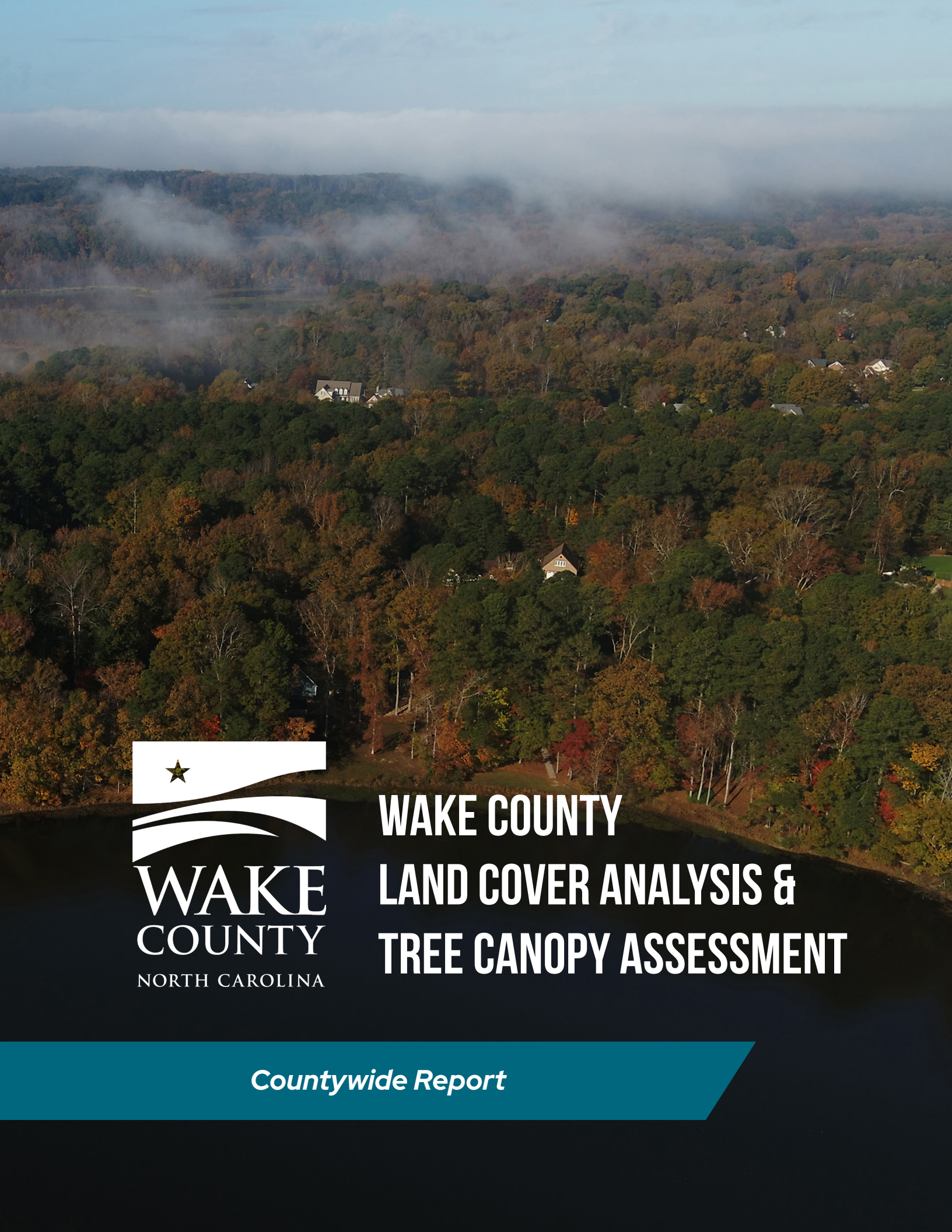

WAKE COUNTY
NORTH CAROLINA

WAKE COUNTY LAND COVER ANALYSIS & TREE CANOPY ASSESSMENT

Countywide Report

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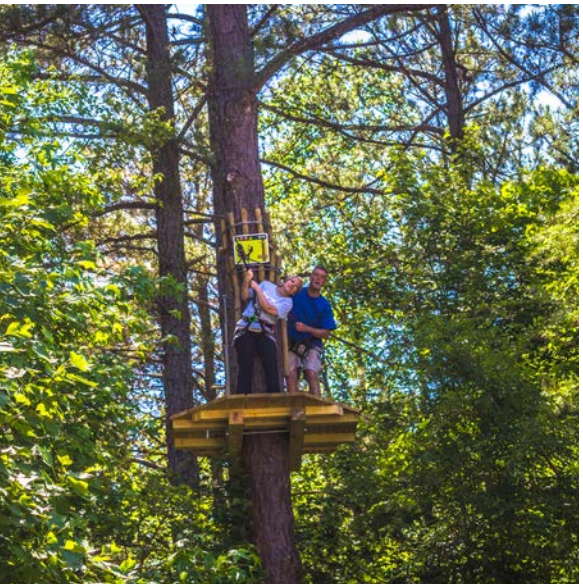

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Executive Summary

Foreword

The Wake County Land Cover Analysis and Tree Canopy Assessment (Wake LCA/TCA). is produced by Wake County Government in collaboration with Davey Resource Group, Inc., a national environmental consulting firm. The Wake LCA/TCA utilized geospatial analysis to identify and measure countywide land cover, including tree canopy, as it existed in 2020. The project also evaluated tree canopy type and health and measured the change in tree canopy cover over the ten-year period from 2010–2020.

This is not a policy document; it is a summary report offering a visual, high-level overview of the project, the accompanying analyses and the results.

The report intention is to leave readers with an impression of the intrinsic value of the data and an understanding of how the various datasets can be leveraged as a resource for policymakers, researchers, civic organizations, residents and stakeholders of the greater Wake community.

Purpose

Provide data to guide and support planning and implementation efforts on both a county and municipal level.

Goals

- Support a higher quality of life for vulnerable residents and communities.
- Preserve and enhance the County residents' quality of life through coordinated land use and transportation planning.
- Preserve and protect a clean and abundant water supply.
- Preserve open space and expand access to parks, preserves, recreation resources and greenways.
- Promote sustainability and address issues associated with climate change.

Objectives

Analyze

Analyze the existing land cover conditions within Wake County.

Evaluate

Evaluate Wake County's tree canopy type, health and change over a 10-year span (2010-2020).

Measure

Measure the environmental and socioeconomic impact of tree canopy cover.

Identify

Identify potential opportunities for canopy restoration, with a focus on equity for vulnerable communities.

Background

Located in the Piedmont of central North Carolina, Wake County spans a total area of 548,338 acres – approximately 857 square miles. Wake is the most populous of the state's 100 counties. The estimated 1.15 million residents who call Wake home account for nearly 11% of North Carolina's statewide population.

County Growth and Development

From 2010–2020, the countywide population climbed from 900,993 to 1.15 million individuals – an increase of 25.4%, which is more than two-and-a-half times the growth rate of North Carolina and nearly three-and-a-half times the national growth rate over the same period.

Economic opportunity and population growth fuel land development. Consequently, the county is experiencing a conversion of open spaces, natural areas and agricultural lands into built environments at a similarly rapid rate.

Community Voices

Over the past several years, residents countywide expressed concern over the loss of the county's traditional farm and forest lands and the impact of that loss here at home and in the broader context of climate change and environmental uncertainty. A chief concern cited by many is the loss of trees.

County Response

Recognizing that a myriad of individual and societal pressures accompany growth, Wake County government responded with a variety of planning advancements made through the Wake Transit Plan, the Wake County Affordable Housing Plan, Live Well Wake, the Wake County Greenways Plan, PLANWake and others. These efforts plan for the next wave of growth in a manner that enhances quality of life for all residents.

This project provides key information for addressing the concerns of the county's residents and achieving healthy, equitable and sustainable outcomes for the greater Wake County community.

Land Cover

Davey Resource Group, Inc. ("DRG") utilized geospatial analysis and remote-sensing methods to identify the land cover composition throughout the entirety of Wake County. The analysis utilized 2020 imagery made available by the United States Department of Agriculture's National Agriculture Imaging Program (NAIP). Imagery analysis is cost-effective and attains a high degree of accuracy.

Countywide Analysis

The analysis classified the entirety of Wake County's 548,388 acres into five distinct types of land cover (Figure E.1):

Tree Canopy – 297,242 acres

Land area that is covered by tree trunks, branches and leaves, as seen from above.

Vegetation – 127,926 acres

Shrubs, grasses and other low-lying vegetation that allow rainfall to infiltrate soil.

Impervious Surface – 81,702 acres

Buildings, roads, sidewalks and other paved or built areas that do not allow rainfall to infiltrate the soil.

Bare Soil – 22,692 acres

Exposed soil that lacks vegetation, such as vacant lots, construction sites, agricultural fields and baseball infields.

Open Water – 18,776 acres

Lakes, ponds, streams, wetlands and other water features.

FIGURE E.1 LAND COVER (2020)

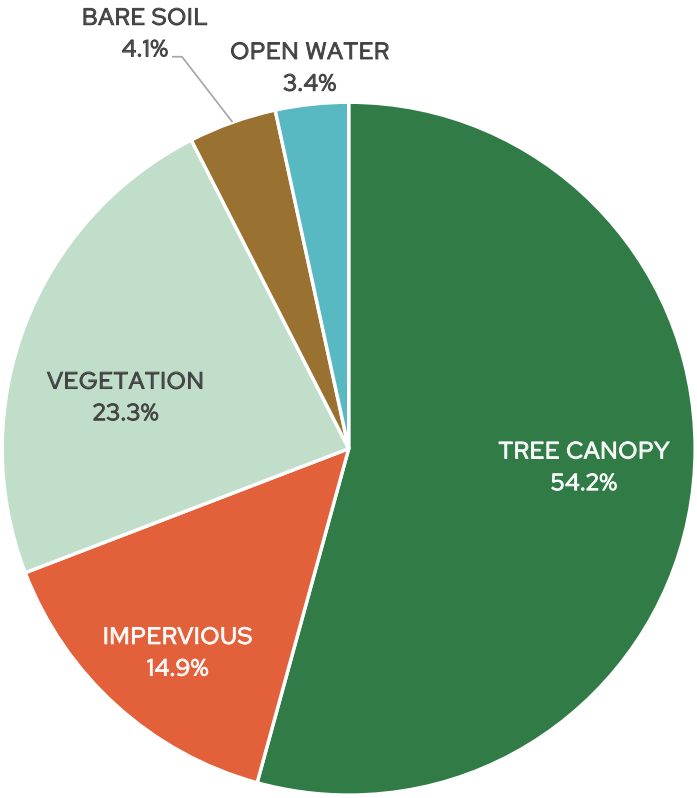
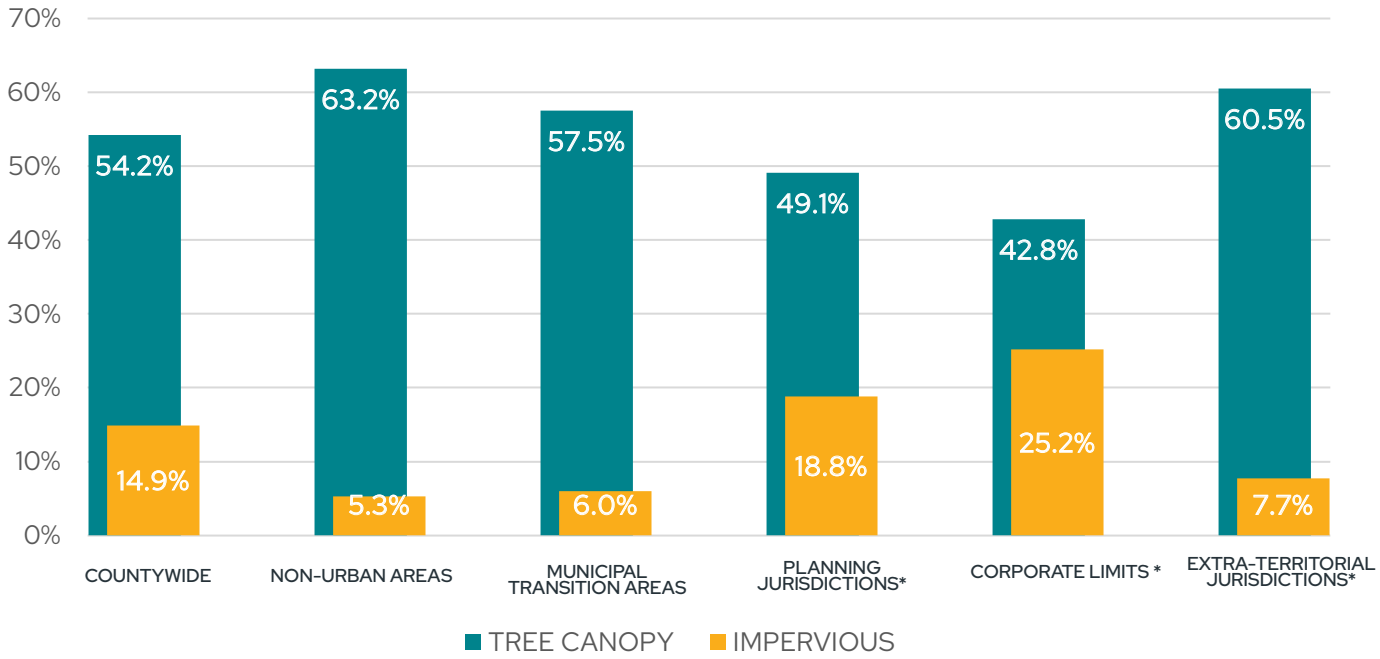


FIGURE E.2 TREE CANOPY AND IMPERVIOUS SURFACE BY JURISDICTION (2020)



* denotes the average percent cover of Wake County core municipalities

Jurisdictional Analysis

After obtaining countywide land cover data, the results were reported and examined across multiple geographic areas of interest, including within unincorporated county land, census tracts and block groups, green spaces and watersheds.

Among unincorporated county land areas, the analysis looked separately at Municipal Transition Areas (MTA) and Non-Urban Area (NUA).

The project also examined land cover within the planning jurisdiction of each of Wake County's 12 core municipalities: Apex, Cary, Fuquay-Varina, Garner, Holly Springs, Knightdale, Morrisville, Raleigh, Rolesville, Wake Forest, Wendell and Zebulon. The planning jurisdiction includes both the corporate limits and extra-territorial jurisdiction (ETJ) of each municipality.

Jurisdictional and cross-jurisdictional analysis provide valuable insights into land cover and land use throughout the county's multiple regulatory jurisdictions. The data can be utilized to support a variety of multidisciplinary efforts, including environmental management, resource conservation, urban planning, sustainable development and climate change mitigation.

It is of note that future land development in Wake County, particularly new residential subdivisions, will largely occur in land areas located within ETJ. As of 2020, canopy cover among the county's twelve core municipalities averaged 60.5% within ETJ and 42.8% within corporate limits (Figure E.2).

Canopy Assessment

A canopy assessment takes a detailed look at the tree canopy data obtained from the land cover analysis. DRG employed a variety of remote-sensing methods to extrapolate additional information such as canopy type**,** canopy health and canopy change over time.

Canopy Type

Canopy type analyses support sustainable forest management and natural resource planning. The data can also help inform decisions about zoning, infrastructure development and urban expansion.

The assessment classified Wake County's tree canopy into two distinct forest types (Figure E.3):

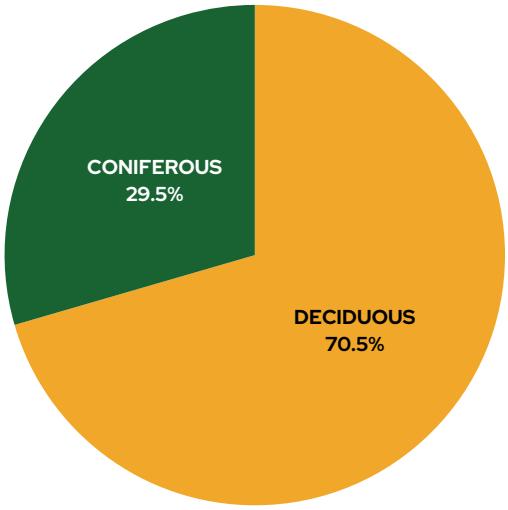
Coniferous – 87,687 acres

The canopy characterized by the predominance of cone-bearing trees which typically retain their leaves or needles year-round. Wax-leaf evergreens, such as hollies and magnolias, are included in this category.

Deciduous – 209,556 acres

The canopy is characterized predominately by trees which lose their leaves during winter. In North Carolina, common deciduous species include oak, hickory, maple, beech and elm.

FIGURE E.3 CANOPY TYPE (2020)



Canopy Health

A canopy health assessment provides valuable insights into overall forest well-being and vitality. The data aids in the detection and management of diseases, nutrient deficiencies and environmental stressors. The analysis also supports proactive tree maintenance in public areas (greenways, parking lots, etc.) or along major road corridors utilized by first responders, a key aspect of an emergency preparedness plan.

Wake County's tree canopy is assessed to be in predominantly Good condition (Figure E.4.).

FIGURE E.4 CANOPY HEALTH (2020)

Canopy Change

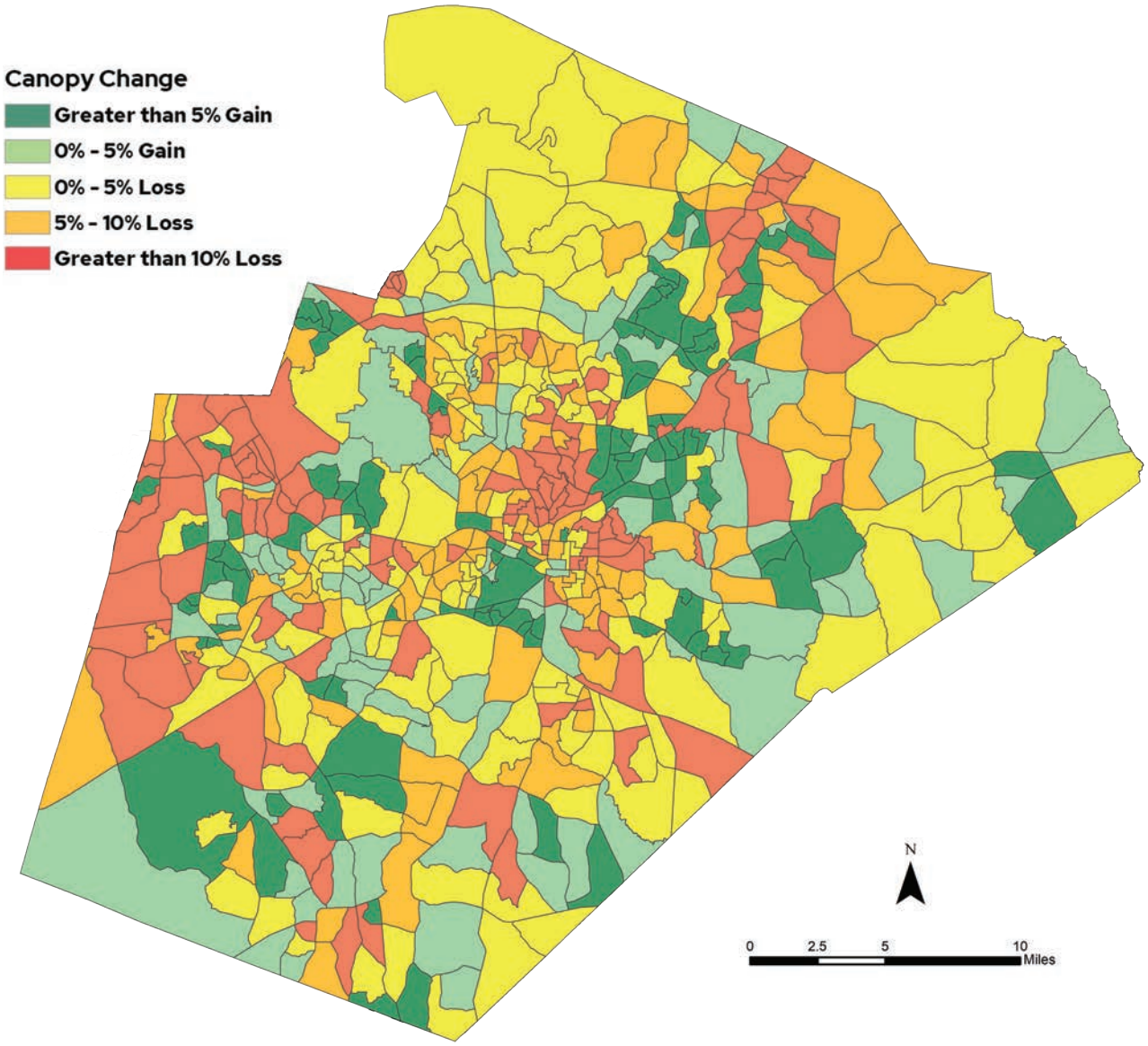
To measure the temporal change of Wake's tree canopy, DRG performed a second land cover analysis utilizing 2010 NAIP imagery. The data then allowed for measurement and comparison of Wake County's tree canopy over the 10-year span from 2010 to 2020.

Canopy Loss

From 2010-2020, Wake County lost 11,122 acres of tree canopy – a total land area more than double the size of William B. Umstead State Park. The loss represents a 3.6% decrease in the total amount of countywide canopy and a 2% decline in canopy cover relative to overall land cover.

Mapping canopy change by census block group illustrates the geographic distribution of canopy gains and losses throughout the county (Map E.1). Most of the county's 597 census block groups experienced net canopy loss during the 10-year period of study.

MAP E.1 CANOPY CHANGE (2010-2020) BY BLOCK GROUP



Benefits and Value of Wake's Tree Canopy

Trees help clean the air we breathe, filter the water we drink and mitigate the impacts of a changing climate. Through their natural biological and ecological functions, trees provide critical community infrastructure.

The ecosystem service capacity of Wake County's tree canopy was measured and valued using i-Tree, a software suite made available by the U.S. Forest Service.

THE TOTAL VALUE OF WAKE'S TREE CANOPY IS $3.2 BILLION

Carbon Storage = $1,742,099,038

Trees are carbon sinks; they absorb carbon dioxide from the atmosphere and convert it into glucose, which is used as food for the tree. The leftover carbon is then stored within tree tissue, including the trunk, branches, leaves and roots.

Over their lifespan, Wake County's trees are estimated to have collectively removed and **stored over 10.2 million tons of carbon** from the atmosphere.

Total Annual Benefits = $1,458,859,441

The benefits analysis measured and valued three specific ecosystem service functions of tree canopy: **air pollution removal**, **carbon sequestration** and **stormwater capture**.

EACH YEAR, WAKE COUNTY'S TREES:

REMOVE 11,022 TONS
OF POLLUTANTS FROM THE AIR

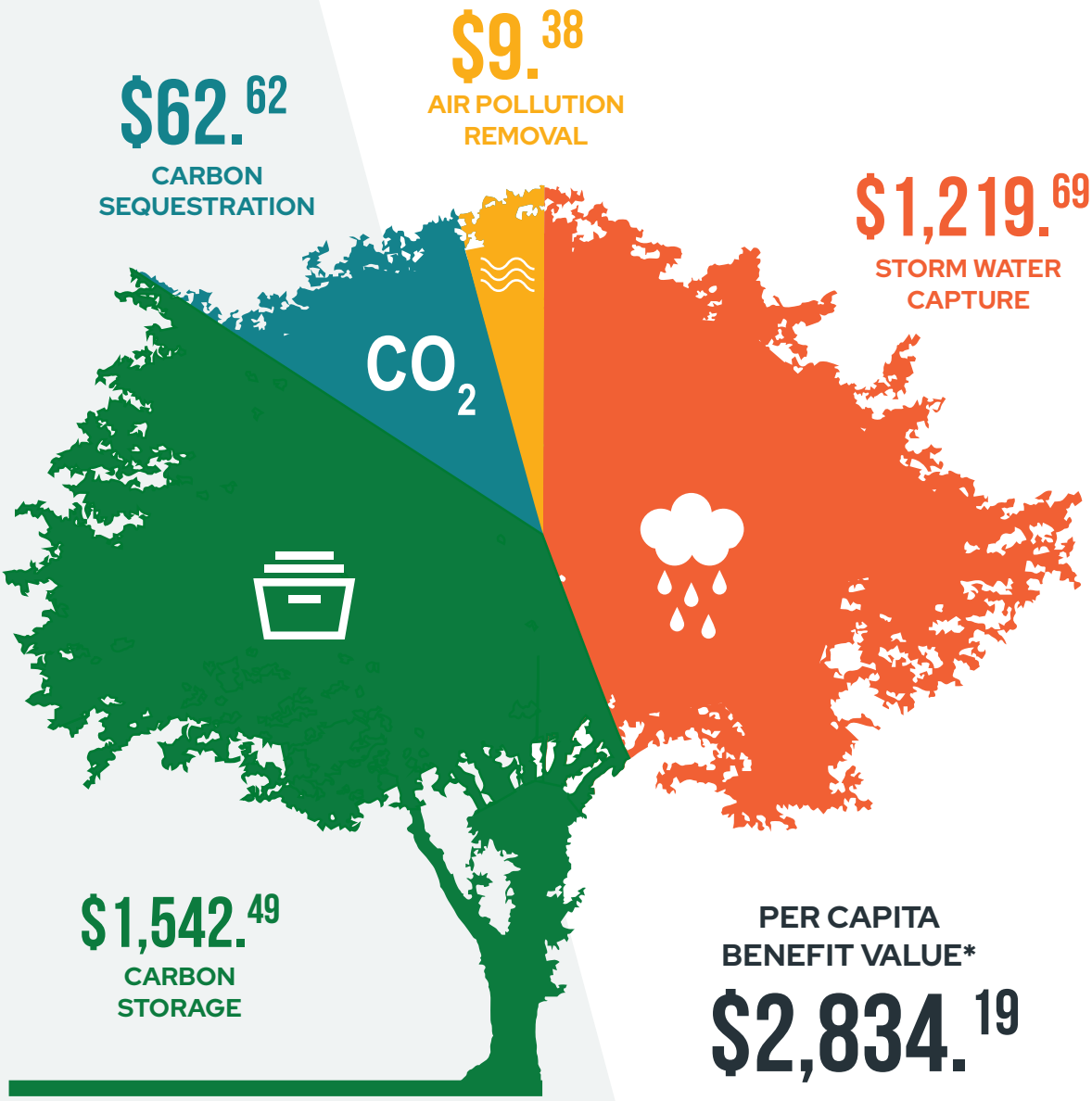
ABSORB 414,710 TONS
OF CARBON DIOXIDE

INTERCEPT 8.1 BILLION
GALLONS OF STORMWATER

Additional, less quantifiable canopy benefits include, but are not limited to:

- Increased property values.
- Shade and cooler air in the summer.
- Energy conservation.
- Improved physical health.
- Improved mental well-being.
- Increased biodiversity and habitat

SPENDING TIME AROUND TREES AND LOOKING AT TREES REDUCES STRESS, LOWERS BLOOD PRESSURE AND IMPROVES MOOD.



What do your community's trees do for you?

Trees provide substantial added value to the quality of life of Wake County's residents. The ecosystem services contributed to the community by its tree canopy infrastructure can be quantified and valued on an individual level.

Over their lifespan, the county's trees have stored an estimated accumulated total of 9.04 tons of carbon per county resident, translating to a per capita carbon storage value of $1,542.49.

Per resident, Wake County's tree canopy annually removes 19.5 pounds of air pollution, capture 7,174 gallons of stormwater and absorbs 734 pounds of carbon. These vital eco-services translate to an annual per capita value of $1,291.70.

The combined per capita benefit value of Wake County's tree canopy is estimated to be $2,834.19.

*Per capita refers to the average value per Wake County resident. As of 2020, Wake County had a resident population of 1,129,410 with a tree canopy valuation of $3,200,958,479.

Planting Opportunities

A key aspect of the study used the land cover data and additional remote sensing methods to identify realistic Potential Planting Area (PPA) throughout the entirety of Wake County.

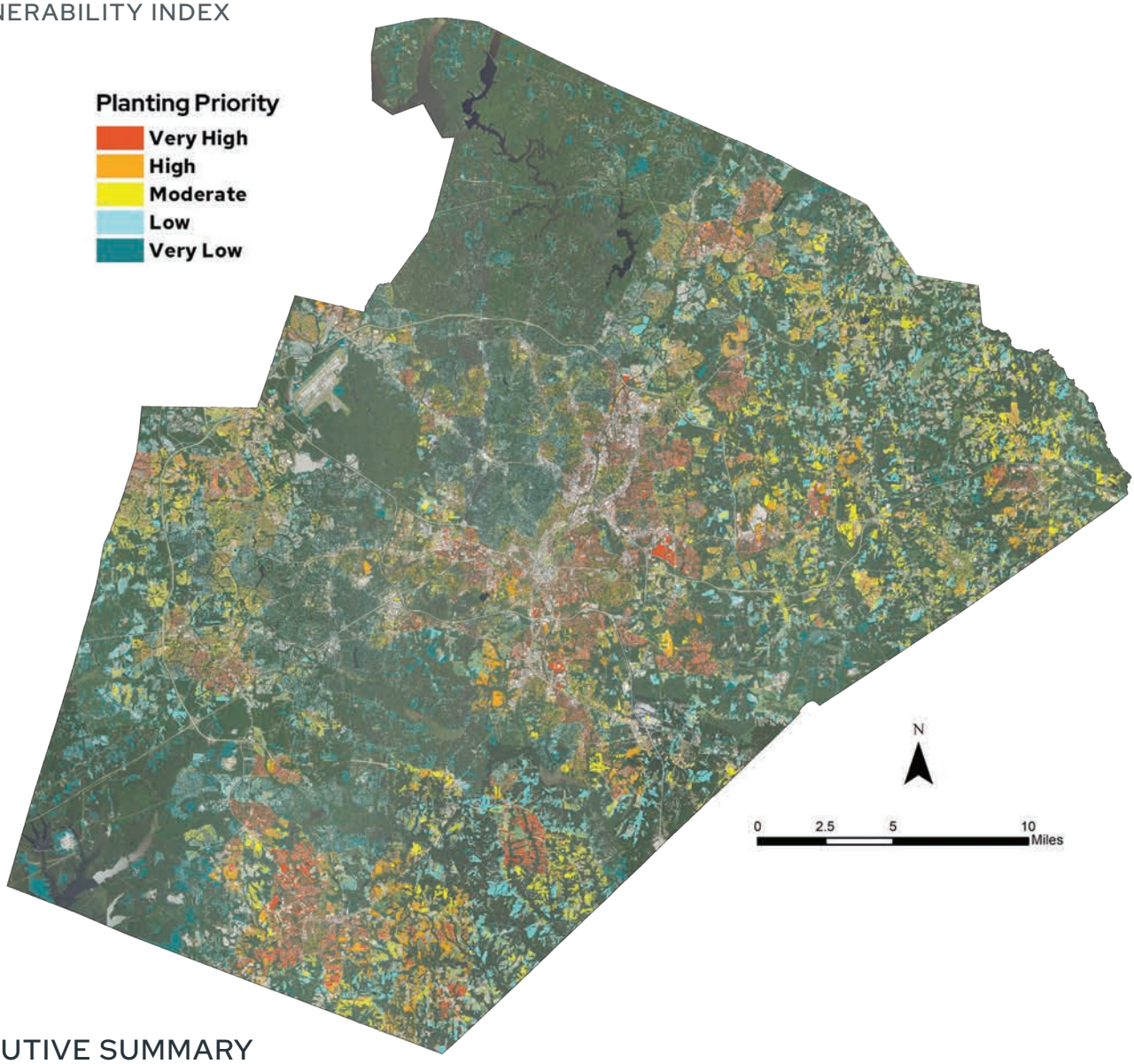
Identification

Possible planting locations were first identified from among land areas within the Bare Soil and Vegetation land cover types. These locations were then narrowed down to include spaces 200 square feet and larger within municipal planning jurisdictions and one acre and larger within unincorporated county lands.

