2011-2020

Tree Canopy Assessment

Cincinnati, OH

PREPARED BY:

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PREPARED FOR:

Cincinnati Area Geographic Information System (CAGIS), The City of Cincinnati, Cincinnati Park Board Urban Forestry Program, and the Metropolitan Sewer District

June 17, 2022

EXECUTIVE SUMMARY

The Cincinnati Urban Forestry Program (CUFP) was founded in the early 80's in response to neighborhood blight and management of hazardous trees. Today, the CUFP continues to operate as the front-line agency, responsible for overseeing the care and monitoring of the City's Urban Forest. This team, housed in the Cincinnati Park Board, provides professional arboricultural services that include:

1. 24-7 emergency response to down trees in the right of way (ROW)
2. Hazard tree abatement on public and private property
3. Inspection, pruning, removal and replacement of public trees (at a minimum six-year cycle)
4. Analyzing and improving city canopy through Urban Tree Canopy Assessments (UTC)

Throughout the past 40 years, leaders in our city and the CUFP have pushed to implement innovative policies and strategies that transpired to the 43% canopy coverage we see today. Our 2020 UTC indicates that all neighborhood canopies have either grown or remained stable over the past 10 years. Though we have achieved great success over this time, the work does not stop there. We must continue to be vigilant by preserving our canopy to ensure targeted growth is attained in areas of our city that need it most. All while not losing ground on the great strides made to date.

To do so, the UTC (conducted every 10 years) has and will continue to be our guiding framework to inform prescriptions to protect our most vulnerable populations, preserve our carbon sinks as we face the ever-growing challenges of a changing climate, and protect the large historic trees that have seen this city grow throughout history. This responsibility falls to all as we strive to reach and maintain our canopy goals across the city:

- 40% city-wide canopy (achieved as of 2020)
- 40% in our residential areas (12 neighborhoods still below this level)
- 25% in our mixed-use residential/industrial areas (6 communities below this level)
- 10% in our Central Business District (currently at 8%)

EXECUTIVE SUMMARY CONTINUED

Beyond this, overlaying Cincinnati population dynamics with the environmental issues impacting these populations at the census block level, provide a granular lens to inform where and what needs to be done to build a city that is climate resilient for current and future populations. Using data to tie these elements together allows the CUFP and corresponding partners to effect change over time to:

1. Protect communities from the influx and severity of storms and stormwater through routine street tree care, innovative streetscape infrastructure, and strategic planting to capture the stormwater impacting properties in low-lying areas and minimize combined sewer overflows.
2. Inform where to install green barriers between major transportation routes and communities to filter air pollutants, such as PM2.5, before entering the lungs of our oldest and youngest populations.
3. Cool our city's hottest areas to minimize the impacts and occurrence of heat stroke and cardiovascular issues currently facing vulnerable populations.
4. Ensure consistent and equitable beautification of our streetscapes for the safety of pedestrians and the improvement of mental health of all whose eyes fall upon the greenness of our city and build economic vitality across our business districts.

To carry on the work of our progenitors, we must continue to implement innovative policies and practices to protect and enhance our urban forest as the city continues to develop into the future. As residents, we must work to build canopy on our own properties, help those who cannot afford to do so through annual tree giveaways, and voice our views as new developments threaten our public greenspaces and natural resources. To do so will continue to put Cincinnati on the map as an innovator that cities across the world look to for guidance.

This UTC is our roadmap to do precisely that. It would have not been possible without the generous financial support of the US Forest Service, the Ohio Department of Natural Resources, and the Metropolitan Sewer District. The quality of this data is a testament to city staff, namely Matt DiBona, Cincinnati Parks GIS Analysist, and the team employed under AppGeo, who worked tirelessly over the past year to ensure the most accurate, detailed, and informative UTC ever produced for our city and county. As one of many leaders in this city focused on the community connection and access to the dynamic benefits provided by our urban forest, it is an honor to serve Cincinnati while working to address the shortfalls and improvements needed to continuously build toward an environmentally just community.

Sincerely,

Crystal Courtney
Division Manager of Natural Resources
City of Cincinnati Park Board

THE NEED FOR GREEN

Trees provide essential ecosystem services in Cincinnati, like reducing stormwater runoff, cooling the pavement in the summer and providing wildlife habitat. Trees are an indispensable part of the region's infrastructure. Research shows that these green assets can improve social cohesion, reduce crime, and raise property values. A healthy and robust tree canopy is crucial to building a more livable and prosperous town.

As with any community, Cincinnati faces a host of environmental challenges while seeking to balance development and conservation. A healthy and robust tree canopy is crucial for maintaining this balance, providing Cincinnati's residents with a resource that will impact the health and well-being of generations to come.

