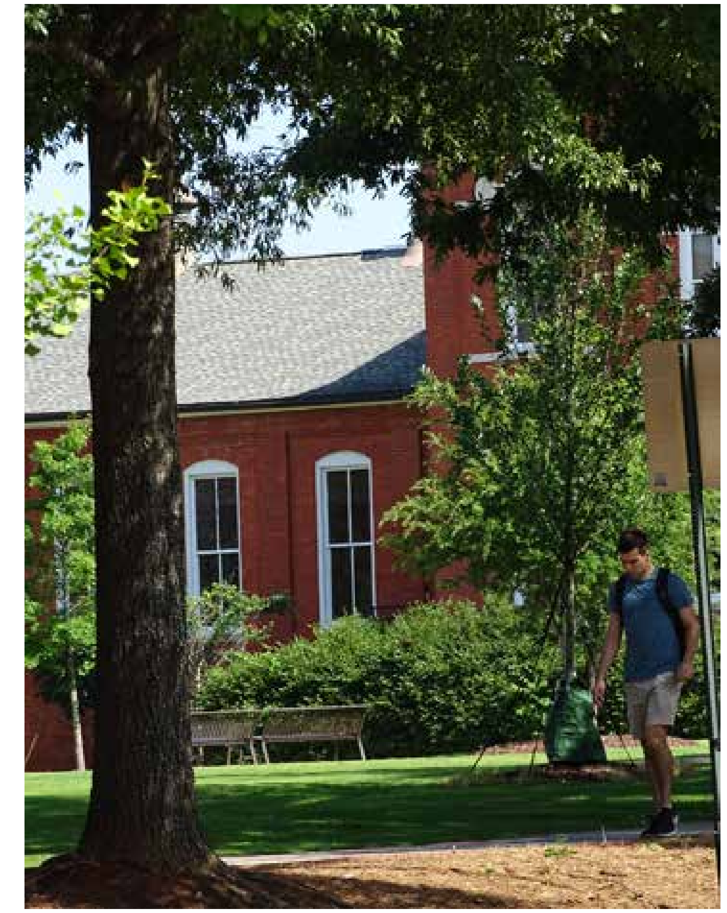
Flowering trees add to the beauty of springtime in Auburn.

General Comments:

- From the meeting site, Opelika Road towards the northeast is 'bleak' and needs more trees (see note on 'dire' area).
- A good source for healthy trees is Thurlow Tree Nursery. They would be interested in this project.
- Have a series of articles in the paper on how to plant trees.
- Help homeowners know what to look for in selecting trees in containers (e.g. how to tell if severely root bound or diseased).
- Trees of 2-4 inches are a 'sweet spot' for ensuring survival if planting large trees.
- Athens GA has a really good tree nursery.
- Revisit and revise the current stormwater ordinance in the city.
- Provide more education for the public about where stormwater goes and why green infrastructure matters.
- In city publications, write a section called 'Tree Myth busters' to provide more information about trees in a humorous way.
- Make the information in the Alabama Smart Yards publication more accessible and digestible for the public.
- Plant natives, not invasives.
- Protect large old trees.
- Provide information for the public explaining why it is so important to have tree canopy downtown as well as in intact forested habitats.
- Collaborate with Boy Scouts, 4H, Master Gardeners, the Auburn Rotary Club, and neighborhood associations to install more tree plantings.
- Provide more education for developers through pre-development meetings.

The final community meeting had lower attendance, but the following priorities were agreed upon:

1. Work with developers to shrink the development footprint.
2. Approve trees as stormwater management practices in Auburn.
3. Increase education for private citizens about the benefits of trees.
4. Accommodate large trees in urban areas by providing adequate soil volume.



These images demonstrate how trees add to the city's quality of life, historic character and support good water quality in the Chewacla watershed.

The beauty of Chewacla Park waters.