As not all pervious surface is realistically suitable or feasible for planting trees, these possible planting locations were then further refined by filtering out certain "no planting" areas, which included utility easements, access easements, public rights-of-way, recreational fields and active agriculture or horticulture sites.

The analysis identified 404,879 individual PPA totaling 82,460 acres of available planting space.

MAP E.2 POTENTIAL PLANTING AREA (2020) PRIORITIZED BY THE COMPOSITE VULNERABILITY INDEX



Assessment

The PPA are individually assessed across three separate measures of community vulnerability:

1. Heat Islands

Heat islands are generally found in urbanized areas that experience higher temperatures than outlying areas. Impervious surfaces such as buildings, roads and other infrastructure absorb and re-emit the sun's heat. In urbanized areas, where these structures are highly concentrated and greenery is limited, this phenomenon creates "islands" of higher temperatures relative to outlying areas. Known as the urban heat island effect, daytime temperatures can range from approximately 1–7°F higher than temperatures in outlying areas and nighttime temperatures range from 2–5°F higher.[4]

2. Stormwater

Stormwater refers to water that originates from a precipitation event, such as rain, that does not soak into the ground. The excess water is runoff that flows over land and carries soil, pollutants and other materials into our rivers, lakes and bays.

3. Social Equity

Social equity refers to the concept of fairness and justice in the distribution of resources and opportunities in a society, particularly as it relates to historically marginalized and disadvantaged groups.

Prioritization

The individual assessments are then combined to produce a composite vulnerability index. The index provides a total aggregate vulnerability score for each PPA which is then used to prioritize the planting locations on a five-category ordinal scale (Very High, High, Medium, Low, Very Low).

The priority ranking corresponds to the assessed need for additional tree canopy to help boost community resiliency and mitigate exposure to the harm caused by urban heat islands, stormwater runoff and social inequity.

The analysis identified 12.4% of PPA as Very High priority and an additional 16.5% as High priority.

Tree Placement Modeling

A GIS-based algorithm modeled how many trees could be planted within each PPA. The model differentiated between tree size at maturity (large, medium and small-growing), giving preference to large-growing trees and utilizing spacing commonly suggested for a landscape setting (Table 3.3).

The tree placement model identified 2,831,295 total individual tree planting sites.

- 52.7% of sites suitable for large-growing trees (1,492,685 sites).
- 13.1% of sites suitable for medium-growing trees (369,726 sites).
- 34.2% of sites suitable for small-growing trees (968,884 sites).

Looking Ahead

The information in this study establishes baseline statistics for land cover and tree canopy in Wake County. It should be considered as a starting point – a springboard for conversations and identification of opportunities that can enhance tree canopy. The data can be leveraged to support tree planting initiatives and tree maintenance. Additionally, the data can assist policymakers, planners and community stakeholders in securing funding to support these activities.

Plant New Trees

This report and the accompanying GIS data provide a tool to help Wake County identify and prioritize tree planting based on levels of canopy cover and an assessment of environmental and socio-economic needs. The information can be used to encourage and support tree planting on both public and private properties.

Review Ordinances and Policies

Existing regulatory and policy documents, such as development ordinances and land use plans, can be evaluated in context of the data provided by the LCA/TCA project. The data can help identify how and where to incentivize and encourage tree planting, tree protection and other ways to expand tree canopy. Review of internal policies, procedures and current projects' impact on publicly owned trees can also be helpful when identifying ways to increase tree planting and protect existing tree canopy.

Small changes in the design of public projects, including sidewalk installation, street and infrastructure improvements, can improve impacts to trees.

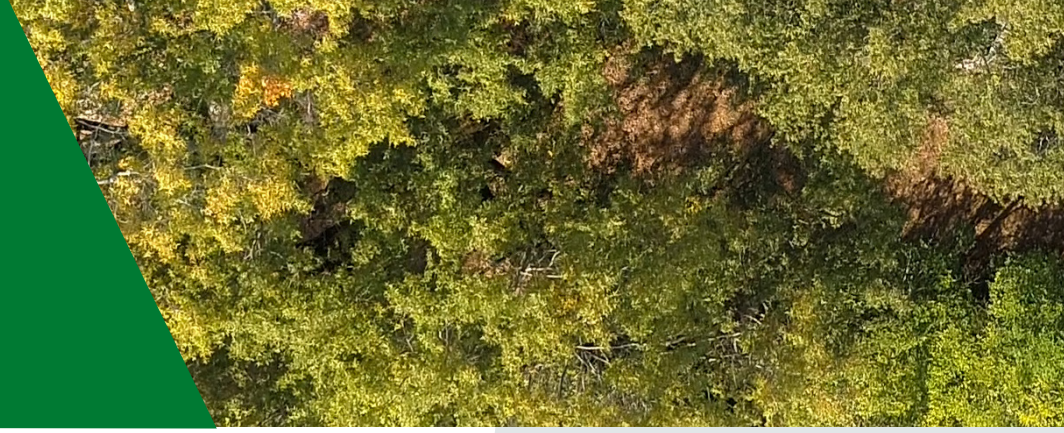
Community Outreach and Involvement

Outreach and education campaigns – including volunteer programs – can encourage residents to care for and retain existing trees. Involving residents in community tree initiatives is a great way to spread the word on the benefits of trees and develop a culture of tree appreciation that can have significant long-term impacts on tree canopy across Wake County. Partnering with local organizations to help spread the word is a way to help get the message out.

Seek New Sources of Funding

The information provided in this study can be used to secure new grant funding with government agencies (state/federal) and private foundations. In addition to the traditional grant programs that support trees, exploring grants that connect to the benefits that trees provide to Wake County, like improving air quality (public health) and increasing canopy in low-income/low canopy areas (equity and environmental justice) can help broaden the types of funding opportunities available.

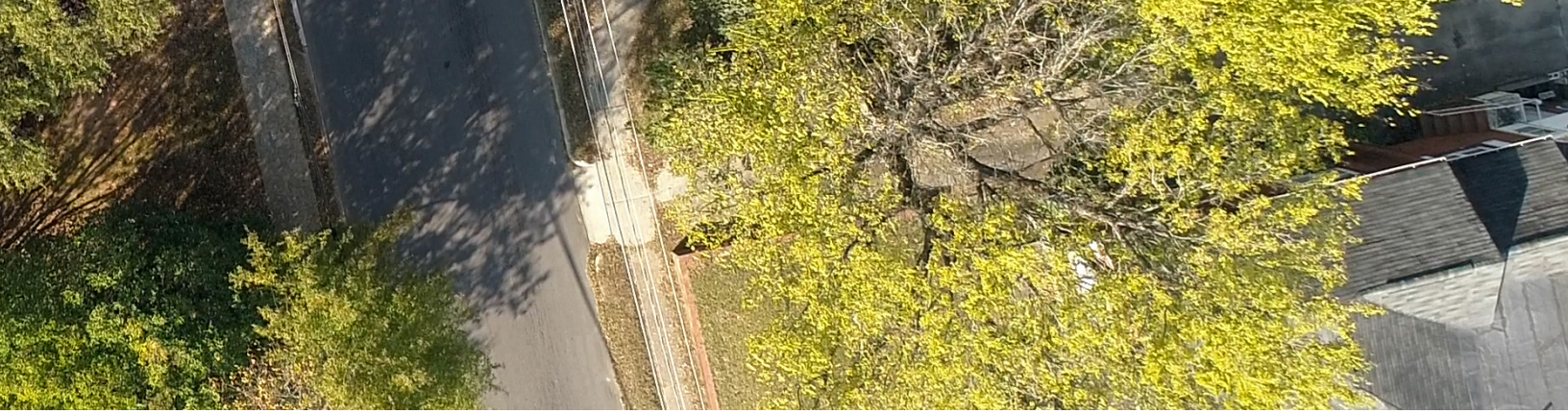
Section One



Land Cover

In This Section:

- Land Cover Types
- Geographies of Study
- Wake County Land Cover



Introduction

A land cover analysis was conducted by Davey Resource Group, Inc., a national urban forestry consulting firm, in collaboration with Wake County Government. The assessment utilized leaf-on, multispectral aerial imagery, vintage 2020, that was available from the National Agricultural Imagery Program (NAIP) and processed by the United States Department of Agriculture. A full discussion of the analytical methods and data sources can be found in the Methodology.

What is Land Cover?

Land cover describes the physical surface types of a given area, as viewed from above.

Why is Land Cover Important?

The analysis informs our understanding and management of natural resources by providing valuable information about the types and distribution of land cover. The data aids in land-use planning, resource conservation, climate change mitigation and sustainable development.

Where is Land Cover Data Acquired?

Land cover data can be acquired from a variety of techniques including remote sensing, ground surveys and aerial imagery. This study utilized an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze high-resolution color infrared (CIR) aerial imagery and remotely sensed data.

How is Land Cover Data Useful?

The metrics and resulting maps hold a variety of multidisciplinary practical applications, including within the following areas of interest:

Urban Planning

» Land cover data can help identify development trends and patterns. Additionally, the data can aid in identifying land areas suitable for development, wildlife conservation or other types of land uses.

Environmental Monitoring

» Land cover data can be used to monitor changes in the environment, including deforestation, urbanization and the expansion of agricultural areas. It helps in assessing the impact of human activities on the natural environment.

Natural Resource Management

» Land cover data can provide information on the distribution and extent of natural resources such as forests, water resources and wildlife habitats. This information can be used to support sustainable management of these resources.

Emergency Preparedness

» Land cover data can be used to assess the risk of natural disasters such as floods, landslides and wildfires. It helps in identifying areas that are most vulnerable to these disasters and in planning disaster response and management activities.

Climate Change

» Land cover data can be used to track, model and analyze the impacts of land cover and land cover change over time in relation to regional climate patterns.

LAND COVER DATA CAN BE USED TO TRACK, MODEL AND ANALYZE CHANGES TO CLIMATE PATTERNS.

Land Cover Types

The analysis utilized the following categories to describe land cover:

Bare Soil

Land areas consisting of exposed soil that lacks vegetation, such as vacant lots, construction sites, agricultural fields and baseball infields.

Grass/Low-lying Vegetation

Pervious land (i.e., surfaces that allow rainwater infiltration) that is covered by shrubs, grasses and other low-lying vegetation that allow rainfall to infiltrate soil. Parks, golf courses and commercial and residential lawns and garden beds are land uses generally characterized by relatively high percentages of grass/low-lying vegetation.

Impervious Surface

Impervious surface describes land area that is covered by buildings, roads, sidewalks and other paved or built areas that do not allow rainfall to infiltrate the soil.

Tree Canopy

Tree canopy describes land area that is covered by tree trunks, branches and leaves, as seen from above. Tree canopy can be further divided into two types:

Coniferous

» Land area that is predominantly covered by coniferous trees, such as pines and spruce. In general, conifers retain their leaves year-round.

Deciduous

» Land area that is predominantly covered by deciduous trees, such as oaks and maples. Deciduous trees shed their leaves seasonally.

Water

Lakes, ponds, streams, wetlands and other water features.

Geographies of Study

The study employed the following geographic areas of interest:

County Limits

The entirety of land area within the bounds of Wake County.

Unincorporated County

Unincorporated Wake County encompasses all land areas not within the planning jurisdiction of a municipality. There are two primary land type classifications: Municipal Transition Areas and Non-Urban Areas.

Municipal Transition Area (MTA)

» Municipal Transition Areas (MTA) are planning areas designated in the Wake County Comprehensive Plan. MTAs are intended to serve as a transition zone between municipalities and generally include areas of the county that are experiencing growth and development but are not yet fully urbanized.

Non-Urban Area (NUA)

» Non-Urban Areas (NUA) are land areas designated within the Wake County Comprehensive Plan. The NUAs in Wake County generally consist of rural and suburban communities and are typically characterized by lower population densities, larger lot sizes and more natural or agricultural land uses.

Municipal Planning Jurisdiction

Land area over which a municipality has zoning control. Each planning jurisdiction is composed of two distinct jurisdictional types: corporate limits and extra-territorial jurisdiction.

Corporate Limits

» The incorporated land area belonging to each municipality.

Extra-Territorial Jurisdiction (ETJ)

» Extra-territorial jurisdiction describes land that is physically located outside of municipal corporate limits, but where a municipality holds regulatory authority over land development and building construction.

Census-Based Geographies

Census-based geographies are useful units of analysis due to the wealth of demographic and socio-economic information collected by the U.S. Census Bureau.

Block Groups

» Block Groups (BGs) are statistical divisions of census tracts that are generally defined to contain between 600 and 3,000 people. BGs are used to present data and usually cover a contiguous area. Within the standard census geographic hierarchy, BGs never cross state, county, or census tract boundaries, but may cross the boundaries of any other geographic entity, such as municipal corporate limits.

Census Tracts

» Census Tracts (CTs) are small, relatively permanent statistical subdivisions of a county or statistically equivalent entity. The primary purpose is to provide a stable set of geographic units for the presentation of statistical data. CTs generally have a population size between 1,200 and 8,000 people, with an optimum size of 4,000 people. A CT usually covers a contiguous area; however, the spatial size varies widely depending on population density.

Green Spaces

Green spaces generally refer to areas designed or preserved for their environmental, social, or recreational benefits; they are found in both urban and non-urban environments. They are important for promoting biodiversity, improving air quality, mitigating the effects of climate change, providing space for outdoor recreation and exercise and enhancing the overall quality of life in communities.

The Wake LCA/TCA project specifically looked at land designated as one of three primary green space types: Parks, Open Spaces and Greenways.

Watersheds

A watershed is the land area that drains to a common body of water, such as a stream, lake, bay, or ocean. Also called a drainage basin, a watershed includes hills, lowlands and the body of water into which runoff drains.

Water Supply Watershed

» A watershed that contains a reservoir or proposed reservoir used for drinking water.

Wake County Land Cover

County Limits

The analysis identified and measured the land cover composition within the entirety of Wake County's 548,338 acres, vintage 2020 (Map 1.1).

The results were summarized and reported for the county as a whole and across multiple geographic areas of interest within the county: municipal planning jurisdiction, corporate limits, extra-territorial jurisdiction, census block groups, census tracts, watersheds and community green spaces.

Observations

Land cover composition tends to vary according to land use. More urban areas are characterized by greater amounts of impervious surfaces and less tree canopy. In less-developed, non-urban areas, the opposite tends to be true.

Map 1.1. provides a visual illustration of land cover distribution throughout Wake County.

The eastern portion of the county, home to most of the county's active agriculture fields, has significant concentrations of low-lying vegetation.

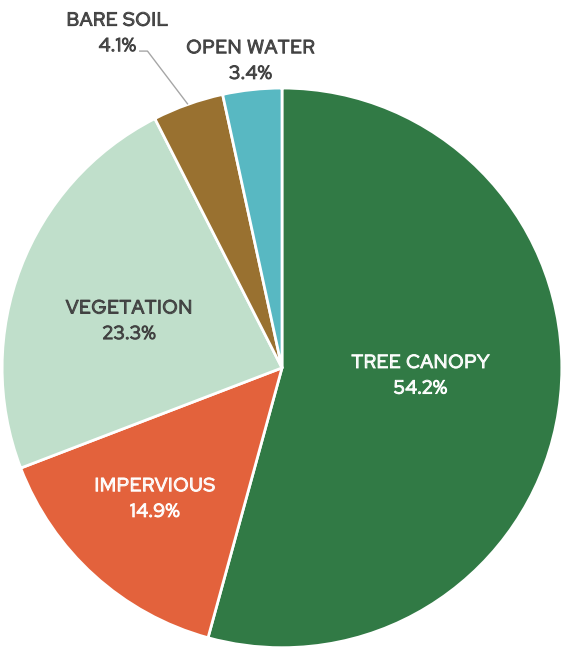
Concentrations of impervious surface are found in and around urban centers within municipal corporate limits.

Large concentrations of canopy occur near and around dedicated recreational areas (e.g., William B. Umstead State Park, Falls Lake Recreational Area).

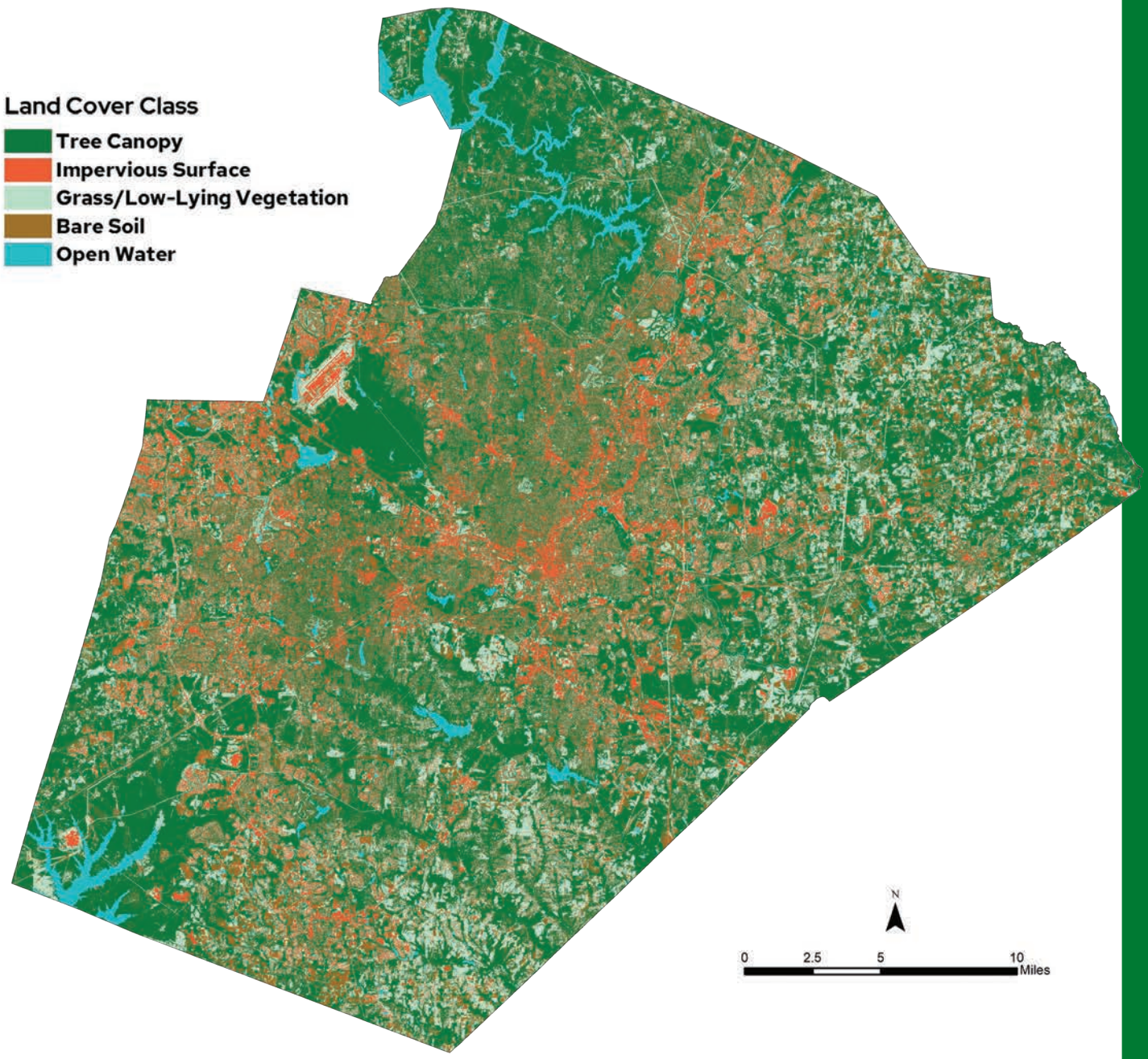
TABLE 1.1 COUNTYWIDE LAND COVER (2020)

LAND COVER TYPE	ACRES	PERCENT
Tree Canopy	297,242	54.2%
Impervious	81,702	14.9%
Vegetation	127,926	23.3%
Bare Soil	22,692	4.1%
Open Water	18,776	3.4%
Total	**548,338**	

FIGURE 1.1 COUNTYWIDE LAND COVER COMPOSITION (2020)



MAP 1.1 WAKE COUNTY LAND COVER (2020)



Unincorporated County

The unincorporated land area of Wake County totals 218,781 acres and consists of two primary land type classifications: Municipal Transition Areas and Non-Urban Areas (Table 1.2).

Municipal Transition Areas (MTAs)

» MTAs account for 109,687 acres of Wake County unincorporated land area. Each MTA is associated with one of the county's core municipalities, and Wake County Government retains jurisdictional authority and zoning control.

Non-Urban Areas (NUAs)

» NUAs total 109,094 acres of area and contain important water-supply watersheds, such as Falls Lake and Swift Creek. They generally consist of rural and suburban communities and are typically characterized by lower population densities, larger lot sizes and more natural or agricultural land uses.

Observations

Land cover within MTAs currently resembles that of NUAs, characterized by significantly more tree canopy and vegetative cover relative to areas close to urban centers. As population growth and land development continue along the current trajectory, it is anticipated that the similarity in land cover composition will gradually diverge, with impervious surface coverage increasing and tree canopy decreasing within MTAs relative to NUAs.

TABLE 1.2 LAND COVER WITHIN UNINCORPORATED WAKE COUNTY (2020)

UNINCORPORATED AREA	ACRES	TREE CANOPY	IMPERVIOUS	VEGETATION	BARE SOIL	OPEN WATER
Municipal Transition Areas	**109,687**	**57.5%**	**6.0%**	**28.0%**	**5.0%**	**3.5%**
Apex	3,852	69.1%	4.7%	22.7%	1.7%	1.7%
Cary	5,923	67.0%	9.8%	19.7%	2.3%	1.1%
Fuquay-Varina	14,527	47.3%	6.4%	36.9%	7.2%	2.2%
Garner	21,875	55.9%	7.9%	31.5%	3.7%	1.0%
Holly Springs	14,610	68.1%	2.6%	12.5%	2.1%	14.8%
Knightdale	2,088	51.9%	10.4%	30.3%	6.8%	0.6%
Morrisville*	--	--	--	--	--	--
Raleigh	18,547	55.7%	6.5%	31.2%	4.9%	1.7%
Rolesville	4,110	50.8%	3.7%	33.2%	9.7%	2.7%
Wake Forest	2,600	59.2%	10.5%	27.3%	1.2%	1.7%
Wendell	12,374	58.9%	4.7%	28.5%	5.8%	2.1%
Zebulon	9,182	55.2%	4.2%	28.0%	9.8%	2.9%
Non-Urban Areas	**109,094**	**63.2%**	**5.3%**	**19.7%**	**3.5%**	**8.4%**
TOTAL UNINCORPORATED	**218,781**	**60.2%**	**5.7%**	**23.9%**	**4.3%**	**5.9%**

*There is not a Municipal Transition Area for the Town of Morrisville

MAP 1.2 WAKE COUNTY
UNINCORPORATED AREAS (2022)

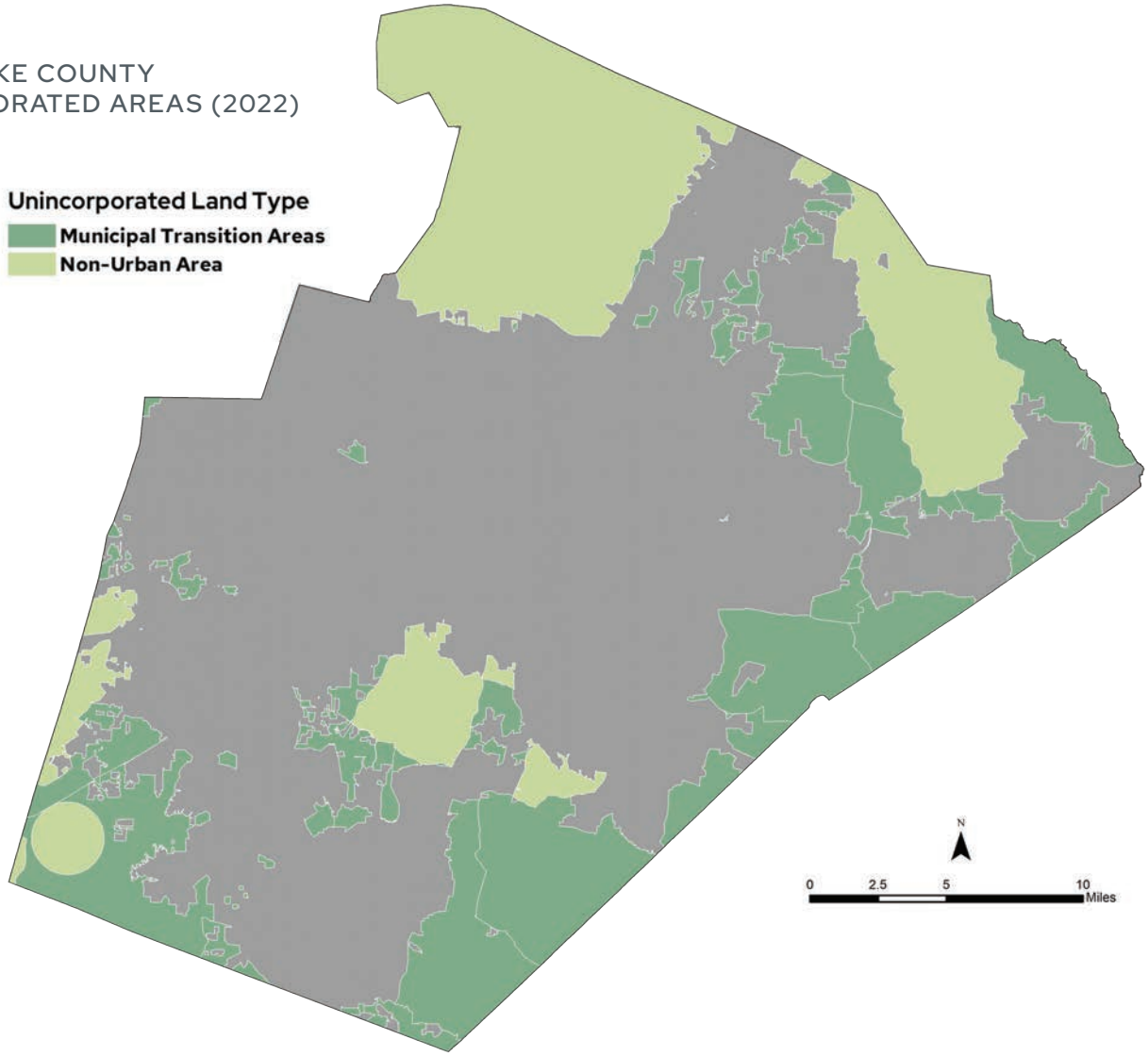
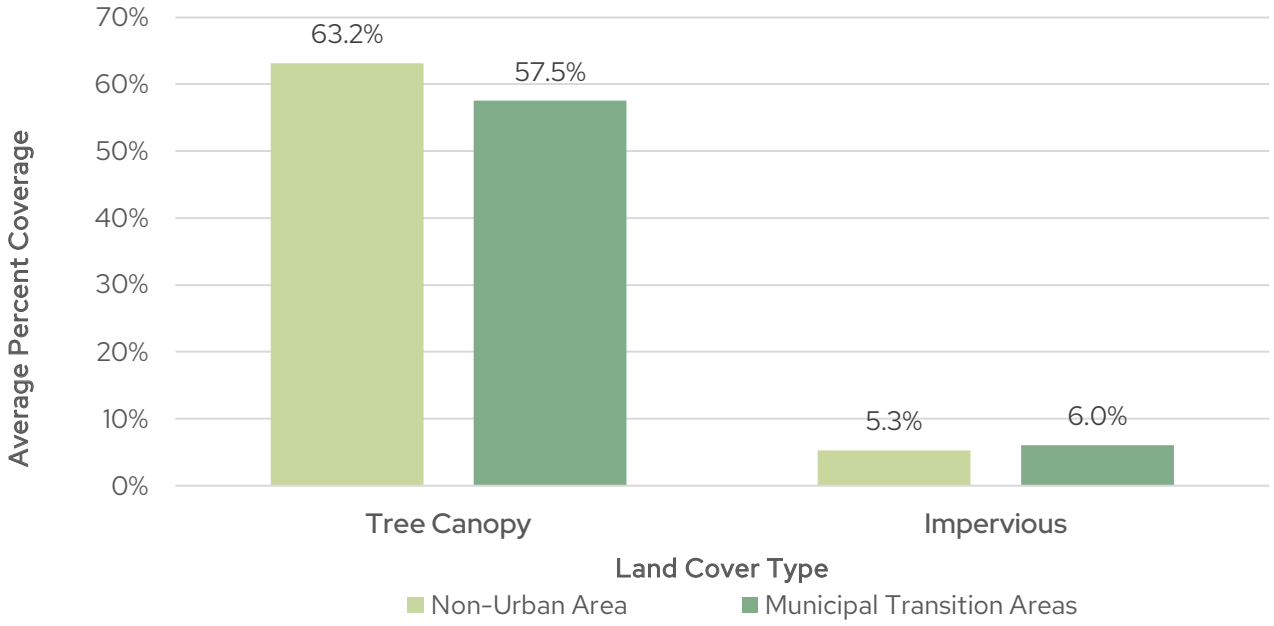


FIGURE 1.2 AVERAGE PERCENT TREE CANOPY AND IMPERVIOUS SURFACE IN NON-URBAN AREAS COMPARED TO MUNICIPAL TRANSITION AREAS (2020)



Planning Jurisdiction

As of 2020, the planning jurisdictions of Wake County's 12 core municipalities have a combined area of 323,280 acres, accounting for approximately 59% of the county's total area.