TREE CANOPY ASSESSMENT

For decades governments have mapped and monitored their infrastructure to support effective management practices. Traditionally, that mapping has primarily focused on gray infrastructure, including features such as roads and buildings. Left out of this mapping has been an accounting of the green infrastructure.

The Tree Canopy Assessment protocols were developed by the USDA Forest Service to help communities better understand their green infrastructure through tree canopy mapping and analytics. Tree canopy is the layer of leaves, branches, and stems that provide tree coverage of the ground when viewed from above. A Tree Canopy Assessment can provide vital information to help governments and residents chart a greener future by helping them understand the tree canopy they have, how it has changed, and where there is room to plant trees. Tree Canopy Assessments have been carried out for over 90 communities in North America. This study assessed tree canopy for Cincinnati over the 2011-2020 period.

THE TREE CANOPY ASSESSMENT PROCESS

This project employed the USDA Forest Service's Urban Tree Canopy assessment protocols and made use of federal, state, and local investments in geospatial data. Tree canopy assessments should be completed at regular intervals, every 3-5 years.

Remotely sensed data forms the foundation of the tree canopy assessment. We use high-resolution aerial imagery and LiDAR to map tree canopy and other land cover features.

The land cover data consist of tree canopy, grass/shrub, bare soil, water, buildings, roads/railroads, and other impervious features.

The land cover data are summarized by various geographical units, ranging from the property parcel to the watershed to the municipal boundary.

These summaries, in the form of tree canopy metrics, are an exhaustive geospatial database that enables the Existing and Possible Tree Canopy to be analyzed.

The tree canopy metrics data analytics provide basic summary statistics in addition to inferences on the relationship between tree canopy and other variables.

The report (this document) summarizes the project methods, results, and findings.

The presentation, given to partners and stakeholders in the region, provides the opportunity to ask questions about the assessment.

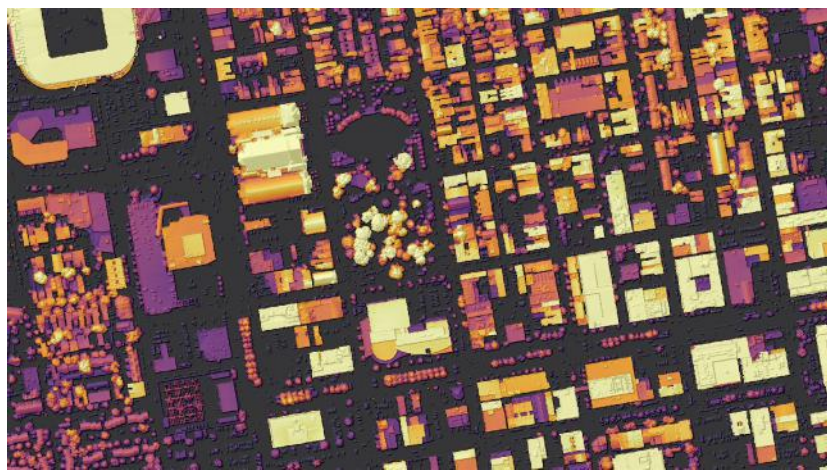
The Importance of Good Data

This assessment would not have been possible without CAGIS's investment in high-quality geospatial data, particularly LiDAR. These investments pay dividends for a variety of uses, from stormwater management to solar potential mapping. This lidar will help the Cincinnati Park Board advance their risk management plan by creating the tree centroids needed to run a risk analysis. Good data supports good governance.

MAPPING THE TREE CANOPY FROM ABOVE

Tree canopy assessments rely on remotely sensed data in the form of aerial imagery and light detection and ranging (LiDAR) data. These datasets, which have been acquired by various governmental agencies in the region, are the foundational information for tree canopy mapping. Imagery provides information that enables features to be distinguished by their spectral (color) properties. As trees and shrubs can appear spectrally similar, or obscured by shadow, LiDAR, which consists of 3D height information, enhances the accuracy of the mapping. Tree canopy mapping is performed using a scientifically rigorous process that integrates cutting-edge automated feature extraction technologies with detailed manual reviews and editing. This combination of sensor and mapping technologies enabled the city's tree canopy to be mapped in greater detail and with better accuracy than ever before. From a single street tree along a roadside to a patch of trees in a park, every tree in the city was accounted for.

Tree Canopy Mapping



Locations of individual trees and their crowns (top) that were derived from the 2020 LiDAR (bottom).