Observations

Across all 12 core planning jurisdictions:

- Tree canopy cover ranges from 33.7% to 56.3%, with an average of 49.1%.
- Impervious surface coverage ranges from 10.5% to 38.2%, with an average of 18.8%.
- Raleigh maintains the largest planning jurisdiction and Morrisville has the smallest planning jurisdiction.

Vintage 2020

It is important to note that the analysis reflects land cover composition in each planning jurisdiction as of 2020.

FIGURE 1.3 AVERAGE LAND COVER COMPOSITION BY PLANNING JURISDICTION, WAKE COUNTY CORE MUNICIPALITIES (2020)

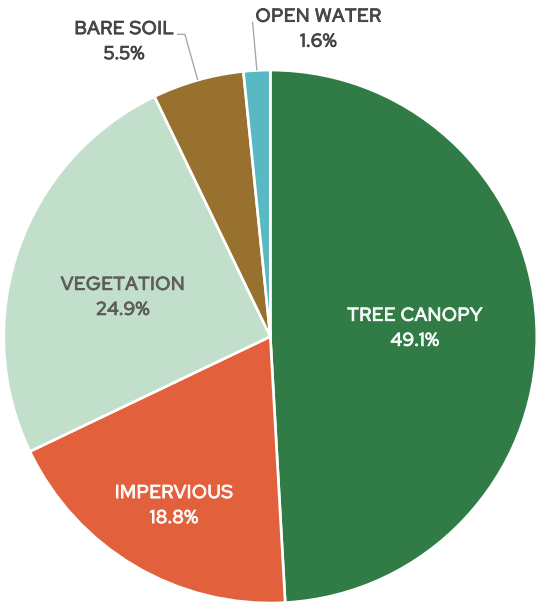
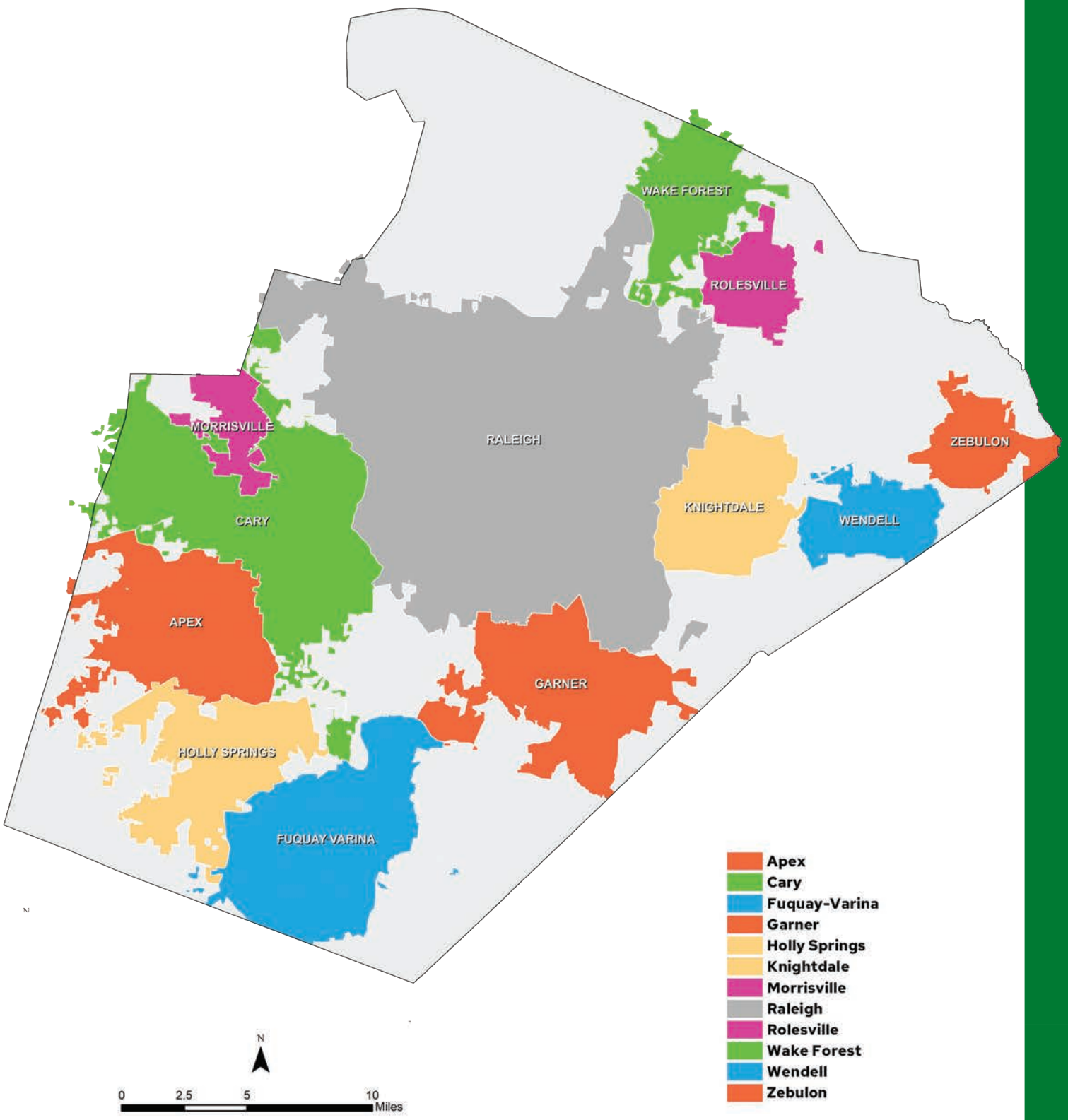


TABLE 1.3 LAND COVER BY PLANNING JURISDICTION (2020)

PLANNING JURISDICTION	ACRES	TREE CANOPY	IMPERVIOUS	VEGETATION	BARE SOIL	OPEN WATER
Apex	24,199	50.4%	20.0%	23.1%	5.2%	1.3%
Cary	43,817	49.3%	26.3%	19.2%	2.4%	2.7%
Fuquay-Varina	29,386	45.0%	14.4%	29.4%	9.0%	2.1%
Garner	25,290	56.3%	15.9%	23.2%	3.4%	1.2%
Holly Springs	20,456	54.8%	14.4%	21.9%	7.4%	1.4%
Knightdale	16,121	52.3%	13.8%	28.2%	4.3%	1.4%
Morrisville	6,304	33.7%	38.2%	22.6%	4.2%	1.4%
Raleigh	116,191	50.5%	25.6%	20.5%	1.9%	1.5%
Rolesville	8,157	51.6%	11.0%	28.5%	7.1%	1.7%
Wake Forest	14,449	45.4%	23.7%	25.6%	3.9%	1.4%
Wendell	10,062	50.3%	10.5%	30.3%	7.3%	1.6%
Zebulon	8,849	49.7%	11.7%	26.7%	10.4%	1.6%

MAP 1.3 PLANNING JURISDICTIONS OF WAKE COUNTY CORE MUNICIPALITIES (2022)



Corporate Limits

As of 2020, the corporate limits of Wake's core municipalities have a combined area of 220,749 acres – approximately 40.3% of the county.

Observations

Looking across the corporate limits of the core municipalities:

- Tree canopy cover ranges from 31.4% to 48.2%, with an average of 42.9%.
- Impervious surface coverage ranges from 16.5% to 41.0%, with an average of 25.2%.

Vintage 2020

It is important to note that the analysis reflects land cover within municipal corporate limits as of 2020.

FIGURE 1.4 AVERAGE LAND COVER COMPOSITION BY CORPORATE LIMITS, WAKE COUNTY CORE MUNICIPALITIES (2020)

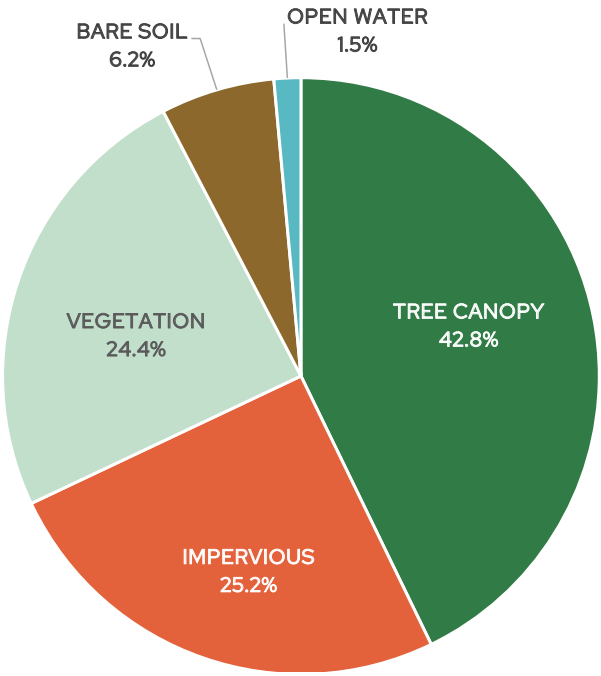
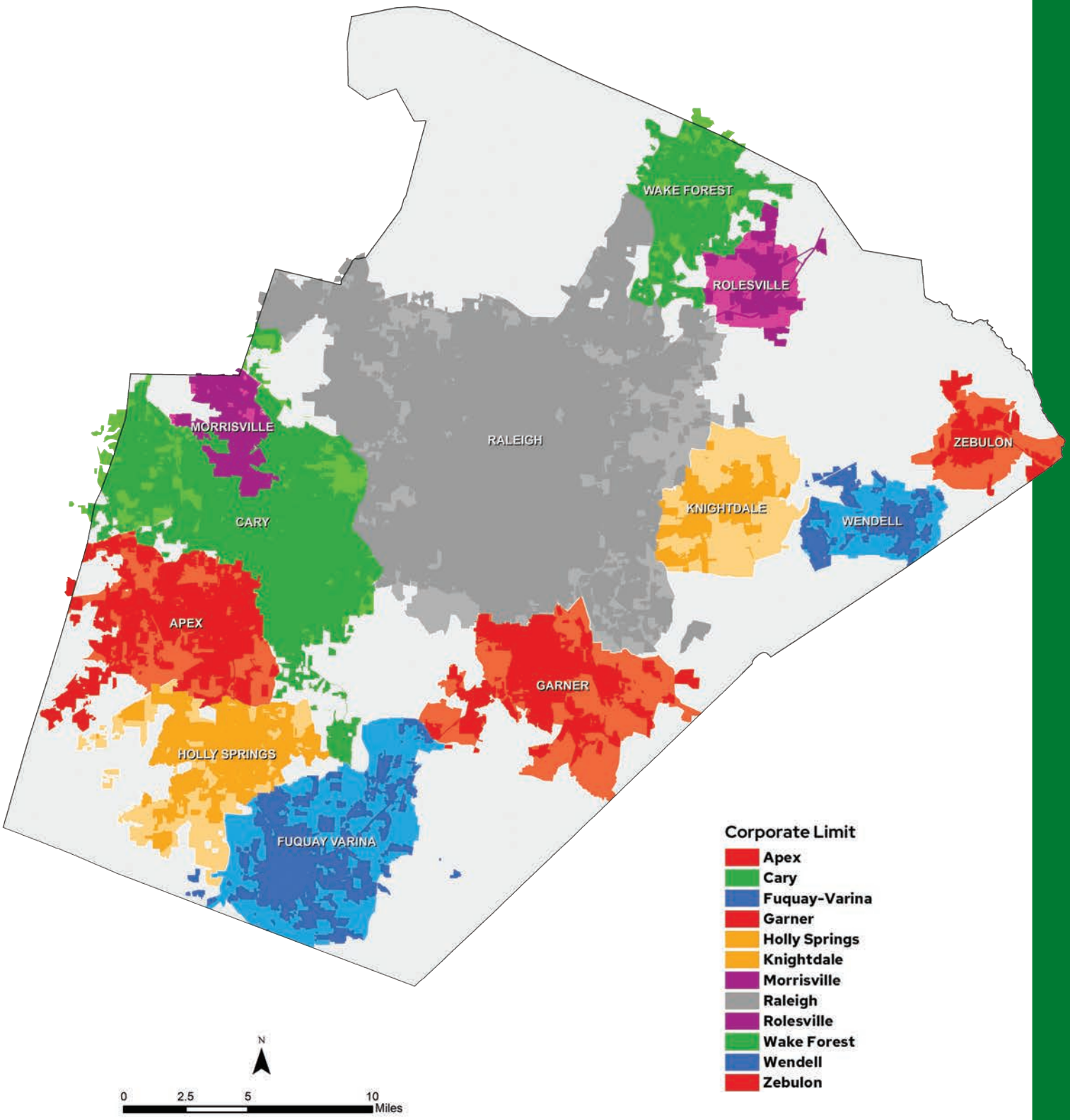


TABLE 1.4 LAND COVER BY CORPORATE LIMITS (2020)

CORPORATE LIMITS	ACRES	TREE CANOPY	IMPERVIOUS	VEGETATION	BARE SOIL	OPEN WATER
Apex	16,217	44.6%	25.5%	22.0%	6.6%	1.3%
Cary	38,964	47.3%	28.4%	19.1%	2.5%	2.7%
Fuquay-Varina	12,044	36.1%	22.9%	27.2%	12.1%	1.7%
Garner	11,616	47.4%	25.3%	22.1%	4.1%	1.1%
Holly Springs	11,914	46.5%	21.6%	23.3%	7.3%	1.4%
Knightdale	5,418	44.5%	24.6%	24.6%	4.9%	1.3%
Morrisville	5,666	31.4%	41.0%	21.8%	4.3%	1.5%
Raleigh	95,722	48.2%	28.9%	19.9%	1.8%	1.3%
Rolesville	3,925	36.3%	20.1%	33.4%	9.0%	1.3%
Wake Forest	12,630	41.7%	25.8%	26.6%	4.4%	1.5%
Wendell	4,554	46.2%	16.5%	28.0%	8.2%	1.1%
Zebulon	3,617	43.6%	21.4%	24.7%	9.1%	1.3%

MAP 1.4 CORPORATE LIMITS OF WAKE COUNTY CORE MUNICIPALITIES (2022)



Extra-Territorial Jurisdiction (ETJ)

As of 2020, land within municipal ETJ has a combined total of 100,992 acres – approximately 18.7% of Wake County's total area.

Observations

Looking across land areas designated as ETJ:

- Tree canopy cover ranges from 51.2% to 72.1%, with an average of 60.5%.
- Impervious surface coverage ranges from 2.6% to 13.5%, with an average of 7.7%.

Vintage 2020

It is important to note that the analysis reflects land cover within the ETJ as of 2020.

FIGURE 1.5 AVERAGE LAND COVER COMPOSITION BY EXTRA-TERRITORIAL JURISDICTION, WAKE COUNTY CORE MUNICIPALITIES (2020)

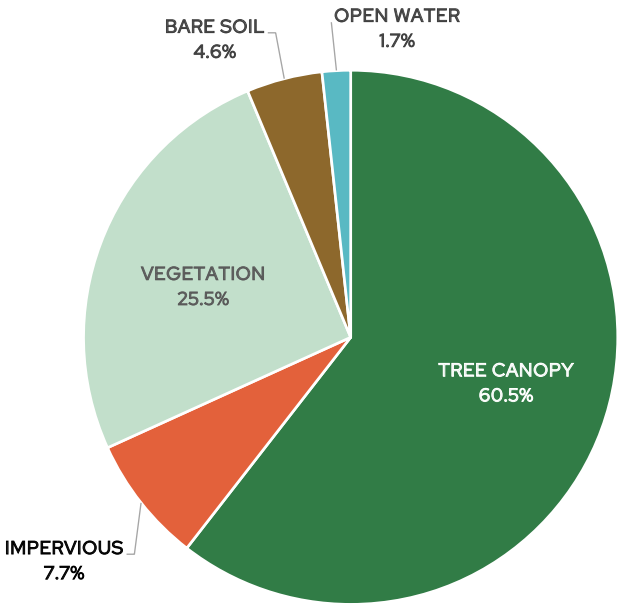
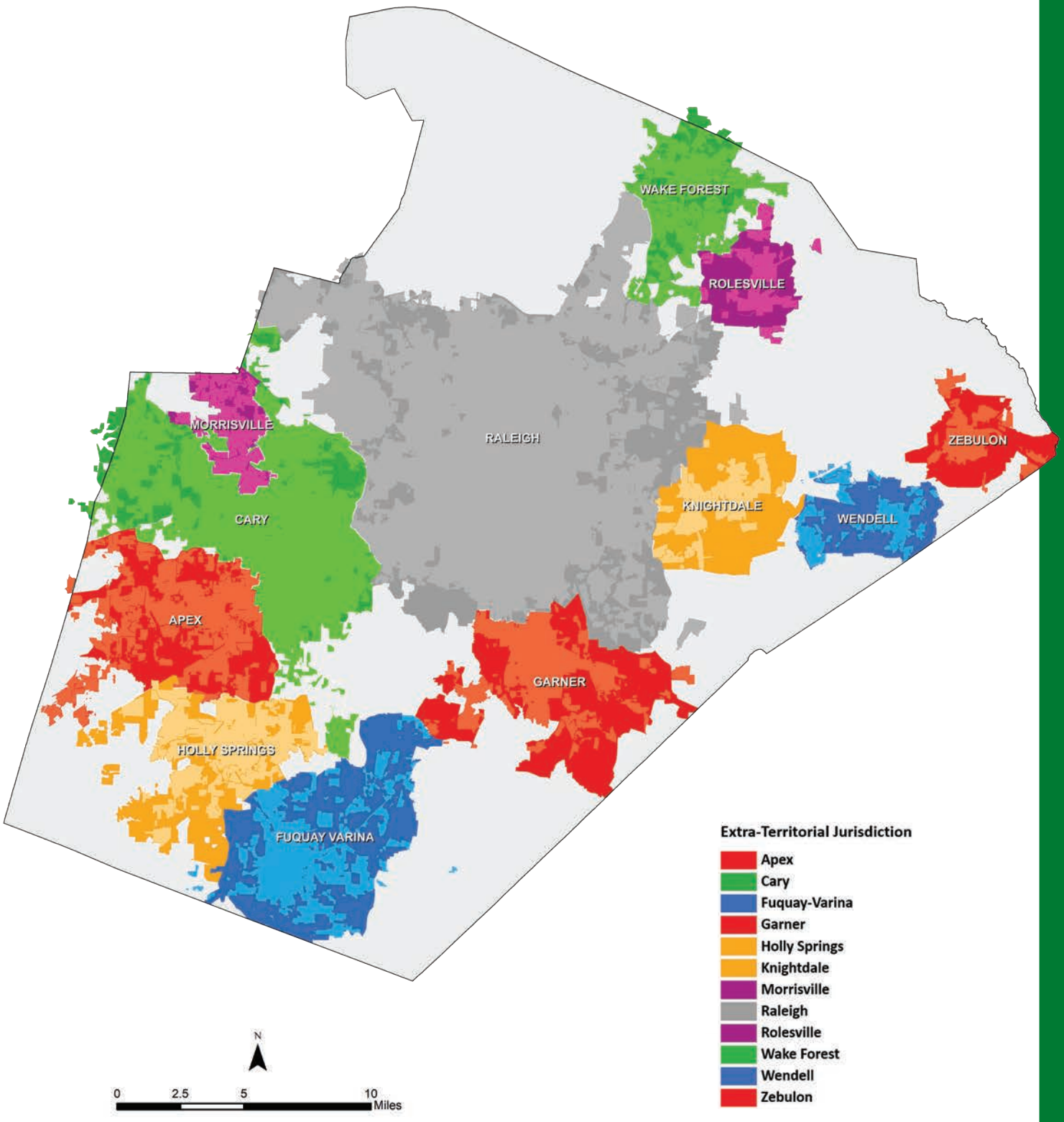


TABLE 1.5 LAND COVER (2020) BY EXTRA-TERRITORIAL JURISDICTION

ETJ	ACRES	TREE CANOPY	IMPERVIOUS	VEGETATION	BARE SOIL	OPEN WATER
Apex	7,981	62.2%	8.9%	25.3%	2.2%	1.4%
Cary	4,853	65.2%	9.4%	20.3%	2.1%	3.1%
Fuquay Varina	17,342	51.2%	8.5%	31.0%	6.9%	2.3%
Garner	13,673	63.9%	8.0%	24.1%	2.8%	1.2%
Holly Springs	8,543	66.5%	4.4%	20.0%	7.7%	1.4%
Knightdale	10,703	56.3%	8.3%	30.0%	3.9%	1.5%
Morrisville	638	53.6%	13.5%	29.1%	3.6%	0.2%
Raleigh	20,469	61.7%	10.1%	23.4%	2.2%	2.5%
Rolesville	4,231	65.9%	2.6%	24.0%	5.4%	2.1%
Wake Forest	1,818	72.1%	8.0%	18.2%	0.7%	1.0%
Wendell	5,508	53.6%	5.6%	32.3%	6.4%	2.1%
Zebulon	5,232	53.9%	5.1%	28.0%	11.2%	1.8%

MAP 1.5 EXTRA-TERRITORIAL JURISDICTION OF WAKE COUNTY CORE MUNICIPALITIES (2022)



Census-Based Geographies

Socioeconomic and population demographic data collected by the U.S. Census Bureau, such as income, education and ethnicity, can be spatially assessed and compared to each other or across other geographies (e.g., voting districts).

Block Groups (BGs)

Wake County is divided into 597 BGs ranging in size from more than 15,000 acres to less than one-tenth of an acre.

Census Tracts (CTs)

Wake County contains 262 CTs, of which 22 are designated by the U.S. Department of Housing and Urban Development (HUD) as a qualified census tract (QCT).

QCTs are utilized to help identify vulnerable populations within a community. HUD designates a QCT when at least one of the following conditions is present:

1. At least half of the households within the CT have incomes below 60% of the Area Median Gross Income ($88,471).[5]
2. The overall poverty rate among all households within the CT is equal to or greater than 25%.

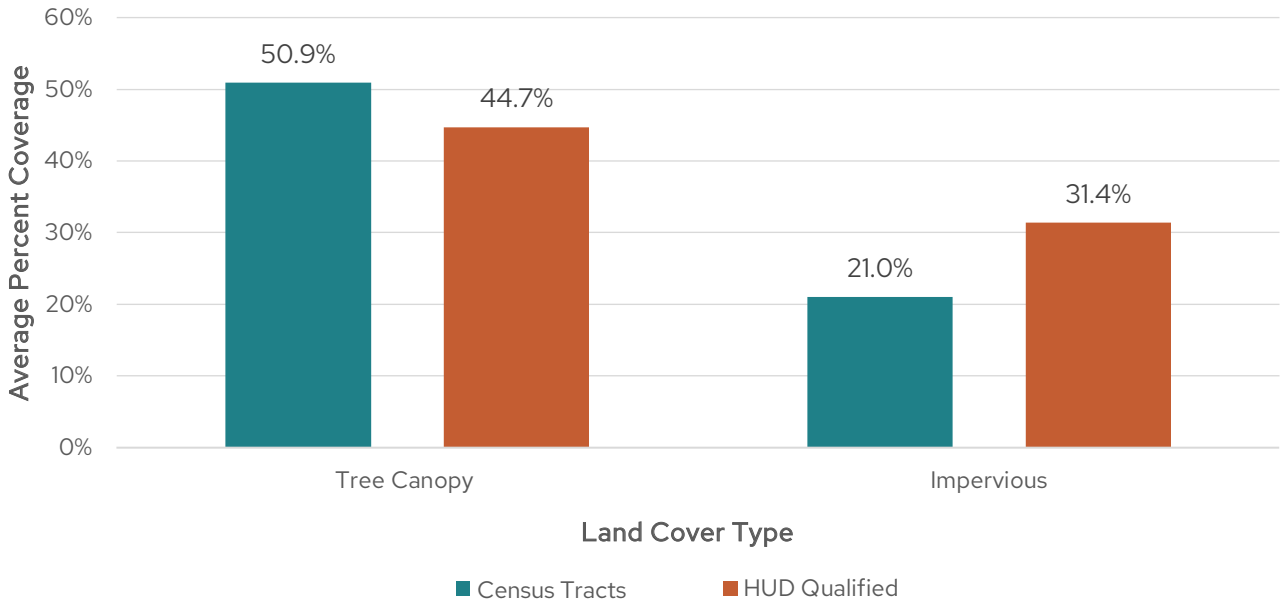
Observations

On average, QCTs in Wake County contain 6.2% less tree canopy cover and 10.4% more impervious surface than their non-qualified cohorts (Figure 1.6).

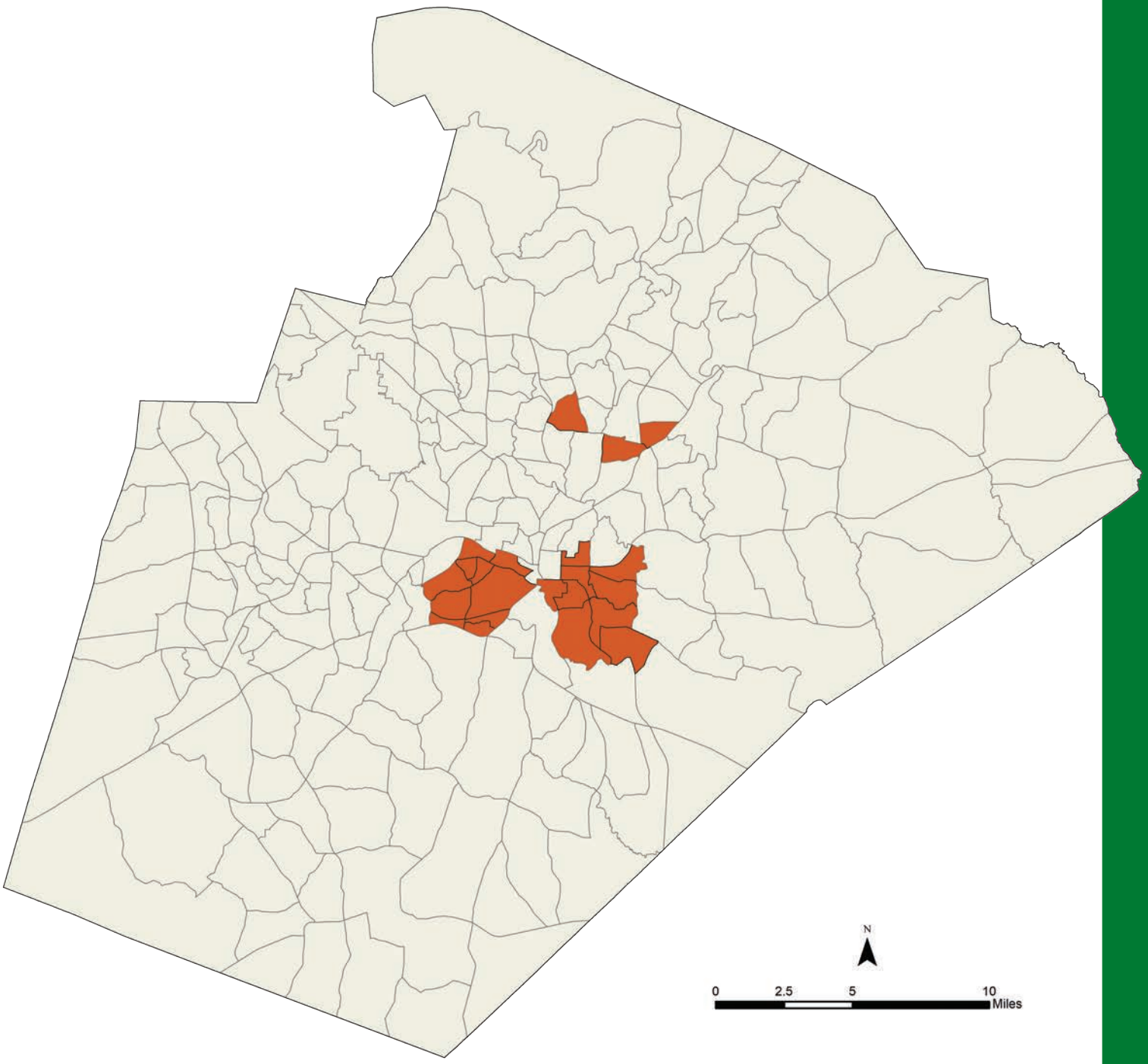
Vintage 2020

It is important to note that the analysis reflects land cover as of 2020.