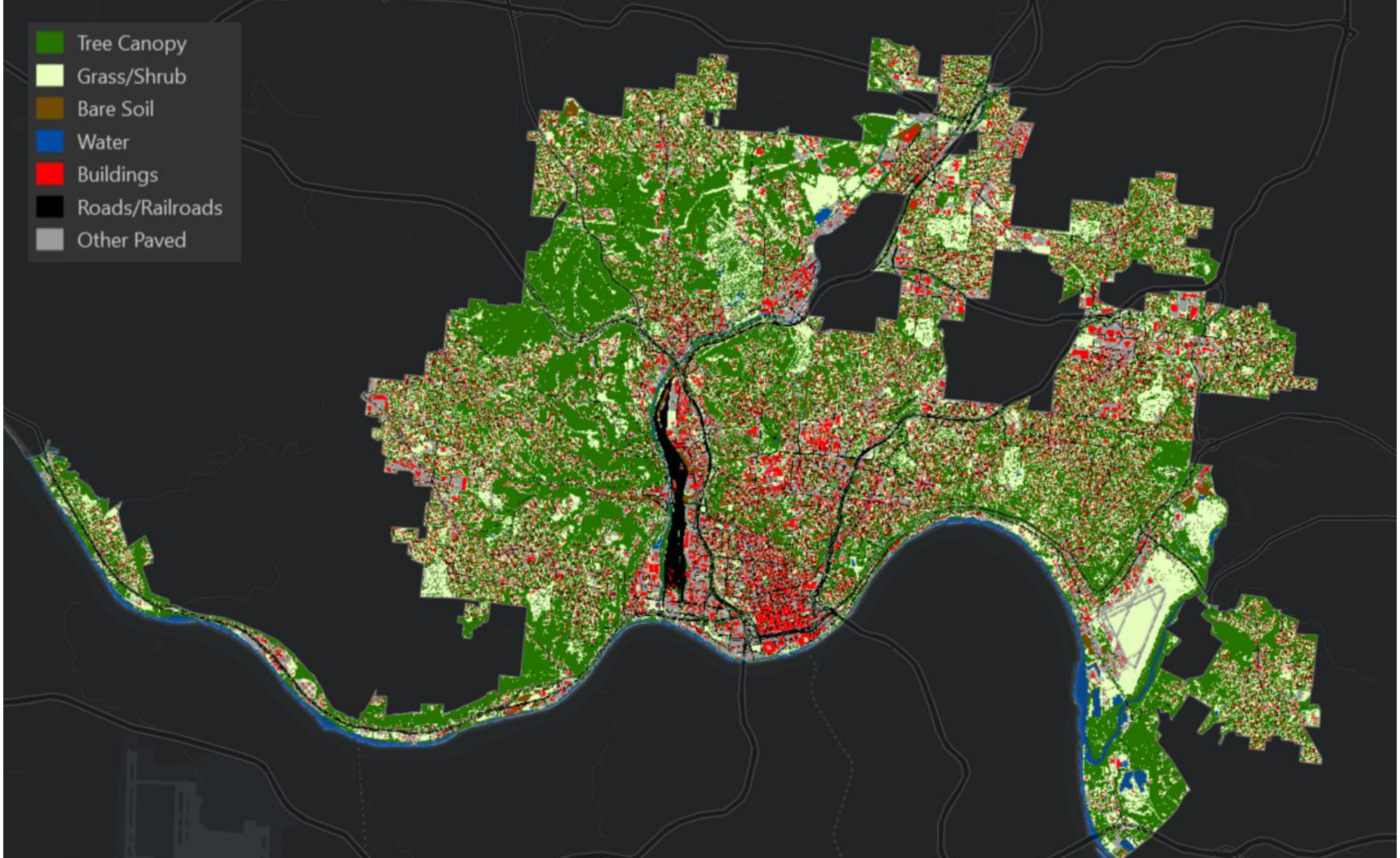
The high-resolution land cover that forms the foundation of this project was generated from the most recent LiDAR, which was acquired in 2020. Compared to national tree canopy datasets, which map at a resolution of 30-meters, this project generated maps that were over 1,000 times more detailed and better account for all of the city's tree canopy.

Land Cover Mapping

High-resolution land cover developed for this project.

LANDCOVER

2020 Land Cover Map



The new 2020 landcover for Cincinnati was used in this assessment to quantify existing tree canopy, possible tree canopy - vegetated, possible tree canopy - impervious, and not suitable. The following terminology is used throughout this report.

Key Terms

Existing Tree Canopy: The amount of tree canopy present when viewed from above using aerial or satellite imagery.

Possible Tree Canopy - Vegetated: Grass or shrub area that is theoretically available for **the** establishment of tree canopy.

Possible Tree Canopy - Impervious: Asphalt, **concrete** or bare soil surfaces, excluding roads and buildings, that are theoretically available for the establishment of tree canopy

Not Suitable: Areas where it is highly unlikely that new tree canopy could be established (primarily buildings and roads).