FIGURE 1.6 AVERAGE PERCENT TREE CANOPY AND IMPERVIOUS SURFACE IN QUALIFIED CENSUS TRACTS COMPARED TO CENSUS TRACTS (2020)



MAP 1.6 QUALIFIED CENSUS TRACTS (2023)

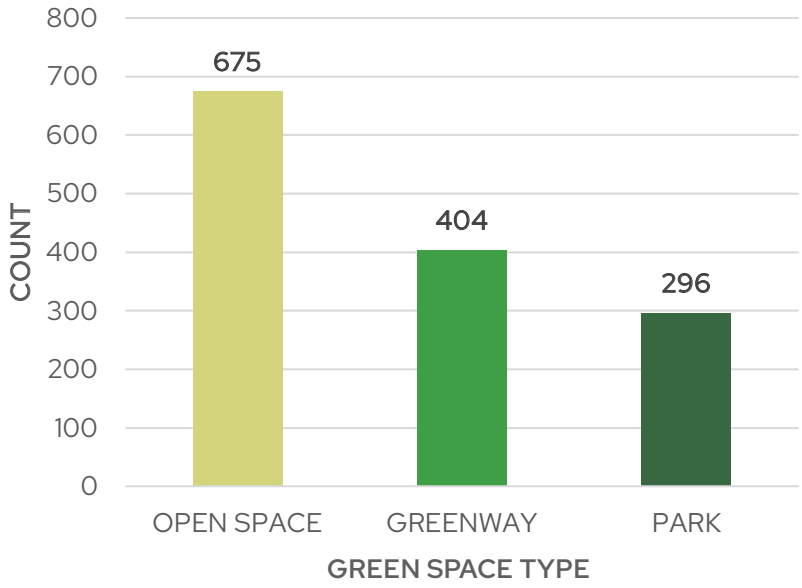


Green Spaces

Summary

Land cover within community green spaces varies with the types of recreational use and the degree of urbanization. Forests and natural areas outside of cities tend to have more tree cover, vegetation and open water. In contrast, urban parks may have more bare soil and lawn for ball fields and more impervious surfaces for recreation centers.

FIGURE 1.7 GREEN SPACES BY TYPE (2022)



The dataset utilized in the analysis was obtained from Wake County in July 2022 and is not considered to be inclusive of all community green spaces throughout the county. As such, land cover metrics and resulting summary statistics should not be considered as an authoritative or exhaustive representation of the entirety of Wake County's green spaces. Map 1.7 and Figure 1.7 reflect only the community green spaces included in the dataset.

Observations

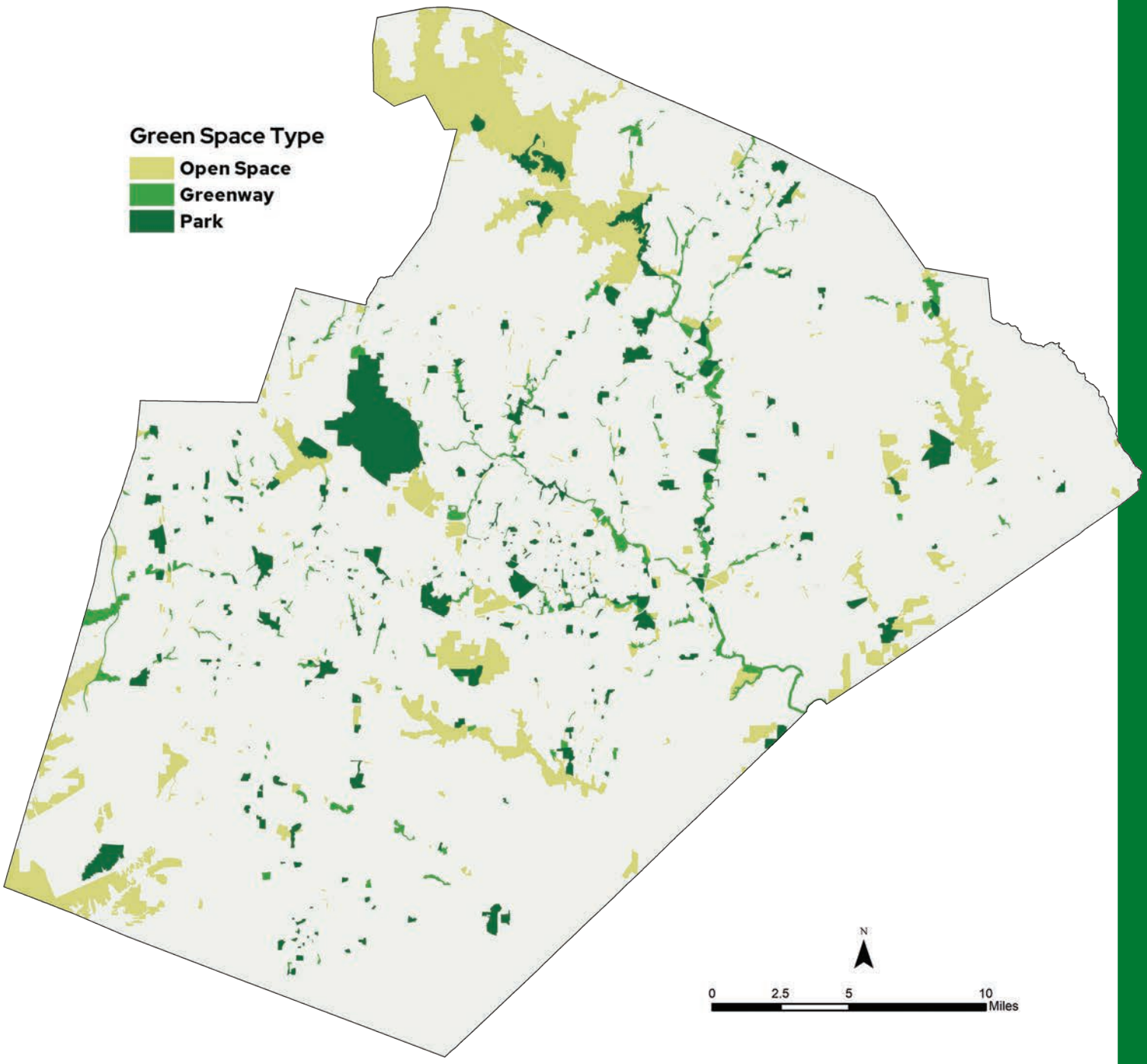
Wake County has 68,759 acres of community green spaces, accounting for 12.54% of the county's total area. More than half of the total countywide devoted to green spaces is managed by Wake County (Table 1.6).

The largest park is William B. Umstead State Park and the largest Open Space is Falls Lake Recreation Area.

TABLE 1.6 LAND COVER BY GREEN SPACE TYPE (2020)

LAND USE	ACRES	TREE CANOPY	IMPERVIOUS	VEGETATION	BARE SOIL	OPEN WATER
Open Space	31,923	64.2%	0.4%	9.3%	1.8%	24.4%
Greenway	2,186	81.3%	0.5%	9.1%	2.8%	6.4%
Park	4,291	85.7%	1.0%	6.8%	1.5%	5.0%
Total	**38,400**	**67.5%**	**0.5%**	**9.0%**	**1.8%**	**21.2%**

MAP 1.7 GREEN SPACES (2022)



Watersheds

Watersheds supply drinking water, habitats for wildlife, soil to grow our food and locations for fishing, boating and swimming. Everyone lives in a watershed. The U.S. Geological Survey has geographically divided the United States into approximately 160,000 individual watersheds with an average size of 40 square miles. Wake County contains portions of 12 individual watersheds (Map 1.8).

Land cover within a watershed will vary according to the area's predominate land use. In general, watersheds characterized by more urbanization tend to have greater amounts of impervious surface and less tree canopy.

Impervious Surface

The amount of pavement and buildings present in a watershed can be an indicator of stream health and overall water quality. As impervious surface coverage increases, stream health tends to decline accordingly.

Tree Canopy

Tree canopy plays an important role in watershed management by intercepting, storing and releasing precipitation in a manner that helps prevent erosion, flooding and pollution. Canopy cover is particularly important in proximity to developed areas to mitigate the impact of impervious surface.

TABLE 1.7 LAND COVER BY WATERSHED (2020)

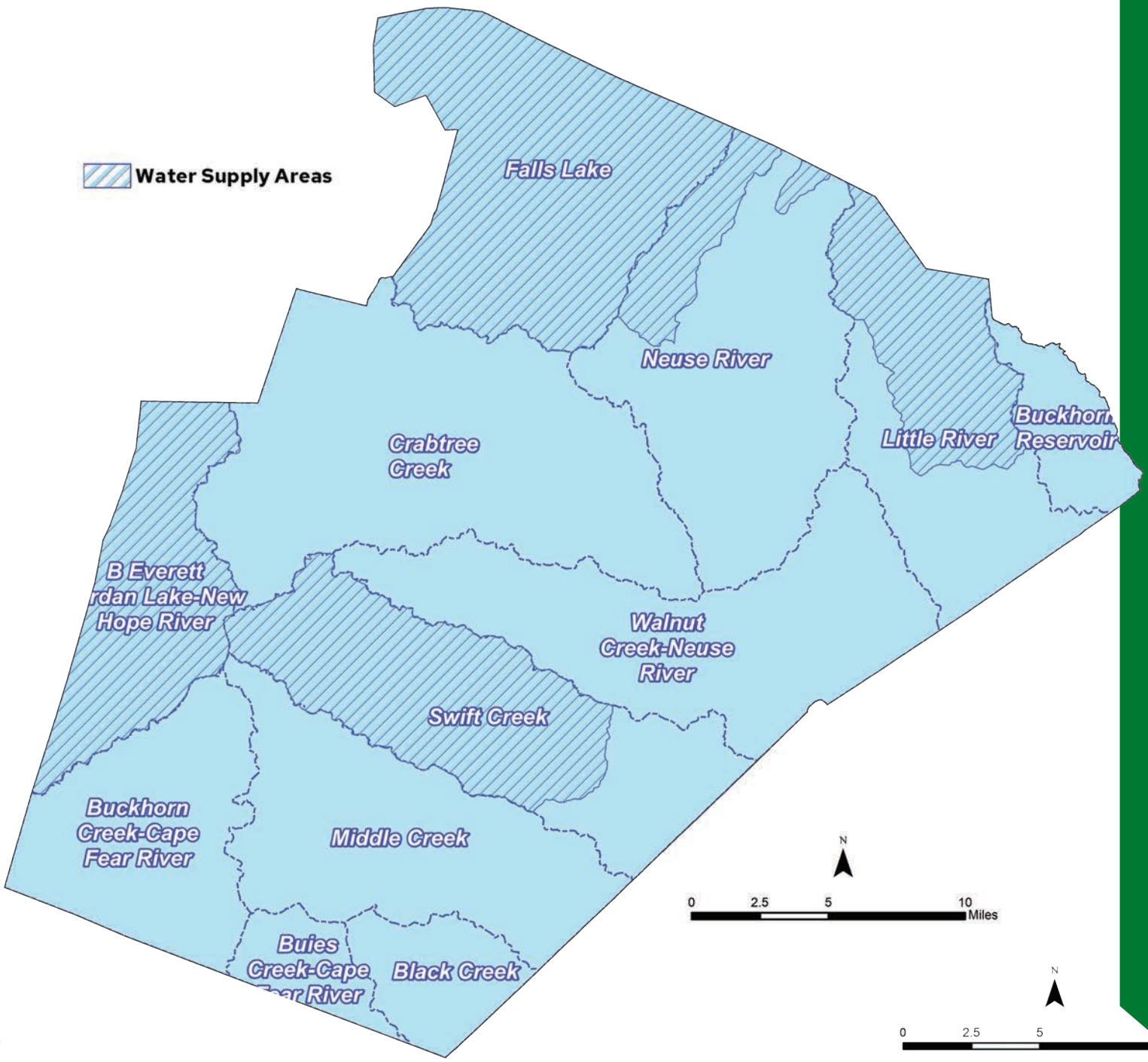
WATERSHED	AREA (ACRES)	TREE CANOPY	IMPERVIOUS	VEGETATION	BARE SOIL	OPEN WATER
Black Creek	14,650	42.3%	8.4%	39.2%	7.6%	2.6%
Buckhorn Creek-Cape Fear River	39,093	62.6%	7.0%	17.4%	4.8%	8.2%
Buckhorn Reservoir	12,853	53.4%	7.6%	26.1%	10.4%	2.5%
Buies Creek-Cape Fear River	9,663	44.2%	14.5%	25.6%	14.1%	1.7%
Crabtree Creek	85,100	50.6%	27.5%	18.3%	1.7%	2.0%
Falls Lake*	64,367	68.3%	6.2%	14.5%	0.9%	10.1%
Jordan Lake*	35,955	50.3%	20.2%	23.2%	4.7%	1.7%
Little River*	49,497	50.4%	5.5%	31.6%	10.2%	2.4%
Middle Creek	50,962	51.1%	13.2%	29.5%	4.5%	1.7%
Neuse River	67,834	50.0%	18.6%	26.2%	3.3%	1.8%
Swift Creek*	58,141	56.5%	15.3%	22.6%	2.5%	3.1%
Walnut Creek -Neuse River	62,014	53.5%	16.5%	24.7%	3.9%	1.4%

*Denotes a Water Supply Watershed (WSWS)

Water Supply Watersheds

Four of Wake's watersheds are classified as a water supply watershed: Falls Lake, Jordan Lake, Little River and Swift Creek. As these lands source drinking water for the county's residents, they merit special consideration when measuring and evaluating the impact of various land cover types on water quality.

MAP 1.8 WATERSHEDS (2022)



Section Two

Canopy Assessment

In This Section:

- Canopy Type
- Canopy Health
- Canopy Benefits
- Canopy Cover
- Canopy Change 2010–2020
- Green Space Focus: Blue Jay Point County Park

Overview

What is a Tree Canopy Assessment?

A Tree Canopy Assessment (TCA) measures and evaluates the amount and extent of tree canopy cover within a particular geographic area of interest.

Why Study Tree Canopy?

Our community forests are integral to the function and well-being of daily life. Trees provide cri tical environmental services and a myriad of socioeconomic benefits that improve and enhance quality of life.

Canopy assessments offer insight into the health, diversity and distribution of tree canopy.

TCAs can determine where residents are benefitting from the presence of trees, the monetary value of those benefits, how benefits change over time and where trees can be planted or preserved to maximize the positive impacts trees make on everyday life while simultaneously mitigating the adverse impacts of the built environment.

While it may not seem like one tree can make a substantial difference, collectively, Wake County's trees play a significant role in supporting and enhancing community livability and resilience.

Canopy Type

Summary

Canopy types are not evenly distributed; deciduous and coniferous forest types prevail in different areas due to historical land use patterns and tree species preferences across a range of environmental factors, including topography, microclimates, soil pH and permeability and other geographical and geological characteristics.

The analysis classified Wake County's tree canopy cover into two distinct forest-type classifications: coniferous or deciduous.

Observations

Wake County's tree canopy is a mix of 70.5% deciduous and 29.5% coniferous.

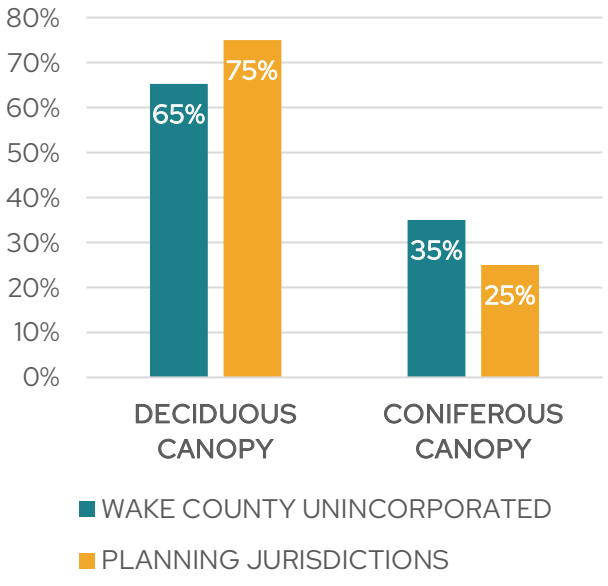
The largest concentrations of coniferous canopy appear to be primarily within or near Non-Urban Areas, including Falls Lake to the north and Harris Lake to the southwest. It is likely many other concentrated areas of coniferous canopy, particularly in the eastern and southeastern portions of the county, are pine stands currently utilized for timber production.

As countywide growth and development continues, it is expected that the amount of coniferous canopy within municipal planning jurisdictions will decline as more former and current timber lands are developed.

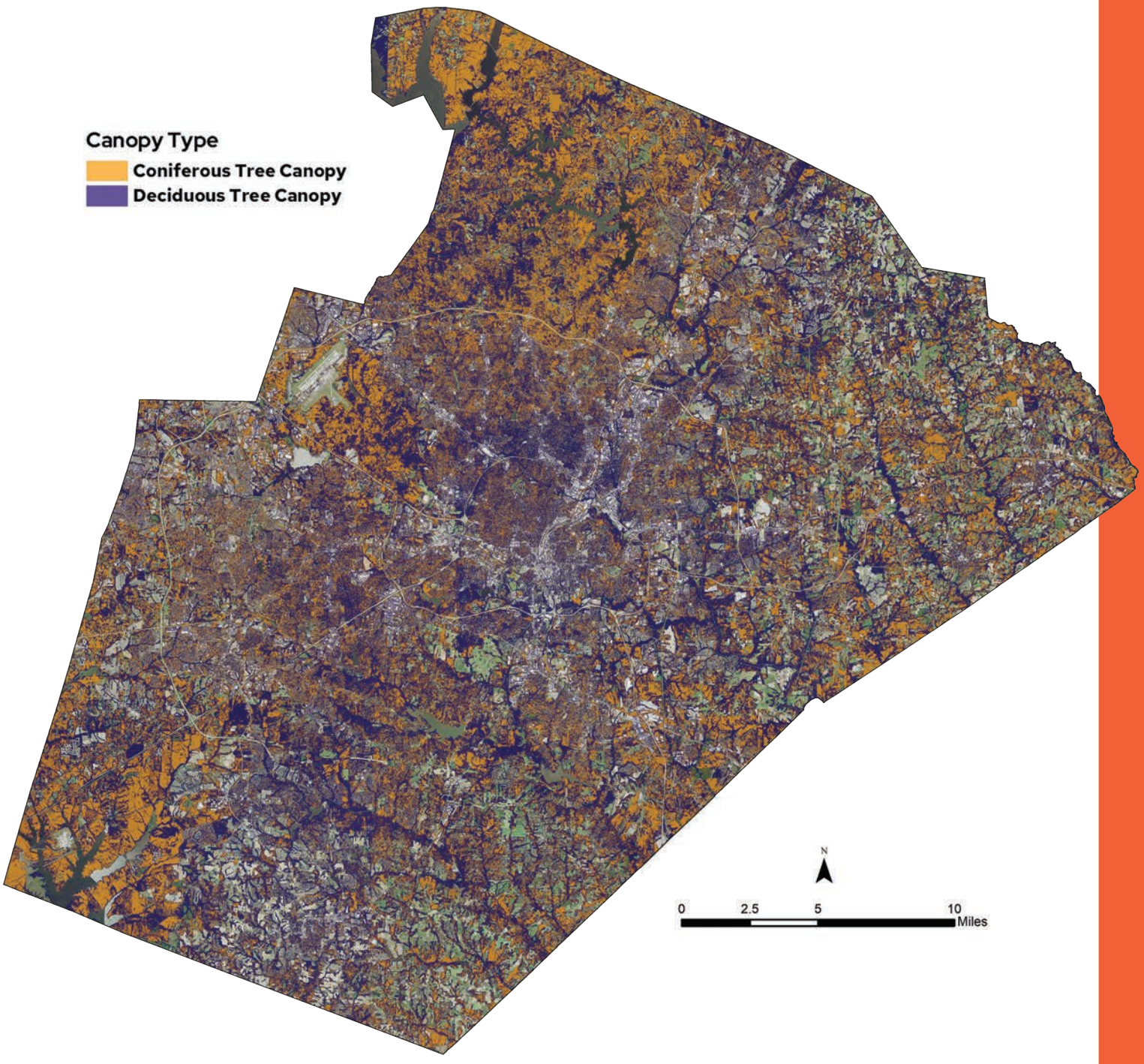
TABLE 2.1 CANOPY TYPE (2020) BY PLANNING JURISDICTION

PLANNING JURISDICTION	CANOPY TYPE	
	DECIDUOUS	CONIFEROUS
Wake County (Unincorporated)	65.2%	34.8%
Apex	73.0%	27.0%
Cary	74.3%	25.7%
Fuquay-Varina	80.7%	19.3%
Garner	68.1%	31.9%
Holly Springs	75.0%	25.0%
Knightdale	74.4%	25.6%
Morrisville	66.4%	33.6%
Raleigh	77.2%	22.8%
Rolesville	78.1%	21.9%
Wake Forest	73.5%	26.5%
Wendell	70.4%	29.6%
Zebulon	69.6%	30.4%
Wake County (Countywide)	**70.5%**	**29.5%**

FIGURE 2.1 CANOPY TYPE IN UNINCORPORATED COUNTY LAND COMPARED TO MUNICIPAL PLANNING JURISDICTION (2020)



MAP 2.1 CANOPY TYPE (2020)



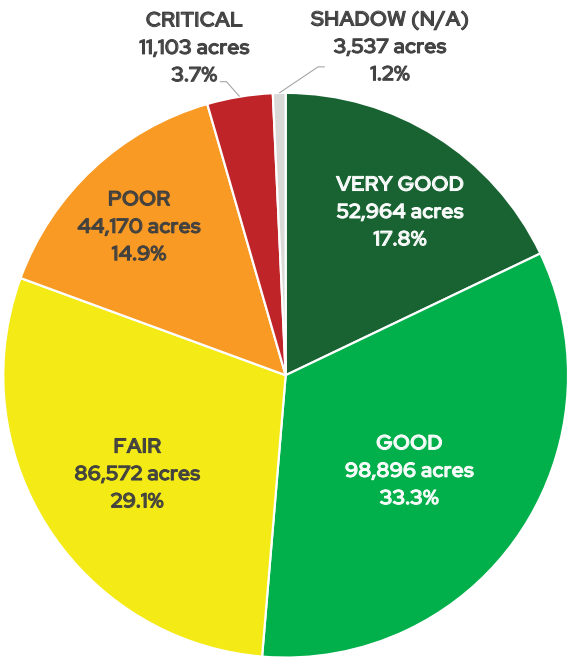
Canopy Health

Summary

A comprehensive canopy assessment provides data on tree health and overall condition. Knowledge of where healthy canopy exists relative to less healthy canopy allows for further investigation of localized "hotspots" (e.g., concentrated areas of canopy in declining health). Targeted ground-truthing to explore areas of piqued interest or potential concern is an efficient and proactive step in maintaining and preserving the community forest (Map 2.2).

Once ground conditions are confirmed, appropriate solutions and action steps can be implemented.

FIGURE 2.2 CANOPY HEALTH (2020)



Observations

The predominant canopy health rating within Wake County is Good, accounting for one-third of Wake County's entire canopy (Figure 2.2, Table 2.2).

Approximately 80% of Wake County's entire canopy is rated to be in Fair or better condition.

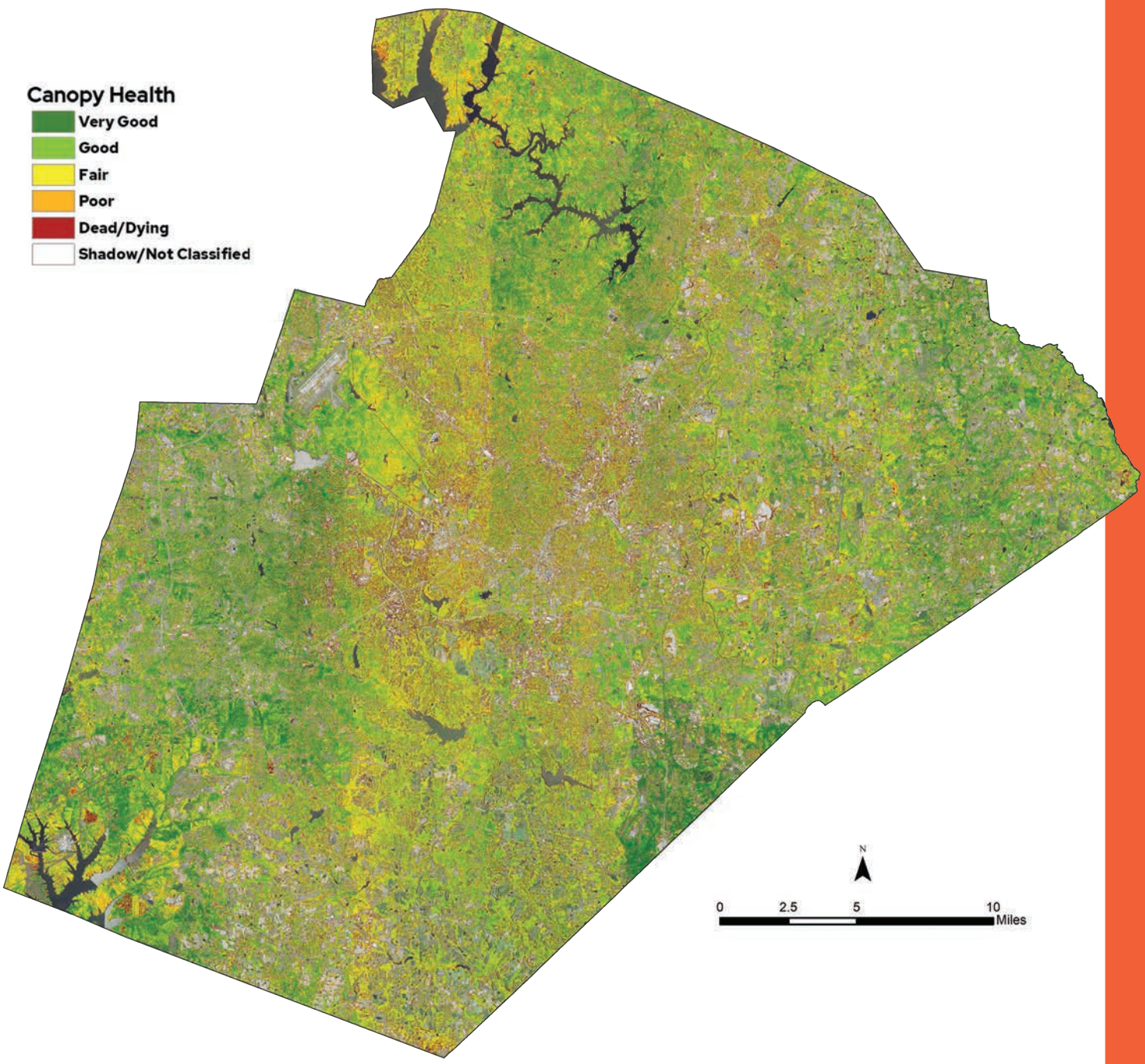
Deciduous forest-types have a greater proportion of trees in Very Good and Good condition (54.3%)than coniferous forest-types (43.4%).

At least 3,500 acres of canopy (1.2% of the total) were unable to be classified, primarily due to shadows on the aerial imagery rendering classification impossible.

TABLE 2.2 CANOPY HEALTH BY CANOPY TYPE (2020)

TREE HEALTH RATING	DECIDUOUS		CONIFEROUS		**TOTAL**	
	ACRES	PERCENT	ACRES	PERCENT	**ACRES**	**PERCENT**
Very Good	42,209	20.1%	10,755	12.4%	**52,964**	**17.8%**
Good	71,933	34.2%	26,963	31.0%	**98,896**	**33.3%**
Fair	53,875	25.6%	32,697	37.6%	**86,572**	**29.1%**
Poor	30,940	14.7%	13,230	15.2%	**44,170**	**14.9%**
Critical	9,297	4.4%	1,806	2.1%	**11,103**	**3.7%**
Shadow (Not Evaluated)	2,003	1.0%	1,534	1.8%	**3,537**	**1.2%**
TOTAL	**210,257**		**86,985**		297,242	

MAP 2.2 CANOPY HEALTH (2020)



Canopy Benefits

Tree canopy positively impacts daily life in ways both seen and unseen. From pollution removal to aesthetic enhancement to habitat provision, the benefits that tree canopy provide to humanity and the built environment are numerous and wide-ranging. Research increasingly demonstrates the crucial role trees play in supporting individual well-being and overall community health and vitality.

The Wake LCA & TCA project took a specific look at a variety of ecosystem services provided by tree canopy. Specifically, i-Tree was utilized to quantify and value the role that trees play in cleaning the air, sequestering carbon and mitigating stormwater runoff (Table 2.3). Details on how i-Tree calculates benefits are provided in the Methodology.

The findings presented below emphasize that the value of tree canopy extends beyond the role of a tree as an aesthetic amenity; the natural, biological functions of trees provide critical infrastructure.

Total Value

Collectively, Wake County's tree canopy has a $3.2 billion valuation. The total value is a combination of structural value and the annual value of the ecosystem service benefits that trees provide.

Structural Value of $1,742,099,038

Trees are carbon sinks. Over their lifespan, Wake County's trees are estimated to have collectively removed and stored more than 10.2 million tons of carbon from the atmosphere. This removal and storage service capacity has an estimated value greater than $1.7 billion.

Annual Benefit Value of $1,458,859,441

Wake County's trees provide annual benefits totaling more than $1.4 billion in air pollution removal, carbon sequestration and stormwater capture.

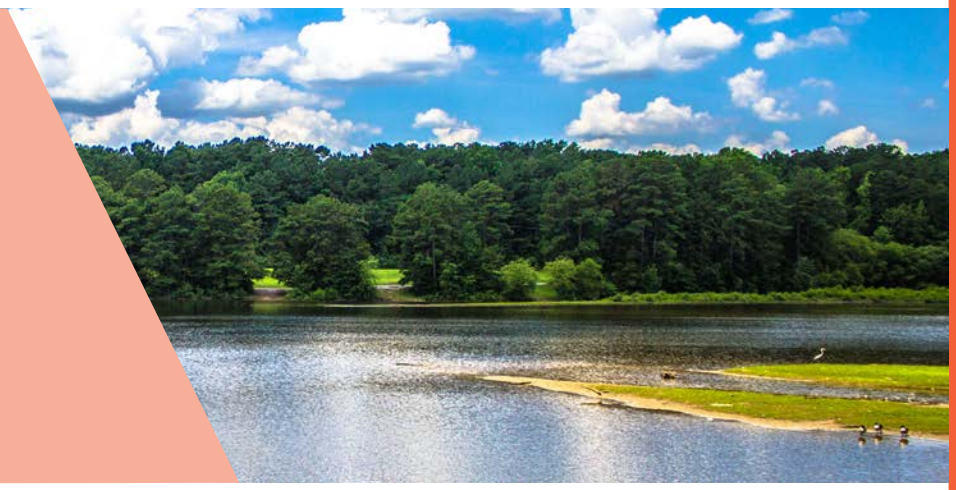
WAKE COUNTY'S TREE CANOPY HAS A $3.2 BILLION VALUATION

Annual Ecosystem Service Benefits

Air Quality Improvement

Wake County's trees collectively remove 11,022 tons of pollutants from the air each year. This includes 208 tons of carbon monoxide (CO), 824 tons of nitrogen dioxide (NO_2), 8,033 tons of ozone (O_3), 258 tons of sulfur dioxide (SO_2) and 1,699 tons of dust, soot and other particulate matter (PM_{10}).