Measuring Tree Canopy Change

Area Change - the change in the area of tree canopy between the two time periods.

Relative % Change -the magnitude of change in tree canopy based on the amount of tree canopy in 2011.

Absolute % Change - the percentage point change between the two time periods.

TREE CANOPY BY THE NUMBERS

1.6 million

Number of trees Cincinnati was estimated to have in 2020

43.1% 2020 Tree Canopy %

38.4% 2011 Tree Canopy %

Change in tree canopy from 2011-2020

4,279
Acres of Gain

1,929
Acres of Loss

2,350 acres of net gain in tree canopy coverage.

4.7%
Absolute change in tree canopy

The net amount of tree canopy gain is the equivalent of 1,780 football fields!

12.3%
Relative change in tree canopy

FINDINGS

Cincinnati's tree canopy increased from 2011 to 2020, with an absolute gain of 4.7%.

There were 4,279 acres of tree canopy gained and 1,929 acres of tree canopy lost from 2011 to 2020.

To enhance urban resilience, Cincinnati can improve access to trees and the benefits that they provide.

Tree canopy loss is neither evenly distributed nor similar. It varies from removal of individual trees in backyards to clearing of patches of trees for new construction.

Cincinnati can improve environmental equity by prioritizing tree plantings in neighborhoods most susceptible to environmental risk.

Tree canopy in the rights-of-way grew by almost 500 acres, reflecting that the City's investment in its street trees is paying off.

Land use history, urban forestry initiatives, natural processes, and landowner decisions, all play a role in influencing the current state of tree canopy in the city.

Despite losing over 1,900 acres of tree canopy, gains in tree canopy coverage were possible thanks to preservation and planting initiatives.

RECOMMENDATIONS

Preserving existing tree canopy is the most effective means for securing future tree canopy, as loss is an event but gain is a process.

Planting new trees in areas where tree canopy is low or in locations where there has been tree canopy removed will also help the city grow canopy.

Having trees with a broad age distribution and a variety of species will ensure that a robust and healthy tree canopy is possible over time.

Community education is crucial if tree canopy is to be maintained over time. Residents that are knowledgeable about the value of trees will help the city stay green for years to come.

Integrate the tree canopy change assessment data into planning decisions at all levels of government from individual park improvements, to comprehensive planning and zoning initiatives, to citywide ordinances.

Reassess the tree canopy at 3-5 year intervals to monitor change and make strategic management decisions.

Tree canopy assessments require high-quality, high-resolution data. Continue to invest in LiDAR and imagery to support these assessments and other mapping needs.

Field data collection efforts should be used to compliment this assessment as information on tree species, size, and health can only be obtained through on-the-ground inventories.

PATTERNS OF CHANGE

Numerous factors contribute to the wide range of tree canopy change patterns of Cincinnati. These include zoning, land use history, urban density, and landowner decisions. The examples that follow illustrate how these factors influence canopy change. Examining patterns and processes over the past decade can provide insights into how the canopy may change in the future.

Urban Forest Patches

Urban forest patches provide essential ecosystem services relating to wildlife habitat and reduced runoff their removal is a concern. Forest patches can be removed in a matter of days and take decades to rebuild.