WAKE COUNTY'S CANOPY CAPTURES OVER 8.1 BILLION GALLONS OF STORMWATER PER YEAR!



Water Quality Improvement

Trees improve water quality by intercepting rainwater, reducing soil erosion and filtering pollutants. Wake County's tree canopy captures over 8.1 billion gallons of stormwater per year – equivalent to the amount of water in 12,300 Olympic-size swimming pools!

Carbon Sequestration

Trees sequester (i.e., absorb) carbon and store it in their trunks, branches, leaves and roots. Each year, Wake's trees sequester approximately 414,710 tons of carbon dioxide (CO_2) from the atmosphere.

TABLE 2.3 ANNUAL BENEFITS AND STRUCTURAL VALUE OF WAKE'S TREE CANOPY (2020)

PLANNING JURISIDICTION	ANNUAL TREE BENEFITS									
	AIR POLLUTION REMOVAL									
	CO		NO_2		O_3		SO_2		PM_{10}	
	TON	$	TON	$	TON	$	TON	$	TON	$
Wake County Unincorporated	92	$83,222	366	$62,710	3,564	$2,005,811	115	$5,075	754	$2,545,762
Apex	9	$7,680	34	$5,787	329	$185,114	11	$468	70	$234,945
Cary	15	$13,599	60	$10,247	582	$327,770	19	$829	123	$416,004
Fuquay-Varina	9	$8,326	37	$6,274	357	$200,678	11	$508	75	$254,699
Garner	10	$8,965	39	$6,755	384	$216,079	12	$547	81	$274,247
Holly Springs	8	$7,058	31	$5,319	302	$170,122	10	$430	64	$215,918
Knightdale	6	$5,310	23	$4,001	227	$127,989	7	$324	48	$162,443
Morrisville	1	$1,338	6	$1,008	57	$32,254	2	$82	12	$40,936
Raleigh	41	$36,944	162	$27,838	1,582	$890,421	51	$2,253	335	$1,130,117
Rolesville	3	$2,655	12	$2,000	114	$63,981	4	$162	24	$81,204
Wake Forest	5	$4,155	18	$3,131	178	$100,146	6	$253	38	$127,104
Wendell	4	$3,185	14	$2,400	136	$76,756	4	$194	29	$97,418
Zebulon	3	$2,766	12	$2,084	118	$66,666	4	$169	25	$84,612
Wake County Total	**208**	**$187,544**	**824**	**$141,318**	**8,033**	**$4,520,158**	**258**	**$11,436**	**1,699**	**$5,736,954**

ANNUAL TREE BENEFITS					STRUCTURAL VALUE	
CARBON (CO_2) SEQUESTRATION		STORMWATER CAPTURE		TOTAL ANNUAL BENEFITS	CARBON STORAGE	
TON	$	GALLON	$	$	TON	$
184,027	$31,385,627	3,595,751,484	$611,277,752	$647,365,959	4,532,686	$773,052,964
10,062	$1,716,128	196,611,345	$33,423,929	$35,574,053	418,316	$71,344,176
25,141	$4,287,791	491,238,625	$83,510,566	$88,566,807	740,688	$126,324,906
6,054	$1,032,480	118,287,918	$20,108,946	$21,611,912	453,488	$77,342,729
7,663	$1,306,892	149,726,422	$25,453,492	$27,266,977	488,291	$83,278,463
7,700	$1,313,241	150,453,894	$25,577,162	$27,289,251	384,439	$65,566,308
3,358	$572,633	65,604,707	$11,152,800	$12,025,501	289,227	$49,327,952
2,478	$422,649	48,421,544	$8,231,662	$8,729,929	72,886	$12,430,760
64,131	$10,937,485	1,253,072,917	$213,022,396	$226,047,454	2,012,154	$343,174,282
1,980	$337,657	38,684,232	$6,576,319	$7,063,977	144,582	$24,658,529
7,142	$1,218,144	139,558,862	$23,725,007	$25,177,941	226,307	$38,596,896
2,928	$499,339	57,207,654	$9,725,301	$10,404,593	173,452	$29,582,287
2,193	$374,079	42,857,082	$7,285,704	$7,816,079	150,649	$25,693,359
414,710	**$70,728,493**	**8,103,138,458**	**$1,377,533,538**	**$1,458,859,441**	**10,214,550**	**$1,742,099,038**

Canopy Cover

Summary

Map 2.3 and Map 2.4 focus on tree canopy at the Block Group (BG) level. As the smallest unit of analysis in the study, mapping at the BG level offers an illustration of the distribution of canopy percent and canopy change within the planning jurisdiction.

Vintage 2020

It is important to keep in mind that this analysis is a snapshot of conditions existing in 2020 and may not be representative of the current canopy percent within a given block group or other geographic area.

Canopy Cover by Block Group

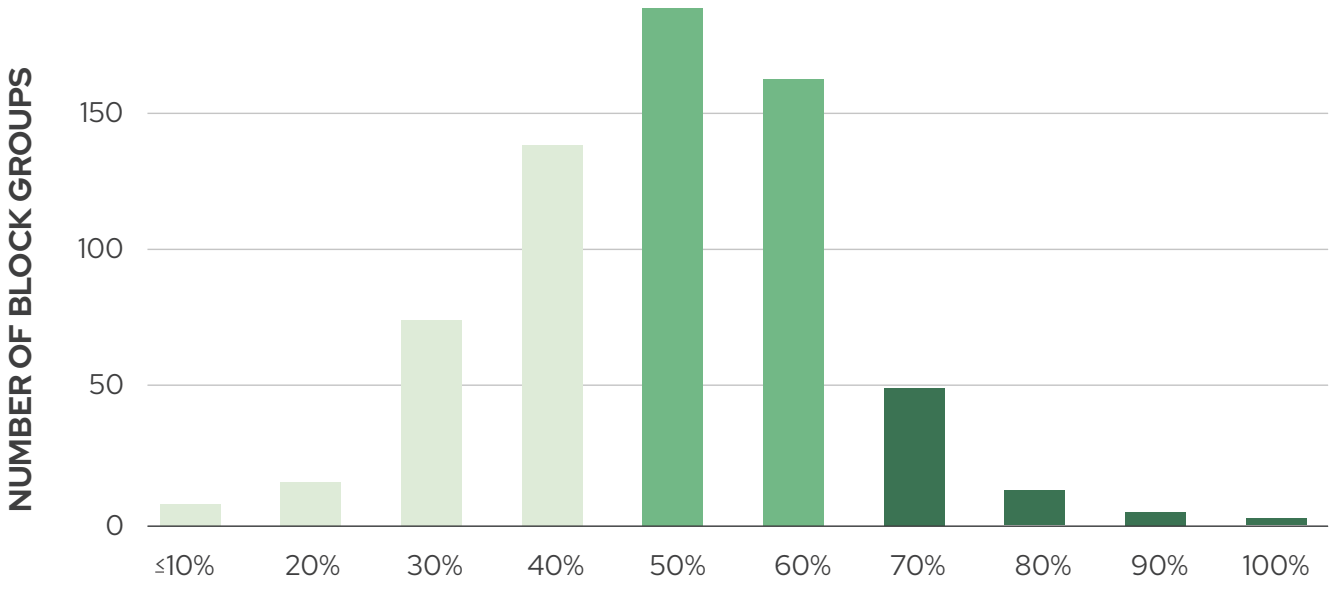
Canopy coverage among BGs varied widely, from 7% to 100%, with a median average coverage of approximately 50%.

Areas with the greatest amount of canopy coincide with the county's larger recreational and natural areas, such as Falls Lake in the northeast, Umstead Park in the central-west and Harris Lake in southwestern Wake.

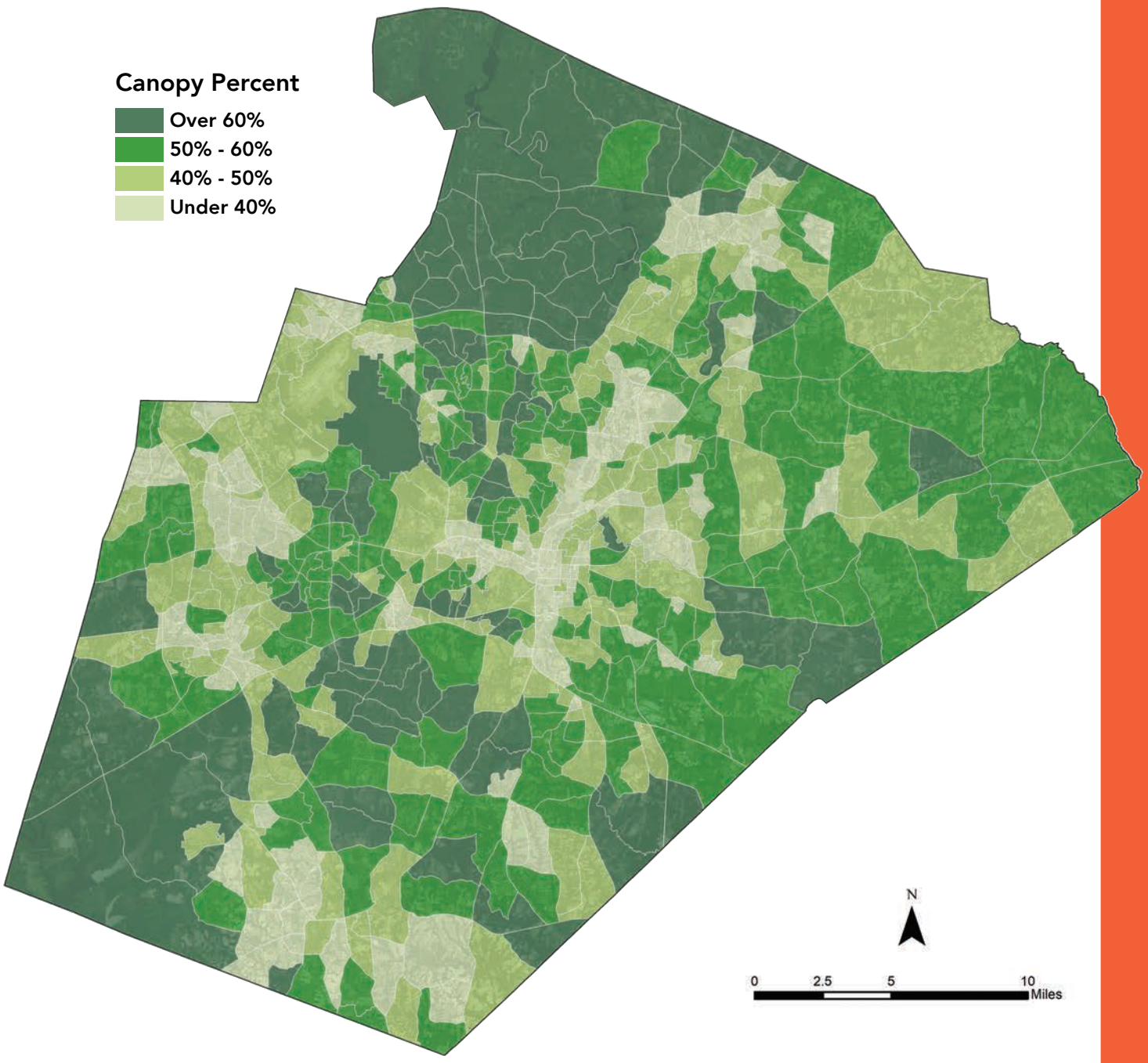
Concentrations of BGs with the least amount of canopy cover are found in the center of the county, which corresponds with more heavily urbanized land area along a major road corridor (U.S. Highway 1).

Map 2.3 visually demonstrates the correlation between population density and canopy cover. The physical size of the BG is directly related to population; the smaller the BG the more dense the resident population.

FIGURE 2.3 DISTRIBUTION OF CANOPY COVER (2020) BY BLOCK GROUP



MAP 2.3 CANOPY COVER (2020) BY BLOCK GROUP



Canopy Change 2010–2020

Summary

The Wake LCA/TCA project examined how tree canopy, changed over the 10-year span from 2010 to 2020. The analysis utilized 2010 NAIP imagery to determine the the historical baseline metrics for comparison.

Observations

From 2010–2020, the amount of tree canopy cover in Wake County declined by 11,122 acres, representing a 3.6% decrease in total amount of canopy and a 2% decline in canopy cover relative to overall land cover.

Vintage 2010 and 2020

It is important to keep in mind that this analysis is a snapshot of conditions existing in 2010 and 2020 and may not be representative of the current canopy percent within a given block group or other geographic area.

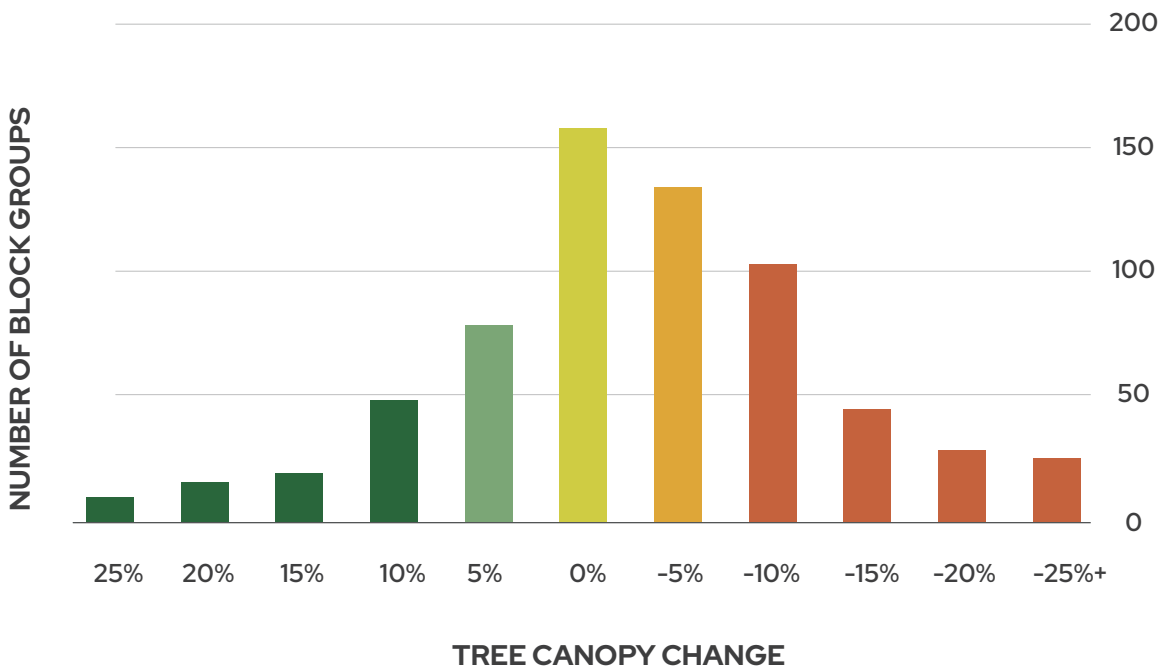
Canopy Change by Block Group

In the study period from 2010–2020, tree canopy cover among Wake County's block groups declined by an average rate of 3% per annum (Figure 2.4, Map 2.4).

Geographic areas exhibiting concentrations of canopy loss greater than 10% are found in the western portion of the county, which is within the Jordan Lake watershed.

Additional concentrations of BGs reporting canopy loss are seen in the heart of the county, Raleigh and areas of recent growth and development to the northeast and southeast of the city.

FIGURE 2.4.DISTRIBUTION OF CANOPY CHANGE (2010-2020) BY BLOCK GROUP



MAP 2.4 CANOPY CHANGE (2010-2020) BY BLOCK GROUP

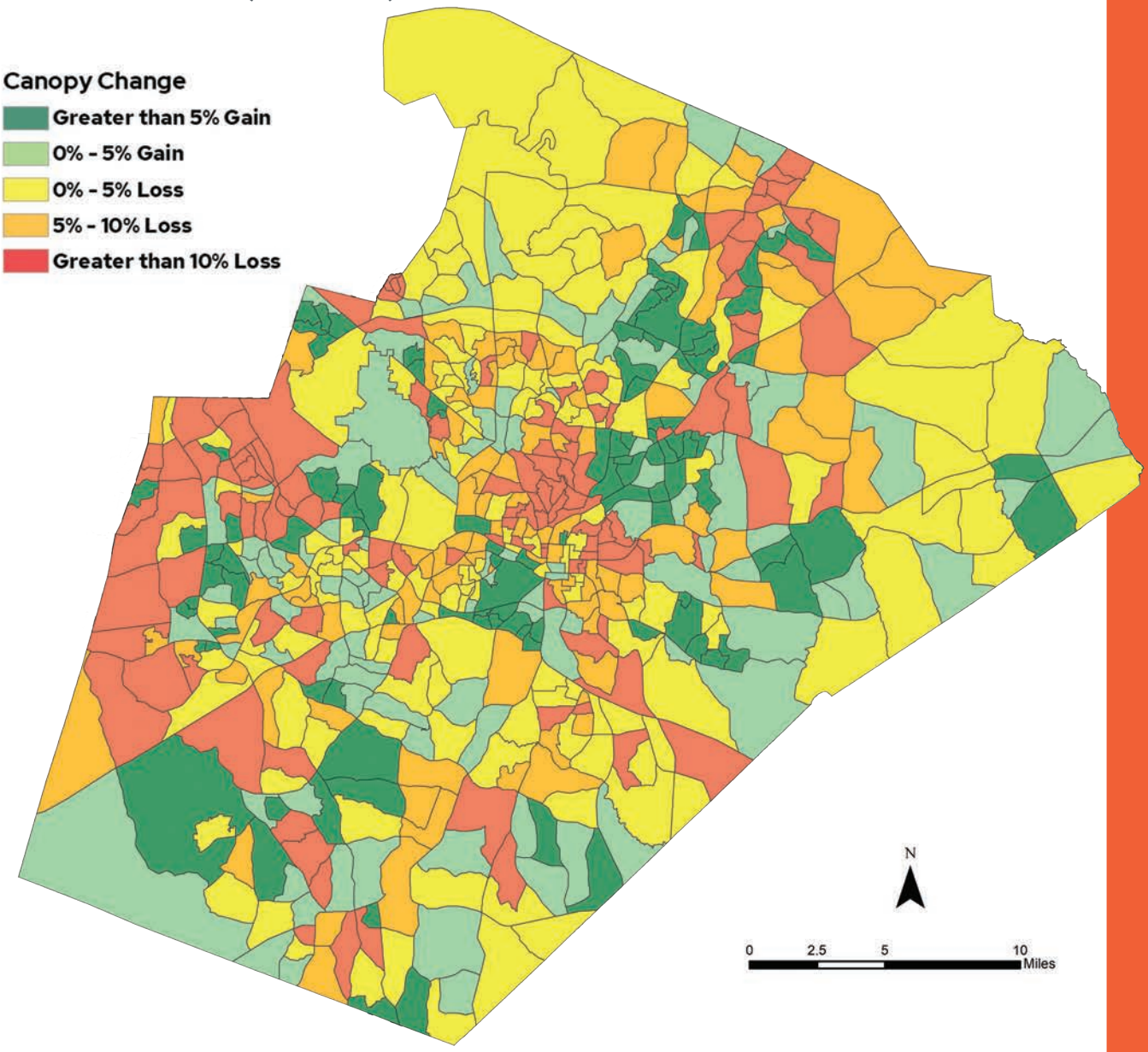


TABLE 2.4 CANOPY CHANGE (2010-2020)

JURISDICTION	CANOPY ACRES 2020	CANOPY PERCENT 2020	CANOPY ACRES 2010	CANOPY PERCENT 2010	CANOPY CHANGE (ACRES)	CANOPY CHANGE (RELATIVE)	CANOPY CHANGE (ABSOLUTE)
Wake Unincorporated	68,906	63.2%	70,597	64.7%	-1,691	-2.4%	-1.6%
Wake County	297,242	54.2%	308,364	56.2%	-11,122	-3.6%	-2.0%

Canopy Change by Watershed

Tree canopy is an important component of watershed management by regulating the water balance of the landscape. It does this by intercepting, storing and releasing precipitation in a manner that prevents erosion and flooding. This is particularly useful in developed areas where storm damage can become an issue. It also reduces pollution dissolved in storm runoff from infiltrating soil or water reservoirs. This enhances the water quality of aquatic regions in Wake County.

Observations

Tree canopy cover ranges from 32%–77% among Wake County's 12 watersheds, with an average of 55%.

Vintage 2010 and 2020

It is important to keep in mind that this analysis is a snapshot of conditions existing in 2010 and 2020 and may not be representative of the current canopy percent within a given watershed.

Water Supply Watersheds

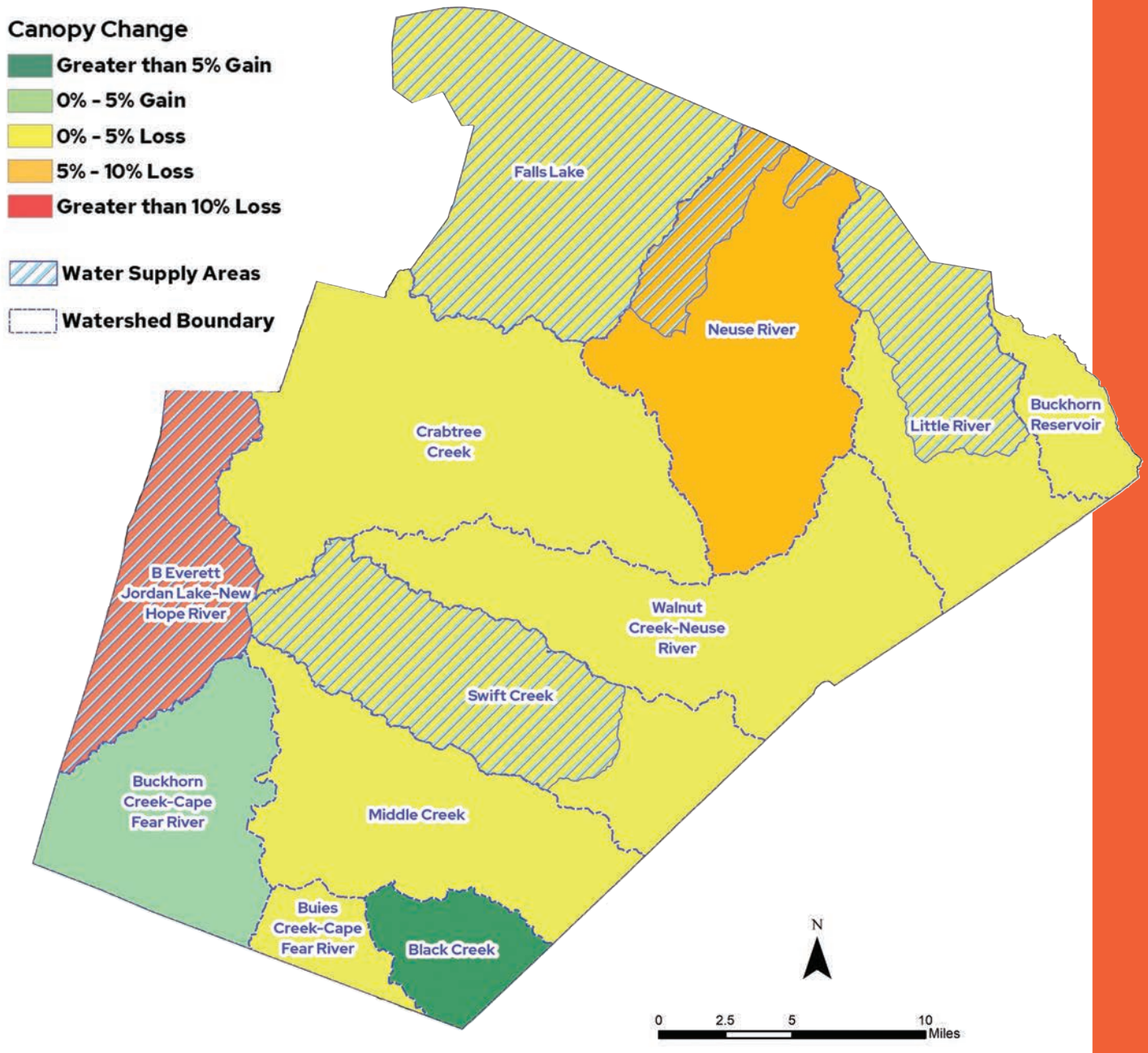
With the most canopy loss occurring within the Jordan Lake watershed in western Wake County. Over the period of study, the Jordan Lake watershed lost 3,312 acres of tree canopy.

TABLE 2.5 WATERSHEDS: CANOPY CHANGE (2010-2020)

WATERSHED	CANOPY PERCENT 2020	CANOPY PERCENT 2010	CHANGE 2010-2020 (ACRES)	CANOPY CHANGE 2010-2020 (RELATIVE)	CANOPY CHANGE 2010-2020 (ABSOLUTE)
Black Creek	42.3%	42.8%	-84	-1.3%	-0.6%
Buckhorn Creek-Cape Fear River	62.6%	62.2%	155	0.6%	0.4%
Buckhorn Reservoir	53.4%	54.4%	-123	-1.8%	-1.0%
Buies Creek-Cape Fear River	44.2%	46.0%	-174	-3.9%	-1.8%
Crabtree Creek	50.6%	53.0%	-2,052	-4.5%	-2.4%
Falls Lake*	68.3%	69.7%	-916	-2.1%	-1.4%
Jordan Lake*	50.3%	59.6%	-3,312	-15.5%	-9.2%
Little River*	50.4%	51.3%	-450	-1.8%	-0.9%
Middle Creek	51.1%	52.4%	-675	-2.5%	-1.3%
Neuse River	50.0%	53.1%	-2,055	-5.7%	-3.0%
Swift Creek*	56.5%	58.9%	-1,393	-4.1%	-2.4%
Walnut Creek-Neuse River	53.5%	54.3%	-491	-1.5%	-0.8%

*denotes a Water Supply Watershed

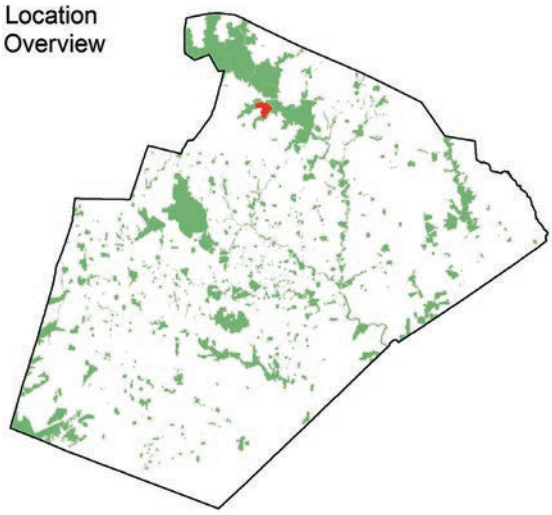
MAP 2.5 CANOPY CHANGE (2010-2020) BY WATERSHED



Green Space Focus: Blue Jay Point County Park

Land cover analysis is useful at the micro level (e.g., individual parks or parcels) as well as the macro (e.g., countywide). Canopy type and health mapping can be utilized to identify and investigate potential areas of concern or to help select locations for future park amenities.

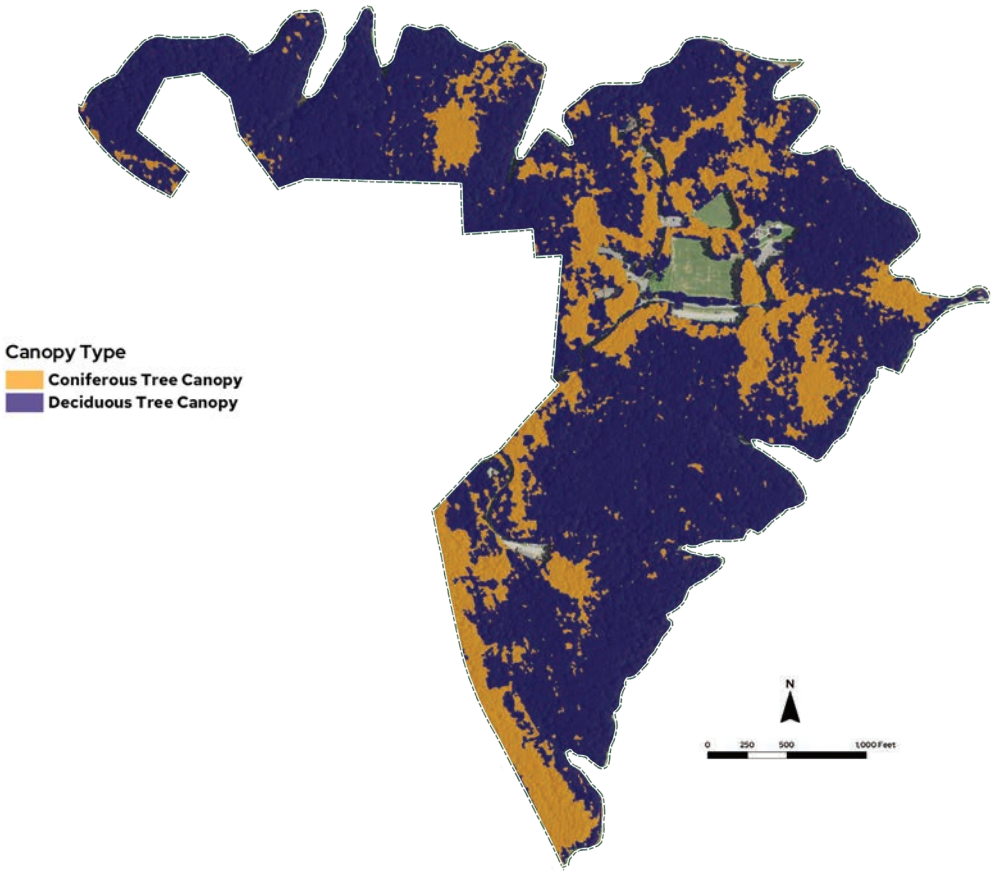
Targeted ground-truthing of "hotspots" (concentrated areas of canopy in declining health) is an efficient and proactive step in maintaining and preserving community forest. Hotspots in and around high-occupancy public areas, such as greenways, are of particular interest when prioritizing field-checks.



Park Overview

Blue Jay Point County Park is situated on the shore of Falls Lake in northern Wake County. Opened in 1992, the park was named after the peninsula – or point – it forms on Falls Lake and for the many blue jays that lived there when the area was farmed by tenant farmers. The wooded, 236-acre park features fishing, picnic areas, playgrounds and five miles of trails, including the popular Falls Lake Trail, which is part of the renowned statewide Mountains-to-Sea trail.

MAP 2.6 CANOPY TYPE: BLUE JAY POINT (2020)



Canopy Cover

Almost the entirety of Blue Jay Point (93.7%) is covered by tree canopy.

Canopy Type

The park contains 225 canopy acres, of which 76.3% is deciduous and 23.7% is coniferous.

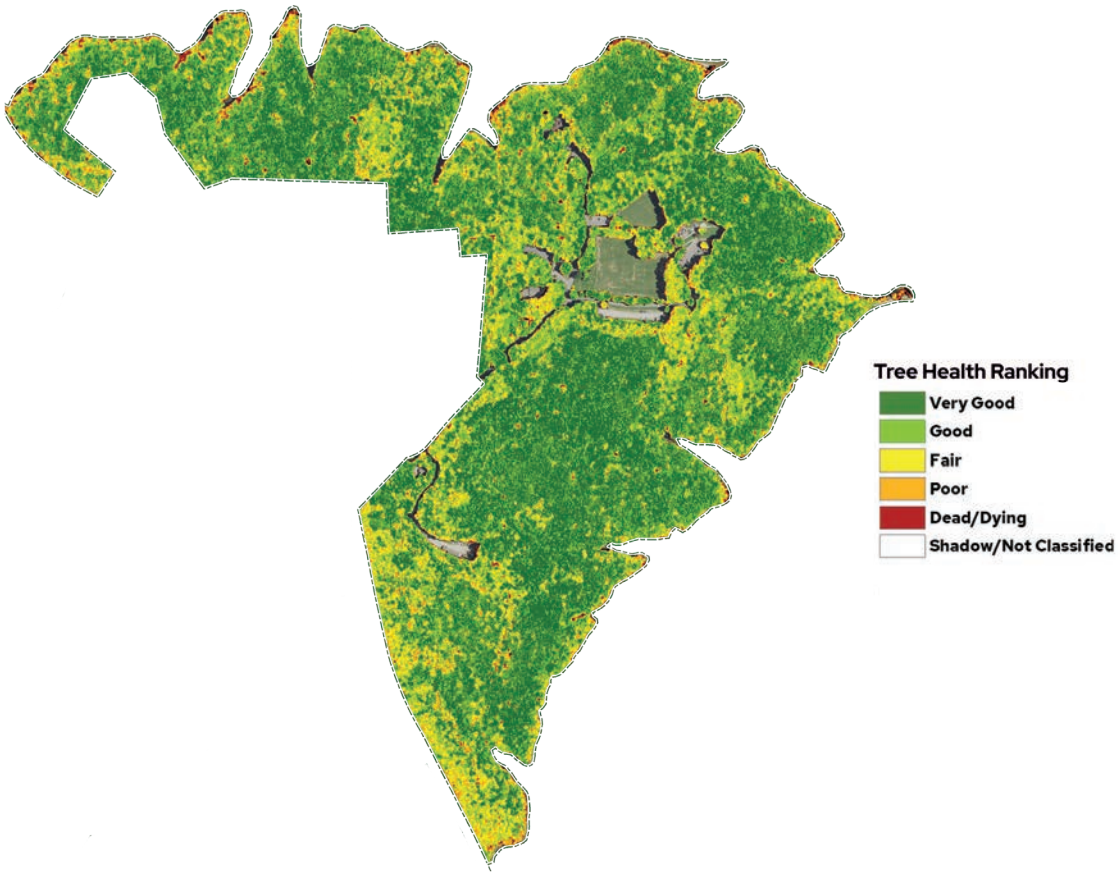
Canopy Health

The majority of Blue Jay Point tree canopy is assessed to be in Very Good or Good condition.

TABLE 2.6 BLUE JAY POINT: CANOPY TYPE, COVER AND HEALTH (2020)

CANOPY TYPE	CANOPY COVER		CANOPY HEALTH					
	ACRES	PERCENT	VERY GOOD	GOOD	FAIR	POOR	CRITICAL	SHADOW
DECIDUOUS	171.6	76.3%	42.8%	37.7%	13.3%	4.4%	1.3%	0.5%
CONIFEROUS	53.4	23.7%	25.0%	39.5%	30.9%	4.0%	0.5%	0.1%
TOTAL	**225.0**	**93.8%**	**38.8%**	**38.1%**	**17.3%**	**4.3%**	**1.1%**	**0.4%**

MAP 2.7 CANOPY HEALTH: BLUE JAY POINT (2020)



Section Three

Planting Opportunities

In This Section:

- Where Should Trees be Planted?
- Identifying Planting Areas
- Assessing Vulnerability
- Prioritizing Planting Areas
- Tree Placement Modeling

Where Should Trees be Planted?

Land cover analysis helps identify opportunities to plant new trees and expand canopy cover to increase and more evenly distribute the benefits of trees. While vacant planting sites present opportunities to plant trees, not all open spaces are candidates for tree planting – examples include roads, sport and recreation areas and agricultural fields.

Ultimately, trees should be planted in sensible and suitable locations, after a thorough assessment of the site and desired outcomes for the planting.

The planting area priority assessment sought to identify possible planting areas, eliminate those areas most likely to be unfit for planting trees and then prioritize the remaining areas based on optimizing community benefits derived from tree canopy.

The assessment identified and prioritized tree planting locations throughout the entirety of Wake County.

Step 1. Identify realistic Potential Planting Area

- The results from the land cover analysis are used to identify possible planting areas.
- The possible planting areas are then refined by filtering through an exclusionary layer of "no planting" areas.
- The result is a GIS polygon layer of realistic Potential Planting Area (PPA).

Step 2. Perform vulnerability assessments.

- The PPA is individually assessed across three separate measures of community vulnerability: urban heat islands, stormwater and social equity.
- The three individual measures are combined into a single composite vulnerability index.

Step 3. Prioritize the PPA

- The PPA is prioritized by the vulnerability index and assigned a priority rank on a five-category ordinal scale (Very High, High, Medium, Low, Very Low).
- The priority rank for each PPA corresponds to the contribution of tree canopy in mitigating the identified vulnerabilities.

Identifying Planting Areas

Summary

The identification of realistic possible planting locations follows from the land cover analysis. First, the Bare Soil and Vegetation land cover types are combined into a single dataset. Then, the dataset is refined by excluding areas which do not meet the minimum PPA size threshold or are otherwise deemed not suitable for planting trees (see below). The minimum size for a PPA within a municipal planning jurisdiction is 200 square feet, which is approximately the size of a standard parking lot island. The minimum PPA size within unincorporated county land area is one acre.

The possible planting locations remaining after filtration and refinement are the Potential Planting Area. The analysis identified 404,879 individual PPA distributed across 82,460 acres of available planting area.

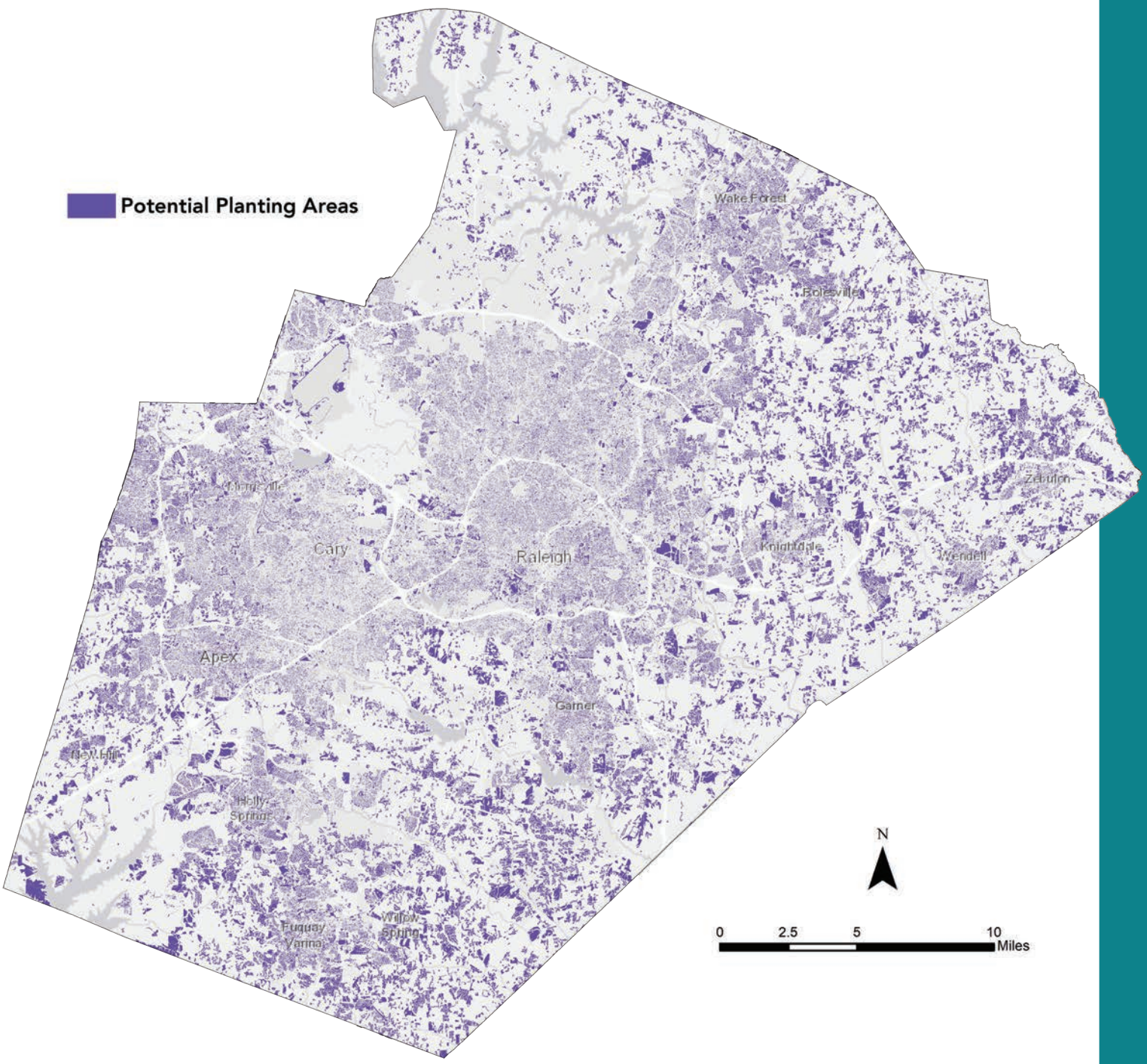
Vintage 2020

It is important to note that the analysis reflects planting areas as they were in 2020. Given the pace of development within Wake County, some of the identified planting areas may no longer be suitable. For example, a tract of land under development in 2020 may have been classified as Bare Soil and included as a PPA.

"No-Planting" Areas

- Sports fields (soccer, football, baseball, softball, etc.)
- Playgrounds
- Major utility corridors
- Golf courses
- Airports
- Wetland areas
- Substations
- Visible cropland
- Water treatment facilities
- Major Utility Easements
- Access Easements
- Parcels with agriculture, horticulture, or water/sewer system as current land use
- Rights-of-Way

MAP 3.1 POTENTIAL PLANTING AREA (2020)



Assessing Vulnerability

What is Vulnerability?

Vulnerability refers to the degree to which a system, community, or individual is susceptible to harm, damage, or negative impacts from an identified hazard. Vulnerability is influenced by various factors, such as socioeconomic status, physical and environmental conditions and access to resources and services.

Assessing Vulnerability

A vulnerability assessment is a process of identifying, analyzing and evaluating the vulnerabilities and risks of a system, community, or organization to potential hazards. The assessment informs decision-making and helps prioritize actions to reduce vulnerabilities and enhance resilience.

The Wake LCA/TCA project individually assessed three distinct measures of community vulnerability: urban heat islands, stormwater and social equity.

Urban Heat Islands

The Urban Heat Island (UHI) effect refers to the phenomenon of urban areas being significantly warmer than surrounding rural areas. The sun heats impervious surfaces faster and to a higher temperature than land covered by tree canopy or vegetation. Impervious surface also takes longer to cool once the sun sets.

Areas with less tree canopy and more impervious surface are more susceptible to the UHI effect, and residents within those areas are at greater risk of harm from the adverse impacts of the phenomenon.

Community Impacts

- **Health risks:** Extreme heat increases the risk of heat-related illnesses, such as heat exhaustion and heat-stroke, particularly for vulnerable populations such as the elderly, young children and those with pre-existing health conditions.
- **Reduced air quality:** The UHI effect worsens air quality by increasing the concentration of air pollutants, such as ozone and particulate matter, which exacerbates respiratory diseases such as asthma.
- **Increased energy consumption**: The demand for cooling can increase energy consumption, which can lead to higher greenhouse gas emissions.
- **Infrastructure damage:** High temperatures can cause damage to infrastructure, particularly roads and buildings, due to thermal expansion and contraction.

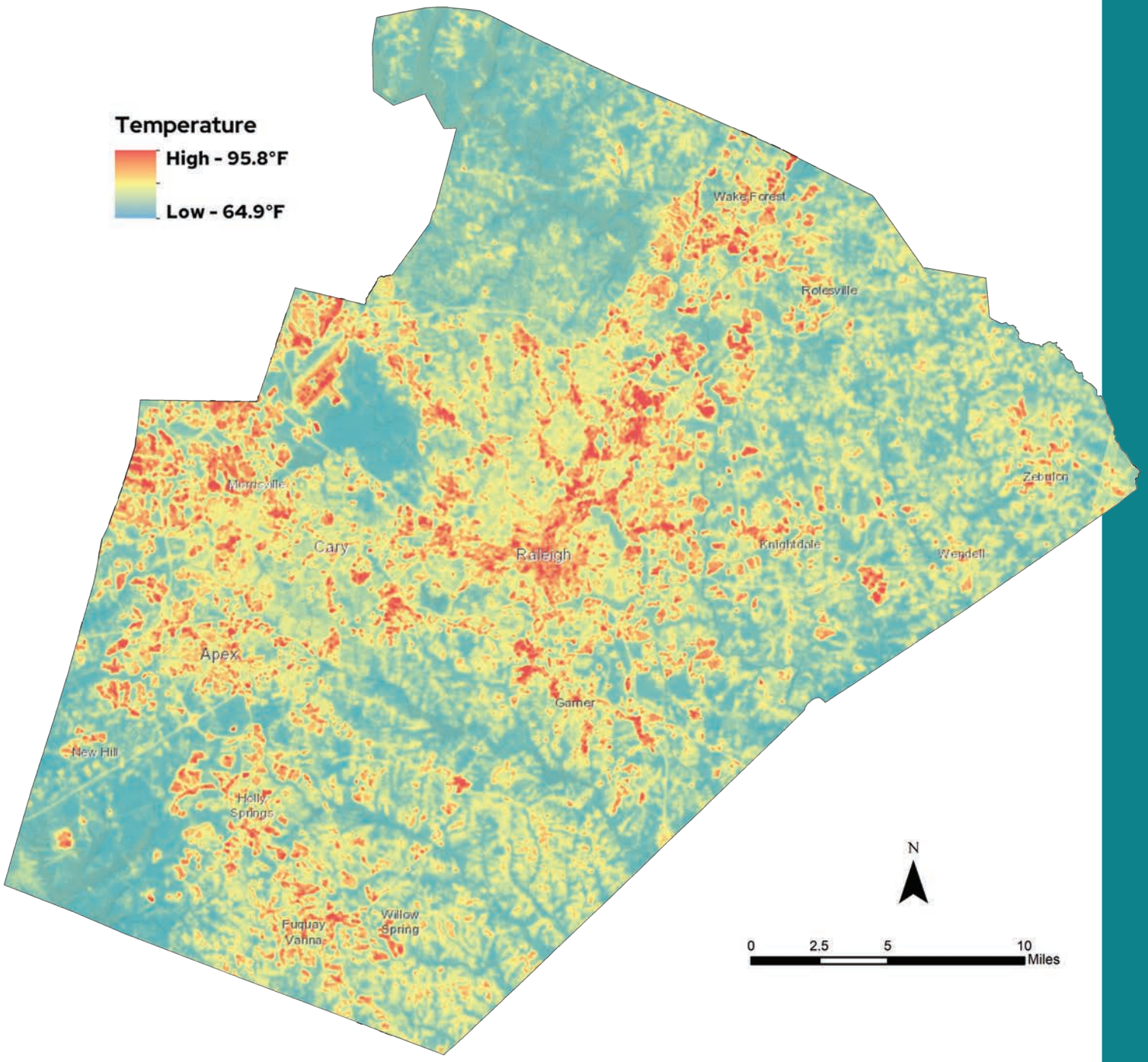
Measurement

A land surface temperature analysis identified UHIs throughout the county (Map 3.2).

Observations

The analysis visually demonstrates the UHI effect; the hottest areas align with areas of less canopy and more impervious surface. The map further shows that cooler areas are associated with areas of greater canopy coverage, many of which are located within the ETJ.

MAP 3.2 AVERAGE LAND SURFACE TEMPERATURE (2020-2022)



Stormwater

Rain that does not soak into the ground becomes runoff and carries soil, pollutants and other materials from the land into our rivers, lakes and bays. Areas with greater amounts of impervious surface relative to tree canopy generally have more pollution and less tree canopy.

The assessment identifies areas in greatest need of tree canopy to mitigate the impacts and consequences of stormwater runoff.

Community Impacts

- **Pollution:** Stormwater runoff can carry pollutants such as oil, pesticides and fertilizers into rivers, lakes and oceans. This harms aquatic life and can make water unsafe for human use.
- **Soil erosion:** Runoff can lead to streambank and shoreline instability, loss of habitat and decreased water quality.
- **Public health:** Runoff can carry bacteria and other pathogens from animal waste, septic systems and other sources, leading to water supply contamination.
- **Flooding and infrastructure damage:** Stormwater can cause damage to roads, bridges and other infrastructure, leading to costly repairs and maintenance.

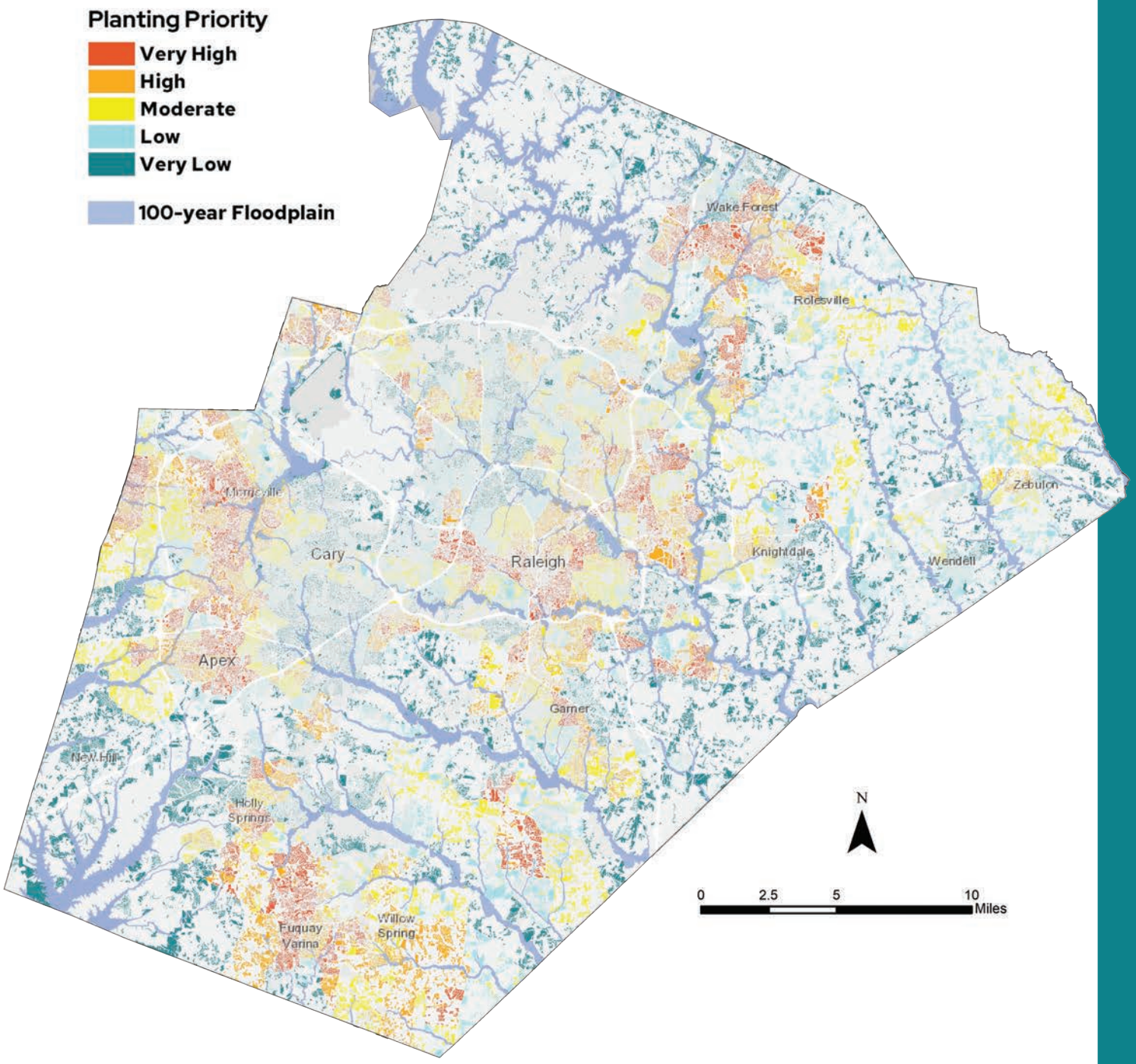
Measurement

Community vulnerability to the impacts of stormwater were measured by a multivariate analysis which included the following variables: distance to hardscape, soil erosion, soil permeability, floodplain proximity, existing tree canopy and possible tree canopy.

Observations

PPA are distributed throughout the county; however, Very High and High priority PPA generally fall within municipal corporate limits (Map 3.3). These areas are often the most urbanized and coincide with high population density and relatively high proportions of impervious surface, as compared to the bulk of the Low and Very Low PPA.

MAP 3.3 POTENTIAL PLANTING AREA (2020) PRIORITIZED BY THE STORMWATER VULNERABILITY INDEX



Social Equity

Social equity refers to the concept of fairness and justice in the distribution of resources and opportunities in a society, particularly as it relates to historically marginalized and disadvantaged groups. It recognizes that not all individuals or communities have equal access to the resources, opportunities and benefits that society has to offer and seeks to address these disparities through policy and practice.

The assessment identifies areas where tree canopy can be expanded to maximize benefits that will have the most impact on human health, economics and wellbeing.

Community Impacts

- **Health Risks:** People in socially disadvantaged communities are more likely to experience poor health outcomes, including chronic diseases, mental health issues and shorter life expectancies.
- **Economic Disadvantages:** Social inequity can limit access to education and job opportunities, which contributes to persistent poverty and income inequality.
- **Political Disengagement:** People in socially disadvantaged communities are less likely to participate in political processes and civic engagement, leading to reduced representation and less investment, both public and private, in these communities.
- **Environmental Injustice:** Social inequity leads to disproportionate impact from environmental hazards (e.g., pollution) and other forms of environmental degradation (e.g., development characterized by high population density and relatively high and low amounts of impervious surfaces and tree canopy, respectively).

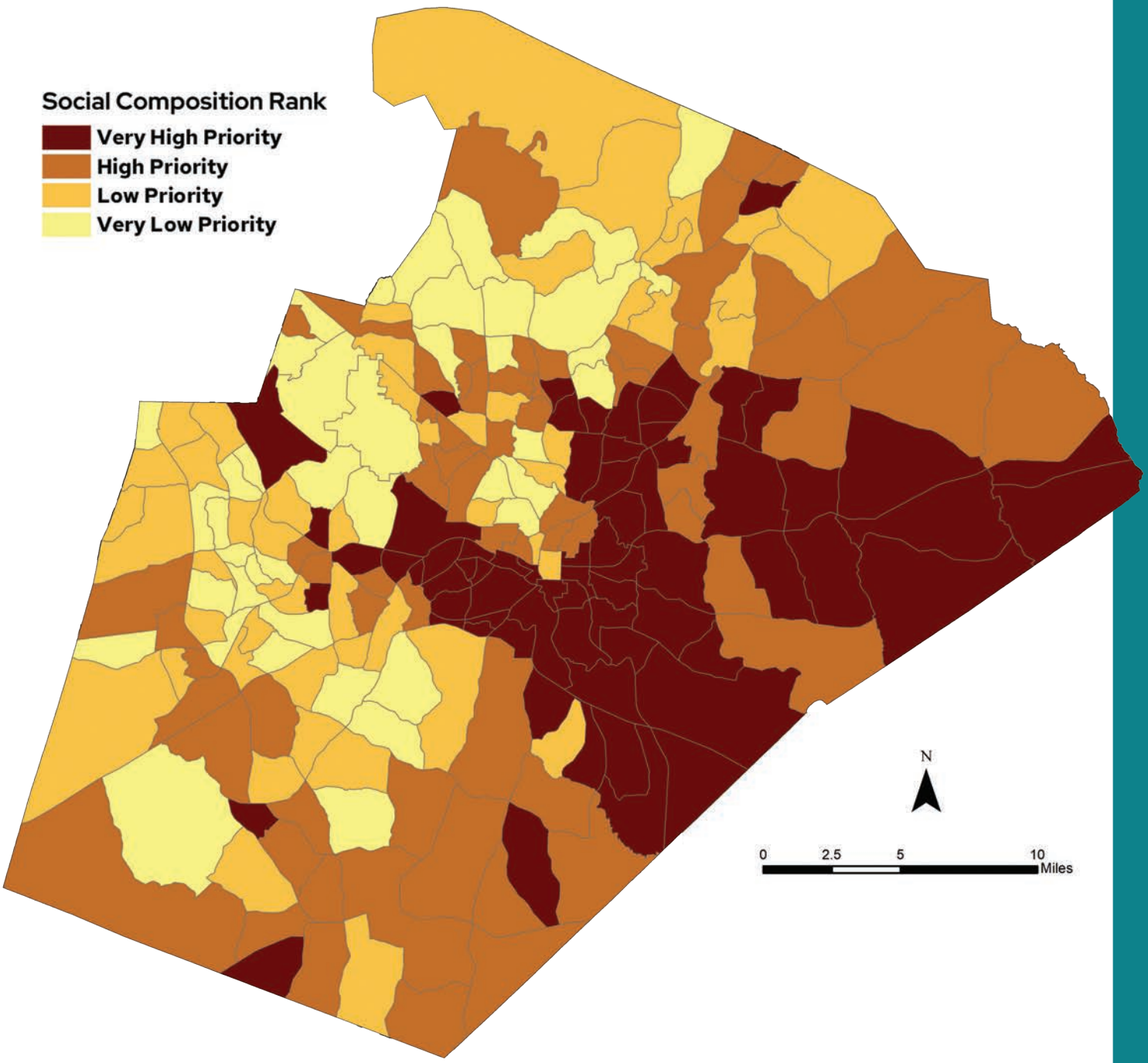
Measurement

A social equity prioritization index was generated by incorporating socioeconomic and demographic data from Wake County's Social Equity Atlas and health data from the CDC PLACES study. Areas scoring higher on the social equity index are in greater need of the environmental and socioeconomic benefits that trees can provide.

Observations

Map 3.4 exhibits the social equity index score distribution by census tract. Most of Wake County's CTs ranking Very High and High priority are in eastern Wake County. In general, residents in the eastern portion of the county are assessed to be in the greatest need of expanded tree canopy to mitigate the impacts of social inequity.

MAP 3.4 DISTRIBUTION OF SOCIAL EQUITY INDEX SCORE BY CENSUS TRACT



Prioritizing Planting Areas

Composite Vulnerability Index

Summary

The analysis ultimately prioritized the identified PPA using a composite vulnerability index that combined 10 weighted measures of community vulnerability (Table 3.1.). Each individual planting area was assigned a priority rank from Very High to Very Low (Table 3.2).

The index is a tool for prioritizing potential planting opportunities according to where tree canopy will make the greatest contribution to mitigating vulnerability and boosting community resilience (Map 3.5).

Observations

The analysis identified 404,879 individual PPA with a combined acreage of 82,460 (approximately 15% of Wake County's total area). A total of 10,262 acres of plantable area ranked as Very High and 13,611 acres of plantable area ranked as High.

The greatest concentration of Very High and High priority PPA are observed in the eastern and southeastern portions of the county. Concentrations of elevated priority PPA are also observed in western Wake, within and near the Jordan Lake watershed.

Vintage 2020

It is important to reiterate that this analysis utilized 2020 NAIP imagery. Some of the identified planting areas may no longer be suitable for planting. This tool should be used as a first pass at coordinating and prioritizing canopy replacement and restoration efforts.