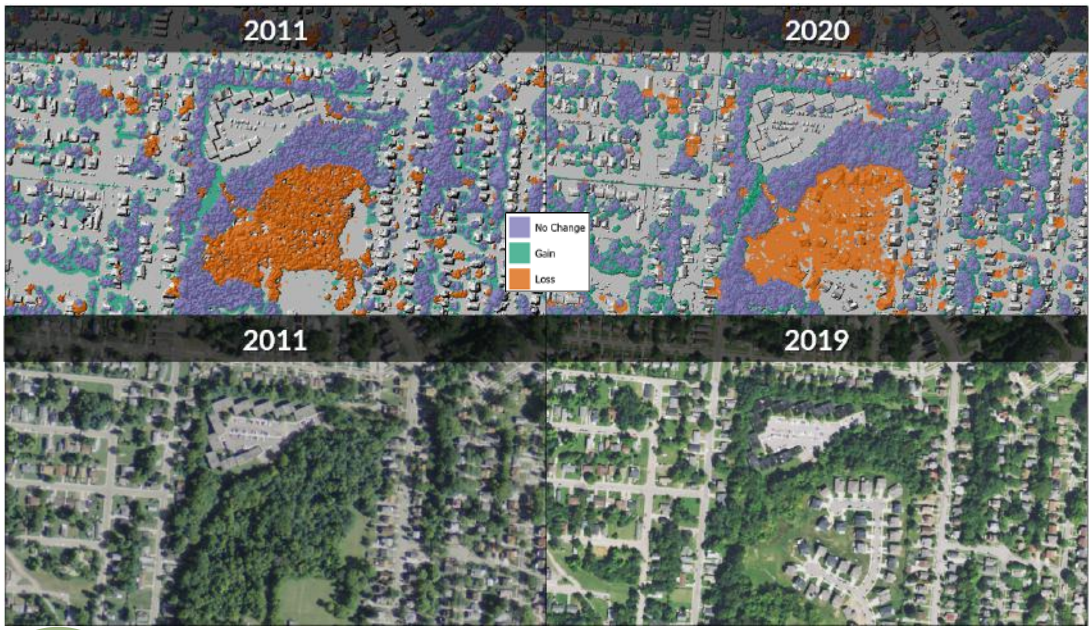


Figure 1. Collegevue Place in Cincinnati. This new residential development resulted in the fragmentation of a forest patch.

Forest Patch Loss

Residential Area

New Construction

Park Redevelopment

Redevelopment projects that prioritize greening can dramatically increase the tree canopy.

Figure 2. Smale Riverfront Park. The redevelopment of the park coupled with tree canopy plantings resulted in a marked increase in tree canopy.

Tree canopy gain

Park

Tree Plantings

Newer Developments

Trees continue to grow and contribute canopy in more established neighborhoods, but age, disease, invasive species, storms, and changing landowner preferences all contribute to removals. As a result, losses may outpace gains over time if replacement trees are not planted.

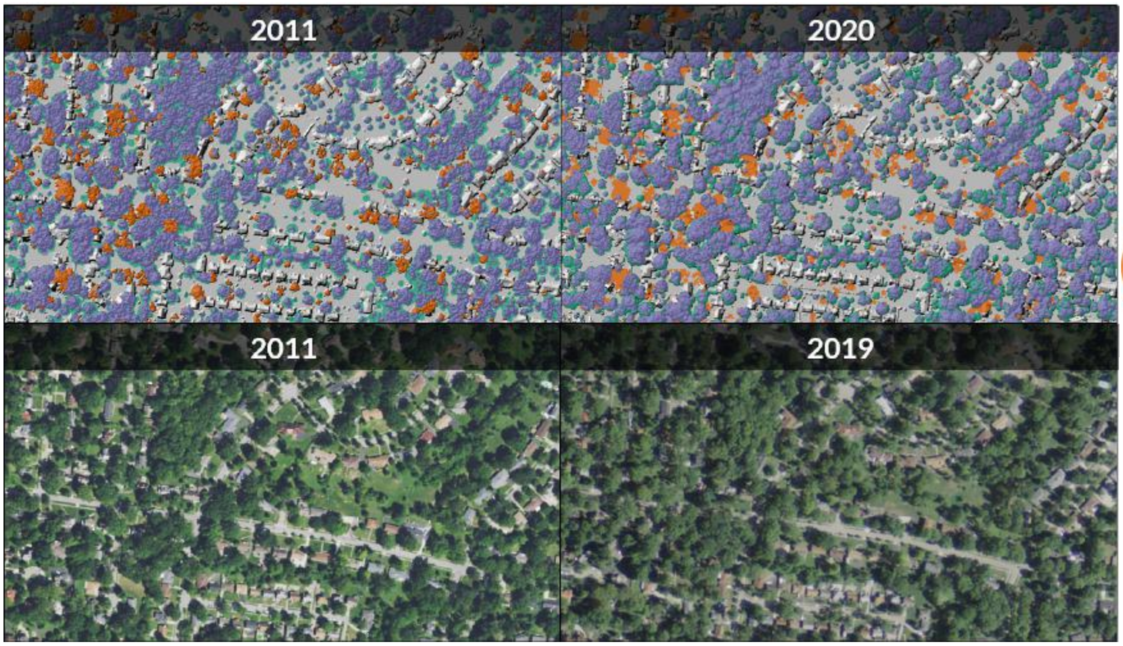


Figure 3. Hollywood Ave and Devonwood Dr. in Cincinnati. Tree removals resulted in an overall decrease in canopy coverage.

Canopy Loss

Gains Have Peaked

Widespread Tree Removal

Commercial & Industrial Areas

There is substantially less tree canopy in the county's industrial and commercial areas. Trees are often removed to provide more room, which is unfortunate given that they would help reduce the urban heat island and stormwater runoff in these impervious surface-dominated areas. Those trees that are left alone contribute canopy despite the less than ideal conditions.

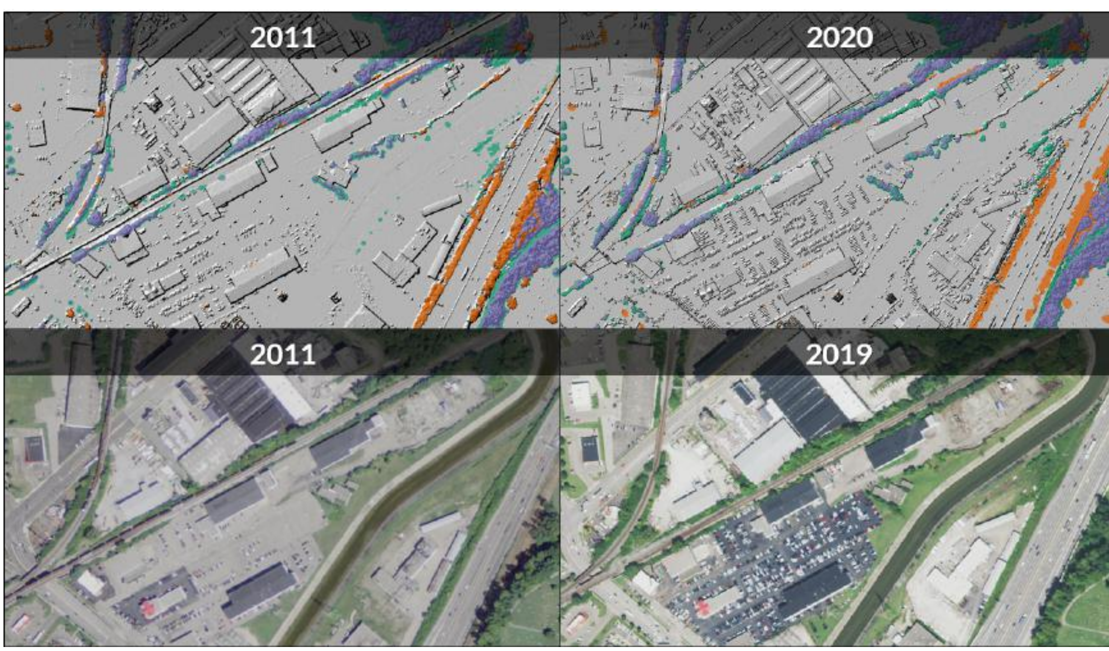


Figure 4. Spring Grove Ave and West Mitchell Ave. in Cincinnati. Trees have been cleared along the transportation corridor but there is also natural growth and new plantings.

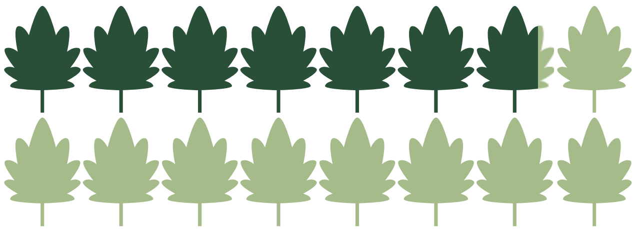
Mix of Loss & Gains

Low Canopy Coverage

High Urban Heat Island

TREE CANOPY METRICS

43.1% *of Cincinnati's land is covered by tree canopy*



Tree canopy and tree canopy change were summarized at various geographical units of analysis, ranging from land use and property parcels to neighborhood boundaries. These tree canopy metrics provide information on the area of Existing and Possible Tree Canopy for each geographical unit.

Existing Tree Canopy

Cities commonly have uneven distribution of tree canopy, a pattern that applies to Cincinnati. There are some 20-hectare hexagons with less than 24% tree canopy and others with nearly 100% tree canopy (Figure 5). This unequal distribution can be traced back to Cincinnati's history of development patterns and open space planning. Those residents who live and work in more treed areas (darker green hexagons) benefit disproportionately from the ecosystem services that trees provide. Conversely, the more urbanized region in the southern part of the city, has lower amounts of tree canopy and therefore receive fewer ecosystem services from trees.