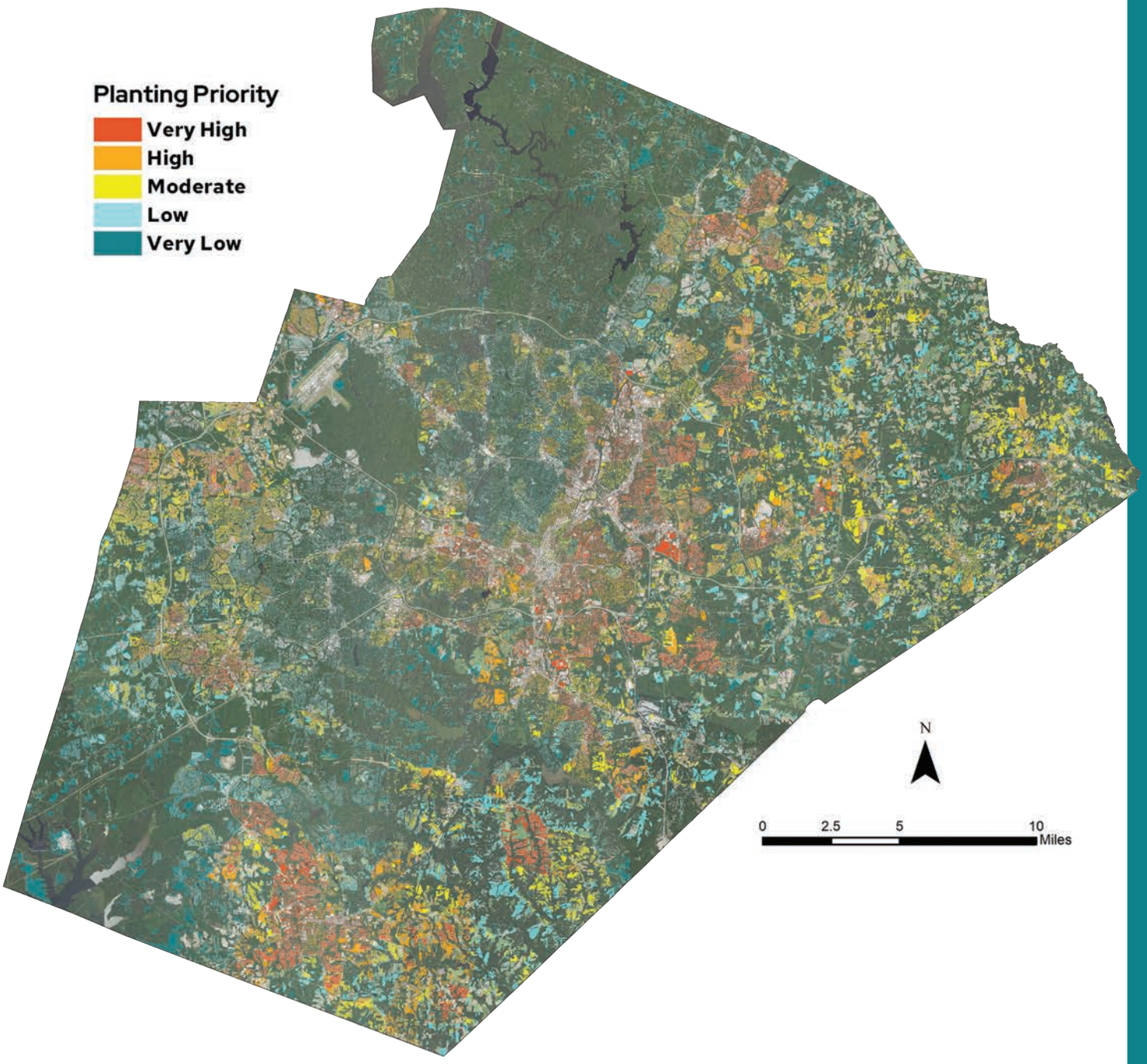
TABLE 3.1 COMPOSITE VULNERABILITY INDEX INPUT CRITERIA

COMPOSITE INDEX CRITERIA
Tree Canopy Percent
Possible Canopy Percent
Heat Islands
Social Equity Index: Score 300+ vulnerability
Mental Health
Air Quality
Stormwater
Asthma Prevalence
Soil Erosion
FEMA Floodplain

TABLE 3.2 POTENTIAL PLANTING AREA (2020) PRIORITIZED BY THE COMPOSITE VULNERABILITY INDEX

PRIORITY	PLANTING AREAS	COMBINED ACREAGE
Very High	82,204	10,262
High	79,600	13,611
Moderate	73,164	16,990
Low	80,422	21,416
Very Low	89,489	20,181
TOTAL	**404,879**	**82,460**

MAP 3.5 POTENTIAL PLANTING AREA (2020) IN QUALIFIED CENSUS TRACTS PRIORITIZED BY THE COMPOSITE VULNERABILITY INDEX



Focus Area: Qualified Census Tracts

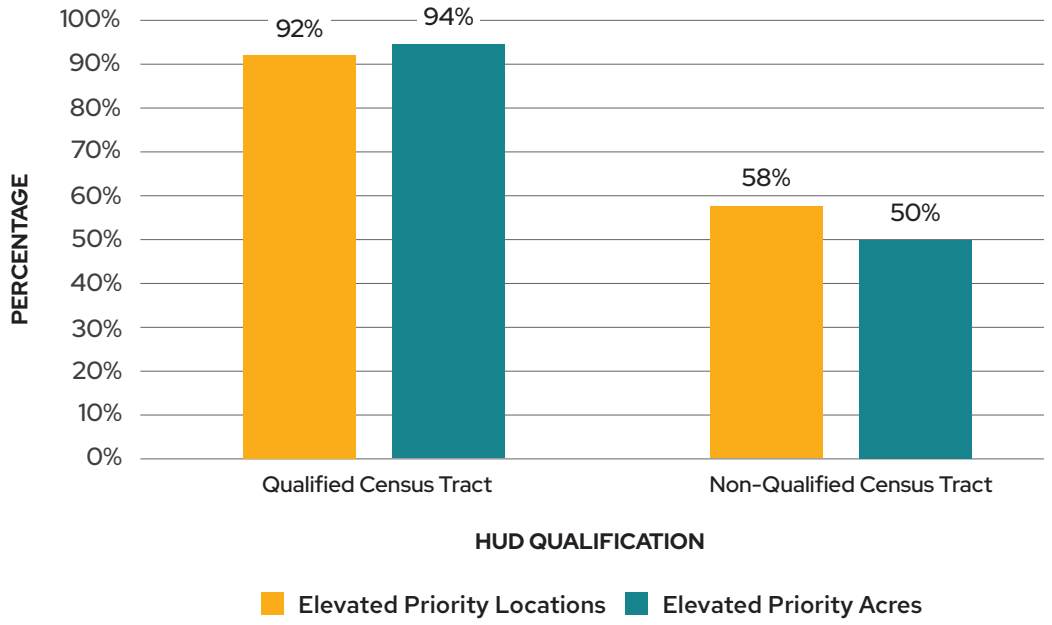
As noted in Section One, HUD-Qualified Census Tracts (QCTs) on average have a greater proportion of impervious surface and less canopy cover than their non-qualifying census tract counterparts. As such, residents within QCTs are at greater risk of harm from the consequences of urban heat islands and stormwater runoff. In addition and by definition, QCTs are expected to rate highly on the social equity index.

The analysis demonstrates that QCTs contain a significantly greater proportion of PPA with elevated priority (i.e., Very High, High and Moderate) than non-qualified CTs (Figure 3.1). The priority planting analysis provides the information necessary to accurately identify where planting new trees will make the greatest impact for those in greatest need of the environmental and socioeconomic benefits that trees provide.

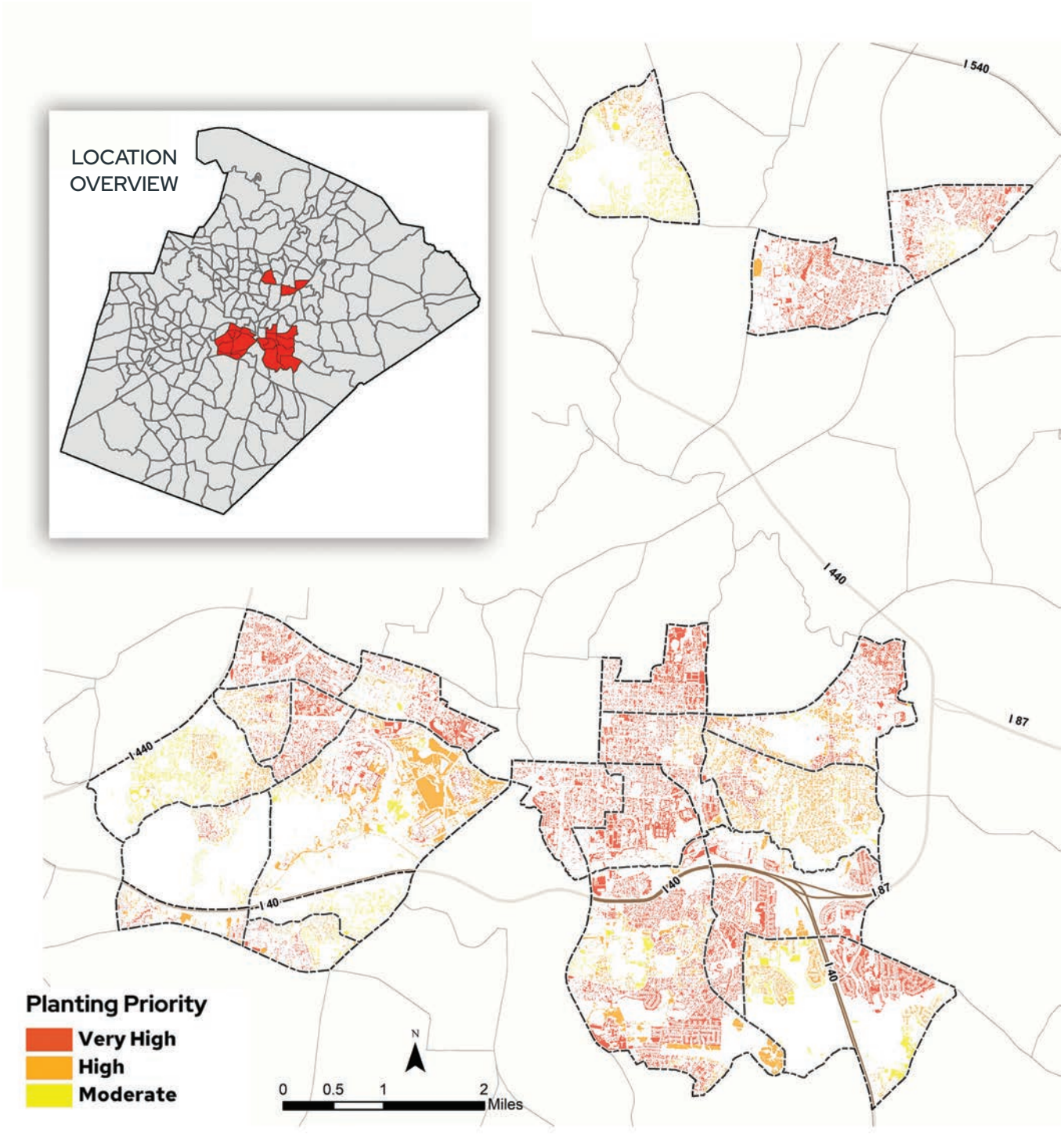
TABLE 3.3 POTENTIAL PLANTING AREA (2020) IN QUALIFIED CENSUS TRACTS PRIORITIZED BY THE COMPOSITE VULNERABILITY INDEX

PRIORITY	PLANTING AREAS	COMBINED ACREAGE
Very High	18,224	1,411.8
High	8,200	867.5
Moderate	4,082	306.5
Low	2,056	145.3
Very Low	507	11.4

FIGURE 3.1 POTENTIAL PLANTING AREA (2020) IN QUALIFIED CENSUS TRACTS COMPARED TO NON-QUALIFIED CENSUS TRACTS (2020)



MAP 3.6 POTENTIAL PLANTING AREA (2020) WITHIN QUALIFIED CENSUS TRACTS RANKED BY THE COMPOSITE VULNERABILITY INDEX



Tree Placement Modeling

Summary

Building from the planting area analysis, a GIS-based tree placement model employs an algorithm to determine how many trees can potentially fit within each PPA. The model differentiates between tree size at maturity (large, medium and small-growing), giving preference to large-growing trees and utilizing spacing commonly suggested for a landscape setting (Table 3.4).

Targeted Planting

To demonstrate the utility of the tree placement analysis for informing targeted tree planting initiatives, we took a closer look at one of Wake County's 22 QCTs: Census Tract 540.01 (Map 3.7).

Observations

The tree placement model identified 6,576 individual tree planting sites within QCT 540.01 (Table 3.5). Among these sites:

- 40.6% of sites are suitable for large-growing trees.
- 18.8% of sites are suitable for medium-growing trees.
- 40.6% of sites suitable for small-growing trees.
- 383 are Very High priority and 1,774 are High priority planting sites (5.8% and 27.0% of all identified sites, respectively).

Vintage 2020

It is important to note that the analysis reflects existing conditions as of 2020 and not all identified sites are suitable for tree planting. This model should be considered a starting point for identifying planting needs and targeting future planning and planting initiatives. Potential sites should be field checked to determine site suitability and inform tree species selection.

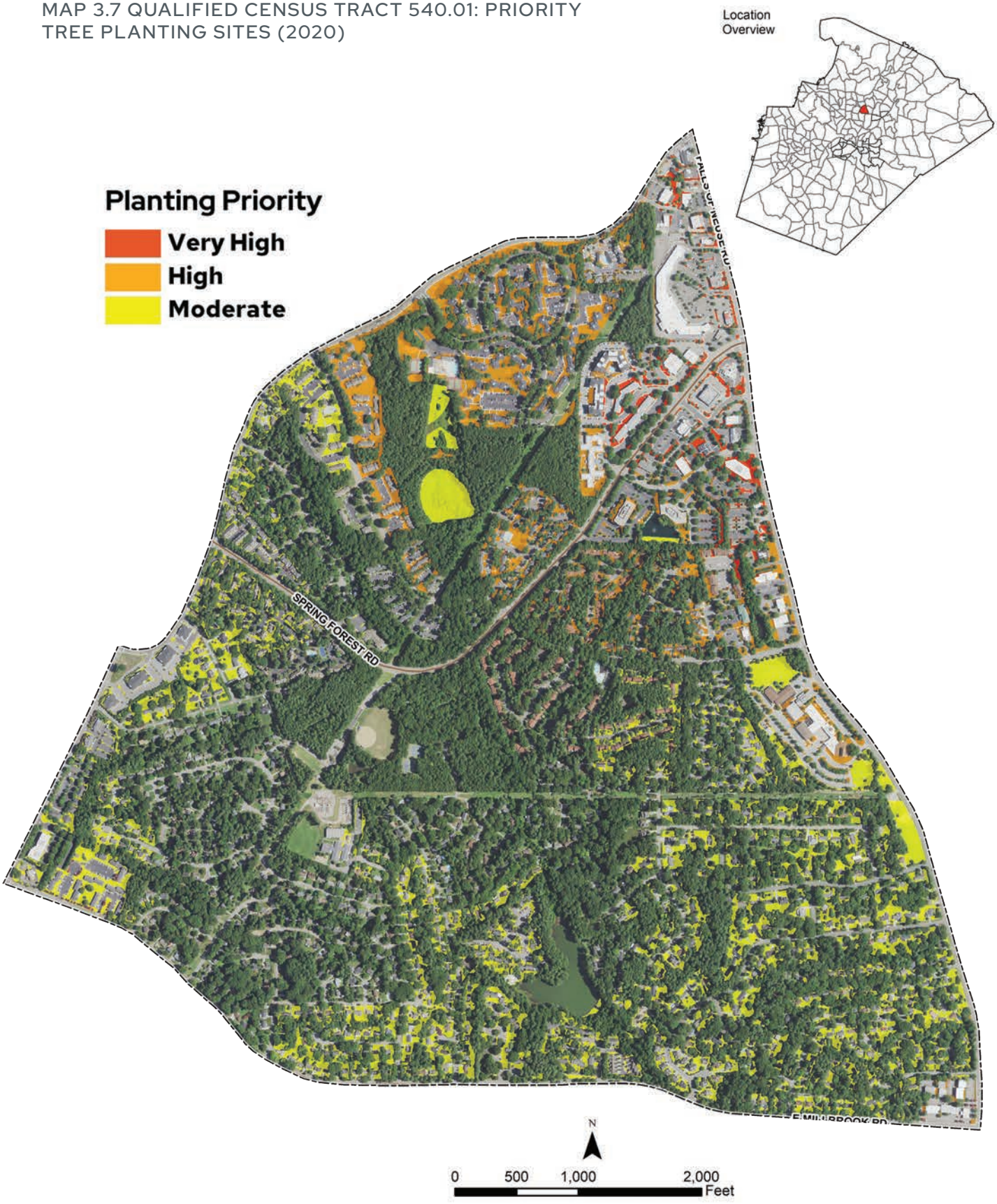
TABLE 3.4 TREE PLACEMENT MODEL: CROWN SIZE AND SPACING PARAMETERS

TREE SPACING IN URBAN/SUBURBAN LANDSCAPES		
Planting Site Size	Mature Crown Diameter	No Other Trees Placed Within:
Small	20 Feet	10 Feet
Medium	30 Feet	15 Feet
Large	40 Feet	20 Feet

TABLE 3.5 QUALIFIED CENSUS TRACT 540.01: PRIORITIZED TREE PLACEMENT (2020)

MATURE CROWN SIZE	PLACEMENT SITE PRIORITY			TOTAL
	VERY HIGH	HIGH	MODERATE	
Small	159	735	1,775	2,669
Medium	99	359	780	1,238
Large	125	680	1,779	2,669
ALL SIZES	**383**	**1,774**	**4,334**	**6,576**

MAP 3.7 QUALIFIED CENSUS TRACT 540.01: PRIORITY TREE PLANTING SITES (2020)



ENDNOTES

1. https://www.census.gov/quickfacts/fact/table/wakecountynorthcarolina,NC#
2. Between 2010 and 2020, North Carolina's population grew by 903,905 individuals, an increase of 9.5%, faster than the national growth rate of 7.3%. https://www.ncdemography.org/2021/08/16/nc-growth-over-last-decade-entirely-from-adult-population/
3. Citation pending
4. https://www.epa.gov/heatislands
5. Citation pending

Glossary

Accuracy Assessment: A process for evaluating the accuracy of a land cover classification by comparing it with ground-truthed data.

Acre: A unit of area measuring 43,560 square feet. One square acre plot of land measures 209 x 209 feet.

Assessment: The process of determining the health and value of a tree, as well as the identification of solutions to mitigate risk.

Canopy Benefits: Ecosystem services provided by trees including air pollution removal, stormwater capture and carbon capture.

Canopy Change: A measure of how tree canopy differs from one point in time to another, typically measured in acres of canopy.

Canopy Change (Absolute): The percent change of tree canopy relative to overall land cover.

Canopy Change (Relative): The percent change of tree canopy relative to prior existing tree canopy cover.

Canopy Cover: The amount of land covered by tree canopy as measured from aerial imagery, expressed as a percentage of the total land area.

Canopy Health: The remotely sensed condition of tree canopy based on the reflectance of visible and near-infrared bands of light from trees. Health information is derived from the Normalized Difference Vegetation Index (NDVI).

Census Block Groups (BGs): statistical divisions of census tracts that are generally defined to contain between 600 and 3,000 people. BGs never cross state, county, or census tract boundaries, but may cross the boundaries of any other geographic entity, such as municipal corporate limits.

Census Tracts: Census Tracts (CTs) are small, relatively permanent statistical subdivisions of a county or statistically equivalent entity. CTs generally have a population size between 1,200 and 8,000 people. A CT usually covers a contiguous area; however, the spatial size varies widely depending on population density.

Color Infrared (CIR): Data that includes part of the visible light spectrum as well as the near-infrared.

Coniferous: This category also includes wax-leaf evergreens, like the American holly.

Conservation: Planned management and wise use of natural resources for present and future generations.

Easement: A right to cross or use another's land for a specified purpose such as utility maintenance or access to specified persons.

Environment: The surrounding area and conditions in which a person or animal lives.

Existing UTC: Any area of land in the city that was covered by UTC at the time of satellite data acquisition.

Forest Management: The process of maintaining the health of a forest to provide products and values a landowner desires.

Geographic Information Systems (GIS): A software platform used to capture, store, manipulate, analyze and display geographic data.

Geoprocessing: A GIS operation used to manipulate GIS data by taking an input data set, performing an operation on that dataset and returning an output dataset. (e.g., geographic overlays, feature selection and analysis and raster processing).

Ground-truthing: The process of validating remote sensing data by collecting ground-level measurements or observations, such as tree height, diameter at breast height (DBH), or species identification.

Habitat: An area with adequate food, water, shelter and living space in which a specific species naturally lives, grows and reproduces.

Heat Island: The significant warming of a given area compared to the surrounding area. Usually heat islands appear in urban settings which are much warmer than the surrounding rural areas.

Land Cover Classification: The process of categorizing the land surface into different types, such as forests, grasslands, water bodies or urban areas.

Land Use: Describes the human use of land for cultural and economic purposes.

Microclimate: The climate of a very small or restricted area, particularly when this area's climate differs from the larger surrounding area.

Municipality: A city or town that has corporate status and local government.

National Agricultural Imagery Program (NAIP): A program started by The U.S. Department of Agriculture. It acquires aerial imagery during the agricultural growing season in the continental United States.

Normalized Difference Vegetation Index (NDVI): A specific vegetation index that uses near-infrared and visible light to estimate the amount of green vegetation in an area.

Parks & Open Space: Publicly owned areas for natural preservation and/or recreational use.

Orthophoto: An aerial or satellite image geometrically corrected so that the scale is uniform.

Pervious Surface: Refers to natural surfaces that allow stormwater to infiltrate into the ground. Examples include lawn, landscape, pasture and native vegetation areas. For the Wake LCA/TCA, both the Bare Soil and Grass/Low-Lying Vegetation land cover classes are pervious surfaces.

Planning Jurisdiction: The region where a municipality has authority to regulate land development and building construction.

Possible Planting Area: Any area of land where it is biophysically feasible to plant trees.

Potential Planting Area (PPA): Land area determined by GIS analysis to be suitable for planting trees. The minimum size of a PPA is one acre within unincorporated Wake County and 200 square feet within municipal planning jurisdiction.

Priority Planting Analysis: A GIS-based analysis to determine potential suitable tree-planting locations and determine their priority rank for planting across a range of environmental and socioeconomic inputs.

Quality Assurance (QA): A process used to verify the product quality after it is produced to ensure that it meets the project's stated goals.

Quality Control (QC): Processes used during production to ensure the quality of the product.

Remote Sensing: The process of acquiring information about an object or phenomenon from a distance, typically using satellites, airplanes or drones.

Resolution: The size of the smallest pixel of a remotely sensed image.

ROW: Right-of-way, a legal right, established by usage or grant, to pass along a specific route through property belonging to another.

Sequester: To isolate. Trees sequester, or isolate, carbon dioxide (CO_2) which is a greenhouse gas.

Socioeconomic: Relating to or concerned interactions of social and economic matters.

Spatial Resolution: The "pixel size" of a remotely sensed image.

Stormwater Runoff: Surface water that fails to infiltrate soil after a rainstorm and flows into natural or artificial channels.

Top-Down Canopy Assessment: The use of aerial imagery to quantify the extent of tree cover.

Tree: A woody plant that reaches a height of more than 15 feet at maturity.

Urban Forests: All of the trees that occupy residential properties, parks, public spaces and along streets.

Urban Tree Canopy (UTC): The top layers of foliage and branches of trees in an urban area as seen from above.

Methodology

Land cover analyses are crucial for understanding the distribution and composition of different land cover types. The following methodology outlines the steps taken to conduct a land cover assessment for a tree canopy assessment:

1. **Project Study Area Description:**

   The Wake County LCA/TCA project study area consisted of the entirety of land area within the county limits. Additionally, the project included the entire planning jurisdiction for each of the county's twelve core municipalities, including jurisdictional land areas that extend beyond county limits. Within the defined boundary there are several parks and open spaces, watersheds, agricultural, industrial and residential areas.

2. **Data Collection:**

   The data collection process involved the use of high-resolution aerial imagery provided by the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP). The one-meter resolution imagery was captured in the Spring, when trees are in full leaf. The imagery was processed using photogrammetric techniques to generate a high-resolution orthophoto, which was used to identify tree canopy cover.

3. **Image Analysis:**

   The image analysis was conducted using a combination of manual and automated methods. The manual analysis involved visual interpretation of the orthophoto to identify individual trees and their canopy cover. The automated analysis involved the use of computer algorithms to extract information on the tree canopy cover from the orthophoto.

4. **Data Analysis:**

   The final dataset was used to generate several maps of the canopy cover for Garner which illustrate a wide range of useful data including land cover types, canopy percentage, canopy health and land use types. The tree canopy cover was calculated as the percentage of the municipality covered by the crowns of the trees.

5. **Interpretation and Reporting:**

   The results were reported using maps, figures and tables, to facilitate understanding by the public, stakeholders and decision-makers.

Land Cover Analysis

Classification Methodology

Davey Resource Group utilized an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution color infrared (CIR) aerial imagery and remotely sensed data to identify tree canopy cover and land cover classifications. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage. This supports responsible tree management, facilitates community forestry goal setting and improves urban resource planning for healthier and more sustainable urban environments.

Advanced image analysis methods were used to classify, or separate, the land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst, an extension of ArcGIS®. Feature Analyst uses an object-oriented approach to cluster together objects with similar spectral (i.e., color) and spatial/contextual (e.g., texture, size, shape, pattern and spatial association) characteristics. The land cover results of the extraction process were post-processed and clipped to each project boundary prior to the manual editing process to create smaller, manageable and more efficient file sizes. Secondary source data, high-resolution aerial imagery provided by Wake County iMaps and custom ArcGIS® tools were used to aid in the final manual editing, quality checking and quality assurance processes (QA/QC). The manual QA/QC process was implemented to identify, define and correct any misclassifications or omission errors in the final land cover layer.

Classification Workflow

1. Prepare imagery for feature extraction (resampling, rectification, etc.), if needed.
2. Gather training set data for all desired land cover classes (canopy, impervious, grass, bare soil, shadows).
3. Extract canopy layer only; this decreases the amount of shadow removal from large tree canopy shadows. Fill small holes and smooth to remove rigid edges.
4. Edit and finalize canopy layer at 1:2000 scale. A point file is created to digitize-in small individual trees that will be missed during the extraction. These points are buffered to represent the tree canopy. This process is done to speed up editing time and improve accuracy by including smaller individual trees.
5. Extract remaining land cover classes using the canopy layer as a mask; this keeps canopy shadows that occur within groups of canopy while decreasing the amount of shadow along edges.
6. Edit the impervious layer to reflect actual impervious features, such as roads, buildings, parking lots, etc. to update features.
7. Using canopy and actual impervious surfaces as a mask; input the bare soils training data and extract them from the imagery. Quickly edit the layer to remove or add any features. Davey Resource Group tries to delete dry vegetation areas that are associated with lawns, grass/meadows and agricultural fields.
8. Assemble any hydrological datasets, if provided. Add or remove any water features to create the hydrology class. Perform a feature extraction if no water feature datasets exist.
9. Use geoprocessing tools to clean, repair and clip all edited land cover layers to remove any self-intersections or topology errors that sometimes occur during editing.
10. Input canopy, impervious, bare soil and hydrology layers into Davey Resource Group's Five-Class Land Cover Model to complete the classification. This model generates the pervious (grass/low-lying vegetation) class by taking all other areas not previously classified and combining them.
11. Thoroughly inspect final land cover dataset for any classification errors and correct as needed.
12. Perform accuracy assessment. Repeat Step 11, if needed.

Automated Feature Extraction Files

The automated feature extraction (AFE) files allow other users to run the extraction process by replicating the methodology. Since Feature Analyst does not contain all geoprocessing operations that Davey Resource Group utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst, Davey Resource Group created the training set data, ran the extraction and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, Davey Resource Group uses additional geoprocessing tools within ArcGIS®. From the AFE file results, the following steps are taken to prepare the extracted data for manual editing.

1. Davey Resource Group fills all holes in the canopy that are less than 30 square meters. This eliminates small gaps that were created during the extraction process while still allowing for natural canopy gaps.
2. Davey Resource Group deletes all features that are less than 9 square meters for canopy (50 square meters for impervious surfaces). This process reduces the number of small features that could result in incorrect classifications and also helps computer performance.
3. The Repair Geometry, Dissolve and Multipart to Singlepart (in that order) geoprocessing tools are run to complete the extraction process.
4. The Multipart to Singlepart shapefile is given to GIS personnel for manual editing to add, remove, or reshape features.

Accuracy Assessment Protocol

Determining the accuracy of spatial data is of high importance to Davey Resource Group and our clients. To achieve the best possible result, Davey Resource Group manually edited and conducted thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process was completed using ArcGIS® to identify, clean and correct any misclassification or topology errors in the final land cover dataset. The initial land cover layer extractions were edited at a 1:2000 quality control scale in the urban areas and at a 1:2500 scale for rural areas utilizing the most current high-resolution aerial imagery to aid in the quality control process.

To test for accuracy, random plot locations were generated throughout the area of interest and verified to ensure that the data meet the client standards. Each point was compared with the most current NAIP high-resolution imagery (reference image) to determine the accuracy of the final land cover layer. Points were classified as either correct or incorrect and recorded in a classification matrix. Accuracy was assessed using four metrics: overall accuracy, kappa, quantity disagreement and allocation disagreement. These metrics were calculated using a custom Excel® spreadsheet.