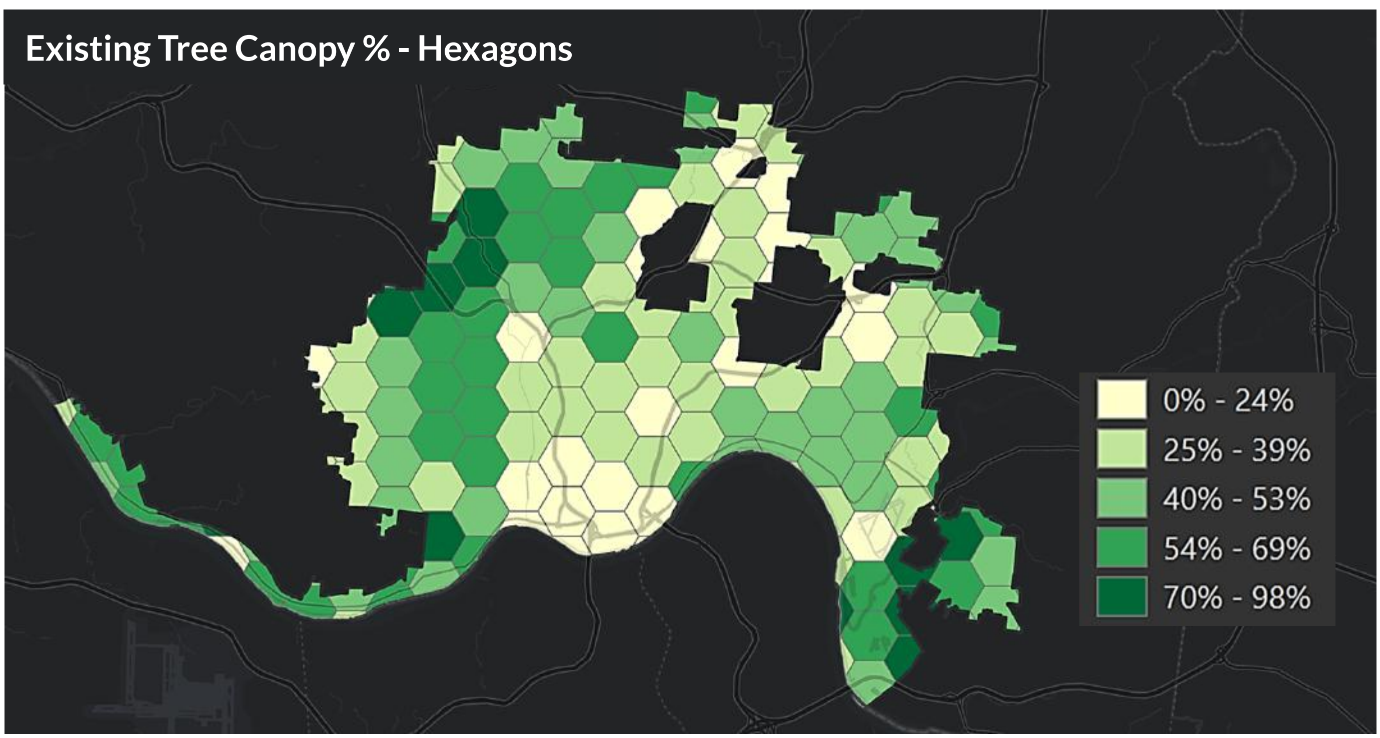


Figure 5. Existing tree canopy percentage for 2020 conditions summarized using 20-hectare hexagons. For each of the hexagons, the percent tree canopy was calculated by dividing the amount of tree canopy by the land area, which excludes water. Using hexagons as the unit of analysis provides a standard mechanism for visualizing the distribution of tree canopy without the constraints of other geographies that have unequal area (e.g., zip codes).

Possible New Tree Canopy

There is available space in Cincinnati to plant more trees. In this assessment, any areas with no trees, buildings, roads, or bodies of water are considered Possible-Vegetation and represent locations in which trees could theoretically be established without having to remove hard surfaces. Many factors go into deciding where a tree can be planted with the necessary conditions to flourish, including land use, landscape conditions, social attitudes towards trees, and financial considerations. Examples include golf courses and recreational fields. While there is open space to plant trees, there is a direct conflict in use; thus, the Possible-Vegetation category should serve as a guide for further field analysis, not a prescription of where to plant trees. With 12,000 acres of land (comprising 23.5% of the city's land base) falling into the Possible-Vegetation category, there remain significant opportunities for planting trees and preserving canopy that will improve the city's total tree canopy in the long term.

In Cincinnati's most densely urbanized areas, significantly increasing the tree canopy will be difficult; nevertheless, it remains vitally important to strive for canopy gains. In the city's residential areas, healthy natural regeneration of the existing tree canopy and planting new trees will be important. There is often a "plant and forget" cycle in residential areas, where trees are generally planted when homes are built, without the follow-up to replace trees as they decline to establish the next generation of canopy.