TABLE 1. LAND COVER CLASSIFICATION CODE VALUES

LAND COVER CLASSIFICATION	CODE VALUE
Tree Canopy	1
Impervious	2
Pervious (Grass/Vegetation)	3
Bare Soil	4
Open Water	5

Land Cover Accuracy

The following describes Davey Resource Group's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. **Random Point Generation —** Using ArcGIS, 1,000 random assessment points are generated.
2. **Point Determination —** Each point is carefully assessed by the GIS analyst for likeness with aerial photography. To record findings, two new fields, CODE and TRUTH, are added to the accuracy assessment point shapefile. CODE is a numeric value (1–5) assigned to each land cover class (Table 1) and TRUTH is the actual land cover class as identified according to the reference image. If CODE and TRUTH are the same, then the point is counted as a correct classification. Likewise, if the CODE and TRUTH are not the same, then the point is classified as incorrect. In most cases, distinguishing if a point is correct or incorrect is straightforward. Points will rarely be misclassified by an egregious classification or editing error. Often incorrect points occur where one feature stops and the other begins.
3. **Classification Matrix —** During the accuracy assessment, if a point is considered incorrect, it is given the correct classification in the TRUTH column. Points are first assessed on the NAIP imagery for their correctness using a "blind" assessment – meaning that the analyst does not know the actual classification (the GIS analyst is strictly going off the NAIP imagery to determine cover class). Any incorrect classifications found during the "blind" assessment are scrutinized further using sub-meter imagery provided by the client to determine if the point was incorrectly classified due to the fuzziness of the NAIP imagery or an actual misclassification. After all random points are assessed and recorded; a classification (or confusion) matrix is created. The classification matrix for this project is presented in Table 2. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement and confidence intervals (Figure 1 and Table 3).

TABLE 2. CLASSIFICATION MATRIX

REFERENCE DATA	CLASSES	TREE CANOPY	IMPERVIOUS SURFACES	GRASS & LOW-LYING VEGETATION	BARE SOILS	OPEN WATER	ROW TOTAL	PRODUCER'S ACCURACY	ERRORS OF OMISSION
	Tree Canopy	521	3	14	1	0	539	96.66%	3.34%
	Impervious	3	151	6	1	0	161	93.79%	6.21%
	Grass/ Vegetation	11	1	207	1	0	220	94.09%	5.91%
	Bare Soils	1	0	6	36	0	43	83.72%	16.28%
	Water	0	0	0	0	37	37	100.00%	0.00%
	Column Total	536	155	233	39	37	1,000		
	User's Accuracy	97.20%	97.42%	88.84%	92.31%	100.00%		Overall Accuracy	95.20%
	Errors of Commission	2.80%	2.58%	11.16%	7.69%	0.00%		Kappa Coefficient	0.9240

The following are descriptions of each statistic as well as the results from some of the accuracy assessment tests.

4. **Overall Accuracy —** Percentage of correctly classified pixels; for example, the sum of the diagonals divided by the total points ((521+151+207+36+37)/1,000 = 95.20%).
5. **User's Accuracy —** Probability that a pixel classified on the map actually represents that category on the ground (correct land cover classifications divided by the column total ([521/536= 97.20%]).
6. **Producer's Accuracy —** Probability of a reference pixel being correctly classified (correct land cover classifications divided by the row total ([521/539 = 96.66%]).
7. **Kappa Coefficient —** A statistical metric used to assess the accuracy of classification data. It has been generally accepted as a better determinant of accuracy partly because it accounts for random chance agreement. A value of 0.80 or greater is regarded as "very good" agreement between the land cover classification and reference image.
8. **Errors of Commission —** A pixel reports the presence of a feature (such as trees) that, in reality, is absent (no trees are actually present). This is termed as a false positive. In the matrix below, we can determine that 2.8% of the area classified as canopy is most likely not canopy.
9. **Errors of Omission —** A pixel reports the absence of a feature (such as trees) when, in reality, they are actually there. In the matrix below, we can conclude that 3.34% of all canopy classified is actually classified as another land cover class.
10. **Allocation Disagreement —** The amount of difference between the reference image and the classified land cover map that is due to less than optimal match in the spatial allocation (or position) of the classes.
11. **Quantity Disagreement —** The amount of difference between the reference image and the classified land cover map that is due to less than perfect match in the proportions (or area) of the classes.
12. **Confidence Intervals —** A confidence interval is a type of a population parameter and is used to indicate the reliability of an estimate. Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter based on the observed probability of successes and failures. Since all assessments have innate error, defining a lower and upper bound estimate is essential.

CONFIDENCE INTERVALS

CLASS	ACREAGE	PERCENTAGE	LOWER BOUND	UPPER BOUND
Tree Canopy	298,110.0	54.1%	54.1%	54.2%
Impervious Surfaces	82,191.6	14.9%	14.9%	15.0%
Grass & Low-Lying Vegetation	128,567.1	23.4%	23.3%	23.4%
Bare Soils	22,864.8	4.2%	4.1%	4.2%
Open Water	18,796.9	3.4%	3.4%	3.4%
Total	550,530.4	100.00%		

STATISTICAL METRICS SUMMARY

Overall Accuracy =	95.20%
Kappa Coefficient =	0.9240
Allocation Disagreement =	4%
Quantity Disagreement =	1%

ACCURACY ASSESSMENT

CLASS	USER'S ACCURACY	LOWER BOUND	UPPER BOUND	PRODUCER'S ACCURACY	LOWER BOUND	UPPER BOUND
Tree Canopy	97.2%	96.5%	97.9%	96.7%	95.9%	97.4%
Impervious Surfaces	97.4%	96.1%	98.7%	93.8%	91.9%	95.7%
Grass & Low-Lying Vegetation	88.8%	86.8%	90.9%	94.1%	92.5%	95.7%
Bare Soils	92.3%	88.0%	96.6%	83.7%	78.1%	89.4%
Open Water	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Canopy Type

A separate geospatial analysis was done to identify and classify all the forests within Wake County as either coniferous or deciduous forests. A supervised classification method was used to classify, or separate coniferous forests from deciduous forests. This semi-automated classification was done in ArcMap using the Feature Analyst extension and a 2021-high resolution leaf off imagery provided by Wake County. The leaf off imagery used for the analysis was a high-resolution imagery with a spatial resolution of 0.5 feet. The imagery was later resampled to 3.2808 feet (1-meter) to allow for easy processing in ArcMap.

Advanced image interpretation methods were used by a GIS Analyst to take training set data samples from areas of the leaf off imagery that were considered as conifers. Conifers are easy to distinguish from deciduous forests in a leaf off imagery due to their distinct dark green color. The deciduous forests on the other hand have light to deep gray hues. The Feature analyst software was then used to extract the coniferous forests and finally edited by GIS Technicians.

Prior to editing the extracted coniferous forests, the conifer layers were clipped to the overall canopy layer (Which includes both conifer and deciduous forests) to stamp out all the areas that are grass but misclassified as tree canopy due to their spectral similarities. This process is done to speed up editing time, improve accuracy and enable the inclusion of smaller individual trees in the final canopy layer.

Canopy Health

Methodology

Canopy health can be determined using near-infrared imagery and Normalized Difference Vegetation Index (NDVI) transformation. The NDVI is used to find the health of the tree canopy and to locate areas of stress in the tree's foliage. This is used by cities to assess the health of their trees and to locate areas of canopy stress in order to find problem areas. This allows identification of where plants are in very good condition and where they are in decline.

This data set should be considered as a relative health of trees compared to the surrounding trees. Some tree species have different reflectance in multispectral imagery so they could show slightly less healthy. As a part of our process, the separation of deciduous and coniferous trees is necessary due to the spectral differences. If this process was not used, most of the health data would show coniferous trees in a dead, dying, or poor health state, which would not be the case.

Process

The NAIP imagery, collected for the landcover analysis and gathered from the United States Department of Agriculture (USDA), was used to create an NDVI by utilizing the red band (Red) from the natural color image and the near infrared band (NIR) from the colored infrared image. These bands were then extracted from their images and the following equation was run.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

This returned a raster that ranges from -1 to 1, with values close to -1 being non-vegetated areas and values close to 1 are healthy vegetation. This raster was then clipped to the canopy layer derived from the landcover layer. In the case of Wake County, the NDVI was clipped to the deciduous and coniferous canopy layers, resulting in two NDVI layers.

These layers were classified into 6 classes using the natural breaks (jenks) classification methods. [DEFINE JENKS ONCE HERE] The layers were reclassified using these 6 classes into the ranks of the tree health analysis.
Below is the breakdown of the NDVI values in each health rank for both the coniferous and deciduous canopy.

DECIDUOUS CANOPY HEALTH	
NDVI Value	Health Rank
-1 - -0.105	Not Classified
-0.105 – 0.098	Dead/Dying
0.098 – 0.223	Poor
0.223 – 0.309	Fair
0.309 – 0.396	Good
0.396 - 1	Very Good

CONIFEROUS CANOPY HEALTH	
NDVI Value	Health Rank
-1 - -0.176	Not Classified
-0.176 – 0.035	Dead/Dying
0.035 – 0.168	Poor
0.168 – 0.255	Fair
0.255 – 0.349	Good
0.349 - 1	Very Good

Canopy Benefits

How are Tree Canopy Benefits Are Calculated?

Air Quality

The i-Tree Canopy v7.1 Model was used to quantify the value of ecosystem services for air quality. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model used the estimated canopy percentage and reports air pollutant removal rates and monetary values for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2) and particulate matter (PM) (Hirabayashi 2014).

Within the i-Tree Canopy application, the U.S. EPA's BenMAP Model estimates the incidence of adverse health effects and monetary values resulting from changes in air pollutants (Hirabayashi 2014; US EPA 2012). Different pollutant removal values were used for urban and rural areas. In i-Tree Canopy, the air pollutant amount annually removed by trees and the associated monetary value can be calculated with tree cover in areas of interest using BenMAP multipliers for each county in the United States.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for each of the five listed air pollutants.

Carbon Storage and Sequestration

The i-Tree Canopy v7.1 Model was used to quantify the value of ecosystem services for carbon storage and sequestration. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports carbon storage and sequestration rates and monetary values. Methods on deriving storage and sequestration can be found in Nowak et al. 2013.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for carbon storage and sequestration.

Stormwater

The i-Tree Hydro v6.1 Model was used to quantify the value of ecosystem services for stormwater runoff. i-Tree Hydro was designed for users interested in analysis of vegetation and impervious cover effects on urban hydrology. This most recent version (v6.1) allows users to report hydrologic data on the municipal level rather than just a watershed scale giving users more flexibility. For more information about the model, please consult the i-Tree Hydro v6.1 manual (http://www.itreetools.org).

To calculate ecosystem services for the study area, land cover percentages derived for the project area and all municipalities that were included in the project area were used as inputs into the model. Precipitation data from 2005–2012 was modeled within the i-Tree Hydro to best represent the average conditions over an eight-year time period. Model simulations were run under a Base Case as well as an Alternate Case. The Alternate Case set tree canopy equal to 0% and assumed that impervious and vegetation cover would increase based on the removal of tree canopy. Impervious surface was increased 6.04% based on a percentage of the amount of impervious surface under tree canopy and the rest was added to the vegetation cover class. This process was completed to assess the runoff reduction volume associated with tree canopy since i-Tree Hydro does not directly report the volume of runoff reduced by tree canopy. The volume (in cubic meters) was converted to gallons to retrieve the overall volume of runoff avoided by having the current tree canopy.

Through model simulation, it was determined that tree canopy decreases the runoff volume in the project area by 8,103,138,458 gallons per year using precipitation data from 2005–2012. This equates to approximately 27,182 gallons per acre of tree canopy (8,103,138,458 gals/298,109.95 acres).

To place a monetary value on storm water reduction, the cost to treat a gallon of storm/wastewater was taken from McPherson et al 1999. This value was $0.17 per gallon. Tree canopy was estimated to contribute roughly $1,377,533,538 to avoid runoff annually to the project area.

References for Canopy Benefit Methodology

Hirabayashi, S. 2014. i-Tree Canopy Air Pollutant Removal and Monetary Value Model Descriptions. http://www.itreetools.org/canopy/resources/iTree_Canopy_Methodology.pdf [Accessed 29 December 2022]

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McPherson, E.G., Simpson, J.R.; Peper, P.J.; Xiao, Q. 1999. Tree Guidelines for San Joaquin Valley Communities. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research.

U.S. Environmental Protection Agency (US EPA). 2012. Environmental Benefits Mapping and Analysis Program (BenMAP). http://www.epa.gov/air/benmap [Accessed 29 December 2022]

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Priority Planting Assessment

Summary

This analysis was conducted to assess priority planting locations within Wake County. Analysis included data sets from Wake County Open Data, The US Geological Survey, The US Department of Agriculture, The US Census Bureau and the Federal Emergency Management Agency. The resulting analysis found plantable areas in both public and private properties across the municipality.

Description

An urban tree canopy assessment was conducted by Wake County to assess land cover using 2020 aerial imagery. The study was completed in 2023. An analysis to identify the most suitable locations was conducted by analyzing each planting location to assign a priority ranking for stormwater and urban heat island.

Each data source utilized the most current version available and described in the subsequent sections. Stormwater uses the most recent NAIP imagery, soil data, flood data and benefit data. Heat islands were derived from averaging Landsat 8 surface temperature data from May 31, 2022 and Sept. 6, 2020 data to find hotspots at varying points in time to locate areas of potential heat mitigation. And social equity and health data were used to prioritize planting in area to create social equity

Methodology

In order to create a priority planting plan, the locations for planting must first be determined. Planting location polygons were created by taking all grass/open space and bare ground areas and combining them into a single dataset. Non-feasible planting areas such as agricultural fields, recreational fields, major utility corridors, airports, ROWs, etc. were removed from the possible grass and bare soil locations. This layer was reviewed and approved by Wake County before the analysis proceeded. The remaining planting space was consolidated into a single feature and then, exploded to multipart features creating separate, distinct polygons for each location.

Planting Area Exclusions:

Davey Resource Group identified and removed the following areas from the planting analysis:

- Sports fields (soccer, football, baseball, softball, etc.)
- Playgrounds
- Major utility corridors
- Golf courses
- The airport
- Wetland areas
- Substations
- Visible cropland
- Water treatment facilities

The planting area exclusions were then further refined by use of the following data layers:

Additional Exclusionary Layers

- Major Utility Easements
- Access Easements
- Parcels (Land use descriptions used: Agriculture, Horticulture, Water/Sewer System)
- ROW (This layer was created using the empty space from the parcel layer)
- Completed540_PermanentROWEasements
- Raleigh_Easement
- UtilityEasements_Wake Forest
- APEX_UtilityEasement

Stormwater:

To identify and prioritize planting potential based on the stormwater analysis, locations were assessed with several environmental features, including canopy percent, possible canopy percent, air quality, distance to hardscape, soil erosion and FEMA floodplain. These factors are based on numerous historic projects completed by DRG for stormwater analysis. Each factor was assessed using data from various sources and analyzed using separate grid maps. Values between zero and four (with zero having the lowest priority) were assigned to each grid assessed. A value of zero indicates that this classified piece of information yielded little or no overall value within the dataset. The grids were overlain with the values averaged to determine the priority levels at an area on the map. A priority ranging from Very Low to Very High was assigned to areas on the map based on the calculated average of all grid maps using quantile classification breaks within ArcGIS. This step of the process was completed to statistically subset data evenly into five classes of increasing importance. Areas of higher potential for runoff and erosion were considered higher priority due to their ability to diminish water quality within urban areas.

Urban Heat Island:

To identify and prioritize planting potential based on heat islands, a land surface temperature analysis was conducted using Landsat 8 imagery data. This data was provided via the United States Geological Survey (USGS). Specifically Landsat 8 thermal bands were used to calculate land surface temperatures. Imagery from May 31, 2022 and September 6, 2020 were used to find the radiance, at-satellite brightness and proportion of vegetation coverage. This data was then used to calculate the land surface temperature for both dates. Surface temperatures were then averaged and a priority ranking of “Very Low” to “Very High” was assigned based on the averaged temperatures using natural (Jenks) breaks classification within ArcGIS. Natural breaks create class breaks so that similar values were grouped together and maximized class differences. Classes with higher surface temperatures were considered higher priority due to the adverse effects of elevates microclimates within urban areas.

Social Equity:

Values were developed to identify and priority planting potential to improve social equity amongst the community. Analysis was conducted using the Social Equity Index data provided by Wake County and health data gathered from the CDC PLACES study. Each factor was separated into its own grid map. Values from each factor were then sorted into five classes ranked from 0 – 4 with zero being the lowest priority and 4 representing the highest priority. The factors were classified into five final rankings from "Very Low" to "Very High" for each of the social equity and public health criteria using quantile classification breaks within ArcGIS. [DEFINE QUANTILE ONCE]. Areas with a higher rating are areas with higher planting priority to provide equal access to trees and tree canopy to all citizens regardless of social status.

Composite Priority:

A composite priority was created utilizing the raster calculator tool and the provided weighting scheme. Each raster dataset for stormwater, heat island and social equity were used to calculate a total aggregate value for each individual planting location polygon. The values were then binned into five classes utilizing quantile classification within ArcGIS. Quantile classification distributes values into groups where all five groups have an equal number of values. Values were binned such that higher numbers were grouped into bins representing a higher priority planting area. These bins ranged from "Very Low" on the low end to "Very High" on the upper end to mirror criteria group rankings mentioned above. Rankings were then used to combine all criteria to create a composite ranking based on all analytical factors pertaining to the municipality.

Group	Criteria	Data Origin	Last Update	Weighting	Full Weighting
Stormwater	Distance to Hardscape (Stormwater)	Wake County Urban Tree Canopy Assessment	2020	0.13	0.07
	Canopy Percent	Wake County Urban Tree Canopy Assessment	2020	0.3	0.18
	Possible Canopy Percent	Wake County Urban Tree Canopy Assessment	2020	0.25	0.16
	FEMA Floodplain	FEMA Natural Hazard	2022	0.05	0.02
	Soil Erosion	Natural Resource Conservation Service	2022	0.07	0.04
	Air Quality	iTree Canopy	2021	0.2	0.09
Urban Heat Island	Heat Islands – Sept. 6, 2020	Earth Explorer – USGS	2020		0.14
	Heat Islands – May 31, 2022	Earth Explorer – USGS	2020		
Social Equity	Social Equity Index	Wake County	2022	0.45	0.13
	Asthma Prevalence	CDC PLACES 2021	2021	0.2	0.06
	Mental Health Prevalence	CDC PLACES 2021	2021	0.35	0.11

Weighted Overlay Equation for Stormwater priority:

("ImperviousDistance" * 0.13) + ("Floodplain" * 0.05) + ("CanopyPercent" * 0.3) + ("SoilErosion" * 0.07) + ("PossibleCanopyPercent" * 0.25) + ("AirQuality" * 0.2)

Weighted Overlay Equation for Social Equity priority:

("SocialEquityIndex" * 0.45) + ("AsthmaPrevalence" * 0.2) + ("MentalHealthPrevalence" * 0.35)

Weighted Overlay Equation for Composite priority:

("ImperviousDistance" * 0.07) + ("Floodplain" * 0.02) + ("CanopyPercent" * 0.18) + ("SoilErosion" * 0.04) + ("PossibleCanopyPercent" * 0.16) + ("AirQuality" * 0.09) + ("HeatIslands" * 0.14) + ("SocialEquityIndex" * 0.13) + ("AsthmaPrevalence" * 0.06) + ("MentalHealthPrevalence" * 0.11)

Vulnerability Assessment Data Details

Stormwater

Distance to Hardscape (Stormwater)

Source: Wake County Urban Tree Canopy Assessment

Data: Distance to Impervious

Distance to hardscape was derived by selecting the impervious surfaces data from the landcover layer. This impervious raster layer is used as an input layer into the Euclidean Distance tool within ArcGIS to create a layer that measure straight-line distance from each impervious surface location within the municipality. These distances were grouped into five classes from 0–4. A value of 0 was given to locations that are currently represented as impervious surfaces in the land cover data while a value of 4 indicated that the open area next to the impervious surface is available for planting trees to reduce the amount of runoff and sedimentation. The table below provides exact distances to impervious surfaces per rank.

Distance to Hardscape	
Rank	**Distance to Impervious (ft)**
0	0
1	Over 100
2	51–100
3	26–50
4	1–25

Canopy Percent

Source: Wake County Urban Tree Canopy Assessment

Data: Canopy Percent

Canopy percent is a derived calculation that is determined by first calculating the total canopy acreage within each census block group (CBG). The total canopy acreage is then divided by the total area of the census block group. The resulting canopy percentage values were then grouped into five classes from 0–4 based on percent coverage. A rank of 4 was assigned to areas with the least amount of canopy percent coverage. The remaining categories are organized such that block groups with higher canopy coverage receive a lower rank. Higher rankings prioritize areas that have a low percentage of canopy coverage, therefore a higher need for tree plantings to increase canopy coverage. This will amplify the benefits the tree canopy benefits currently provide.

Canopy Percent	
Rank	**Canopy Percent**
0	Over 60.1%
1	53.45%–60.1%
2	46.81%–53.45%
3	38.7%–46.81%
4	Under 38.7%

Possible Canopy Percent

Source: Wake County Urban Tree Canopy Assessment

Data: Possible Canopy Percent

Possible canopy percent was derived by first calculating the amount of available plant acres within each census block group and then dividing the available plant acres by the total area of the CBG. The resulting percentage groups were divided into five classes from 0–4 based on percentage with 4 representing areas with the largest percentage of possible canopy. The lower the possible canopy percent, the lower the ranking received. 0 rankings were areas with the lowest percent of plantable area or the lowest among possible canopy. Prioritizing plantings in areas with a high ranking will increase canopy coverage in areas that are not currently benefiting from high amount of canopy.

Possible Canopy Percent	
Rank	**Possible Percent**
0	Under 12.5%
1	12.45%–15.64%
2	15.64%–18.6%
3	18.6%–23.0%
4	Over 23.0%

FEMA Floodplain

Source: FEMA Flood Hazard Layer

Link: https://www.fema.gov/flood-maps/national-flood-hazard-layer

Data Attribute: ZONE_LID_V & ZONESUB_LI

FEMA Flood data was collected from the FEMA website. This data is categorized first by a letter and then by a sub-ranking. Special flood hazard areas in the municipality are labeled with an AE, moderate areas are labeled with an X and a sub-category, the next denotation is labeled as 0.2% annual chance and low risk areas are noted with a X and no sub-category. These were then ranked 0–4, with 4 being the highest priority. A ranking of 4 is given to the AE & Floodway category. Planting in these locations will increase stormwater uptake and therefore reduce the amount of runoff. Lower rankings are given to the X, 1% future conditions and 0.2% annual chance and non-risk areas. Planting in areas of a higher flood risk can help decrease the amounts of standing water and runoff.

Soil Permeability — HSG	
Rank	**Threat**
0	X & Areas not included in the layer
1	0.2 PCT ANNUAL CHANCE FLOOD HAZARD
2	X & 1 PCT FUTURE CONDITIONS
3	AE
4	AE & FLOODWAY

Soil Erosion

Source: Natural Resource Conservation Service – USDA Web Soil Survey

Link: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Data Attribute: K-factor

Soil erosion was determined by analyzing the K-factor information from the USDA Soil Surveys. The data is classified into decimal numbers ranging from 0.02-0.69 with higher numbers within the range indicating the area is more susceptible to sheet and rill erosion by water. 0 rankings were given to areas that had little to no risk of erosion such as quarries, pits and other hard surface types. The ranking increases as the risk of erosion increases with the highest ranking being 4. Planting in priority areas with high rankings will help decrease erosion vulnerability.

Soil Erosion — K-factor	
Rank	**K-factor (expressed as whole numbers)**
0	0–10
1	11–20
2	21 –30
3	31–37
4	Over 38

Air Quality

Source: i-Tree Canopy

Link: https://canopy.itreetools.org/

Data Attribute: Air Pollution Removed Annually (CO – Carbon Monoxide, NO2 – Nitrogen Dioxide, O3 – Ozone, SO2 – Sulfur Dioxide, PM10 – Particulate Matter)

Data shows the amount of air pollution in pounds that were removed annually in each block group. Amounts were classified into five groups using quantile classification within ArcGIS and ranked from 0–4 based on the amount of pollution removed. A ranking of 0 was given to areas with more pollution removed annually. This ranking increased as the pollution removed decreased. Planting in these high priority areas may help address areas of concern regarding air quality and may help to reduce pollution.

Air Quality	
Rank	**Units (lbs.)**
0	Over 46,000
1	19,300–46,000
2	10,900–19,300
3	5,800–10,900
4	0–5,800

Urban Heat Island

Land Surface Temperature (LST)

Source: Earth Explorer (USGS) Landsat 8 Thermal Imagery

Link: https://earthexplorer.usgs.gov/

Data Attribute: Land Surface Temperature (LST)

Land surface temperature was calculated using Landsat 8 imagery thermal bands. Using both thermal bands, a conversion from Digital Number (DN) to radiance, at-satellite brightness temperature and proportion of vegetation can be calculated. These values were used to find the land surface temperature. Imagery from May 31, 2022 and Sept. 6, 2020 was used to create two separate surface temperature raster datasets. The two years were averaged and binned into five classes from 0–4 based on a quantile classification with ArcGIS. Rankings were determined by the surface temperature ranges. The lowest surface temperature range received a 0 ranking. The ranking increased as the surface temperature increases with the high rank being 4. Planting in areas of high surface temperature helps mitigation urban heat islands by providing more shade to cool not only air temperature but heat absorbed by pavements.

Land Surface Temperature — 2 Year Average (2020–2022)	
Rank	**Temperature (Fahrenheit)**
0	64.88–72.15
1	72.15–75.05
2	75.05–78.2
3	78.2–81.96
4	81.96–95.77

Social Equity

Vulnerable Populations

Source: Wake County Social Equity Index

Data Attribute: Combined_S

The social equity data was curated and provided by Wake County. The higher the score given to a block group, the higher the equity need. The social equity score is classified into five groups using info provided by Wake County and ranked from 0–4 based on this score. A ranking of 0 was given to areas with a low equity score. The higher the equity score, the higher the ranking. A ranking of 4 was given to areas that have a score of 300 and over.

Wake County Social Equity Index	
Rank	**Equity Score**
0	1–75
1	150–76
2	151–225
3	226–299
4	300 and Over

Asthma

Source: Center for Disease Control (CDC) PLACES

Link: https://chronicdata.cdc.gov/browse?q=PLACES%202022

Data Attribute: Crude Prevalence

Crude Prevalence was calculated using respondents of the Behavioral Risk Factor Surveillance System (BRFSS) survey or National Survey of Children's Health. This number is a percentage that is calculated by dividing the weighted total of people who have asthma or who have been told they have asthma from a doctor by the weighted number of people who responded to either survey excluding the answers of "don't know" or "refused" in regard to Asthma. Data was recorded by census tract. The asthma rates were grouped into five classes using quantile classification within ArcGIS and ranked from 0–4. A ranking of 0 was given to the lowest prevalence recorded. This ranking increased as the asthma rates increase with the highest ranking being 4. Planting in these priority areas will potentially help decrease asthma prevalence.

CDC — Asthma	
Rank	**Crude Prevalence**
0	0.0–7.5
1	7.6–8.0
2	8.1–8.6
3	8.7–9.2
4	9.3–12.8

Mental Health

Source: Center for Disease Control (CDC) PLACES

Link: https://chronicdata.cdc.gov/browse?q=PLACES%202022

Data Attribute: Crude Prevalence

Crude Prevalence was calculated using respondents of the BRFSS survey or National Survey of Children's Health. This number is a percentage that was calculated by dividing the weighted total of people who have reported 14 or more days during the past 30 in which their mental health was not good by the weighted number of people who responded to either survey excluding the answers of "don't know" or "refused" in regard to mental health. Data was recorded by census tract. The mental health rates were grouped into five classes using quantile classification within ArcGIS and ranked from 0-4. A ranking of 0 was given to the lowest prevalence. This ranking increased as the mental health rates increased with the highest ranking being 4. Planting in these priority areas will potentially help decrease poor mental health prevalence.

CDC — Mental Health	
Rank	**Crude Prevalence**
0	0.0–10.9
1	11.0–12.3
2	12.4–13.5
3	13.6–14.6
4	14.7–22.8

Tree Placement Modeling

Summary

The purpose of this feature class was to create a tree planting placement guide for Wake County. This layer identifies possible locations for tree placement based on the placement analysis.

Description

An urban tree canopy assessment was conducted to determine the current land cover. This landcover was used to find the most suitable locations to plant trees. These locations were narrowed down to spaces over 200 square feet within cities limits and 1 acre on county lands. This analysis creates locations to plant trees based on the Tree Placement Analysis.

Use Limitations

As determined by Wake County Government.

Data Quality

Planting sites and their tree sizes were generalized based on data derived from the Priority Planting analysis and the Tree Placement model. No field verification of planting sites was conducted. Before planting, the Municipality will need to conduct site assessments to ensure planting locations can adequately sustain planting trees.

Lineage

This process used the priority planting areas to create points for tree placement. Grid area created over the designated area and points were placed within these grids within the priority planting areas. The size of the trees is determined by what is able to fit within both the grid and planting area. The model places large trees first and then uses the remaining area to place medium trees and then again for small trees.

Data Attribute Fields

ET_X – X coordinate

ET_Y – Y coordinate

Crown – The diameter of the crown

CrownSize – The size (small, medium, large) of the tree crown

UNIQUEID – unique identifying number

City_County – Specifies the city the tree falls in or if it falls in county land.

Subdivision – Specifies if it falls within a subdivion (subdivisions and planned subdivisions provided by wake county)

PublicLand_Owner – Specifies the owner (city/county/state/federal/park) of the public land. All null values are private land.

StormMean – Stormwater mean rank (mean rank of 0–4)

StormPri – Stormwater priority rank

TempMean – Heat Island mean rank (mean rank of 0–4)

TempPri – Heat Island priority rank

SocialEquMean – Social equity index mean rank (mean rank of 0–4)

SocialEquPri – Social equity index priority rank

AsthmaMean – Asthma prevalence mean rank (mean rank of 0–4)

AsthmaPri – Asthma prevalence priority rank

MentalHMean – Mental Health Prevalence mean rank (mean rank of 0–4)

MentalHPri – Mental health prevalence priority rank

SocialCompMean – Social equity composite (Social equity index, asthma and mental health) mean rank (mean rank of 0–4)

SocialCompPri – Social equity composite (Social equity index, asthma and mental health) priority rank

CompositeMean – Overall composite (Stormwater, heat island, social equity) mean rank (mean rank of 0–4)

CompositePri – Overall composite (Stormwater, heat island, social equity) priority rank