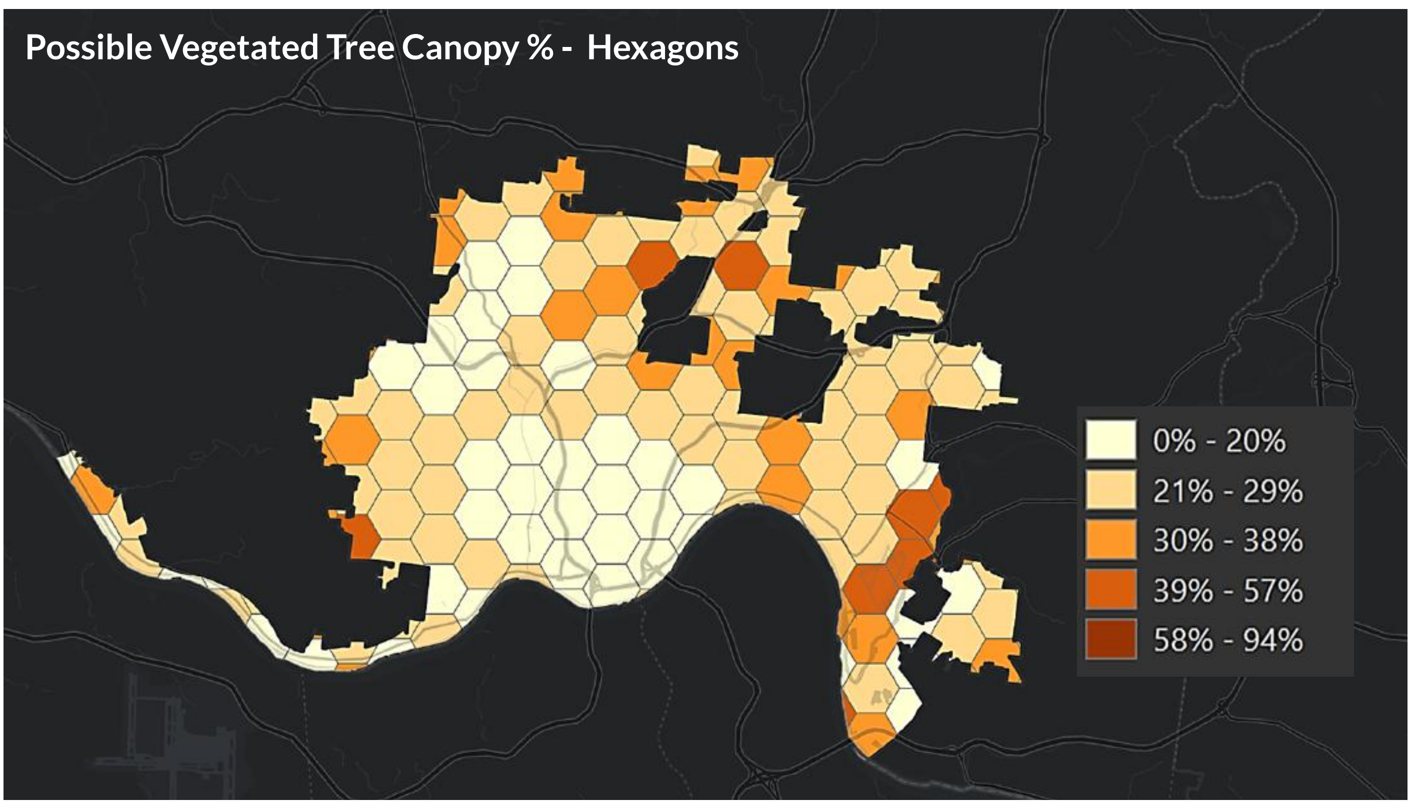


Figure 6. Possible Tree Canopy consisting of non-treed vegetated surfaces summarized by 20-hectare hexagons. These vegetated surfaces that are not currently covered by tree canopy represent areas where it is biophysically feasible to establish new tree canopy. It may be financially challenging or socially undesirable to establish new tree canopy on much of this land. Examples include golf courses, recreational and agricultural fields. Maps of the Possible Tree Canopy can assist in strategic planning, but decisions on where to plant trees should be made based on field verification. Surface, underground, and above surface factors ranging from sidewalks to utilities can affect the suitability of a site for tree canopy planting.

Canopy Change Distribution

The magnitude of tree canopy change across Cincinnati can be measured by the relative tree canopy change over the 2011-2020 period. The relative change is calculated by taking the tree canopy area in 2011, subtracting the tree canopy area in 2021, then dividing this number by the area of tree canopy in 2011. Areas with the greatest change indicate that the canopy is markedly different in 2020 as compared to 2011. In some of the commercial and urbanized areas with little tree canopy in 2011, the growth of street trees resulted in a sizeable relative gain. Conversely, the removal of trees as a result of construction in sparsely treed areas resulted in substantial relative reductions in tree canopy.

The trajectory of Cincinnati's tree canopy in the future is uncertain. There are both environmental and anthropogenic risks facing canopy cover. Invasive species could pose a serious threat if not identified and controlled early. Natural events such as storms can have a mixed impact on the canopy. In conserved areas, tree canopy will return through natural growth, but in urbanized areas, trees lost to storms will need to be replanted. Climate change may cause trees to grow more quickly but could also result in inhospitable conditions for native species. Anthropogenic factors include preservation and conservation efforts and the strength of tree ordinances. Managing these risks will be key to achieving canopy growth.

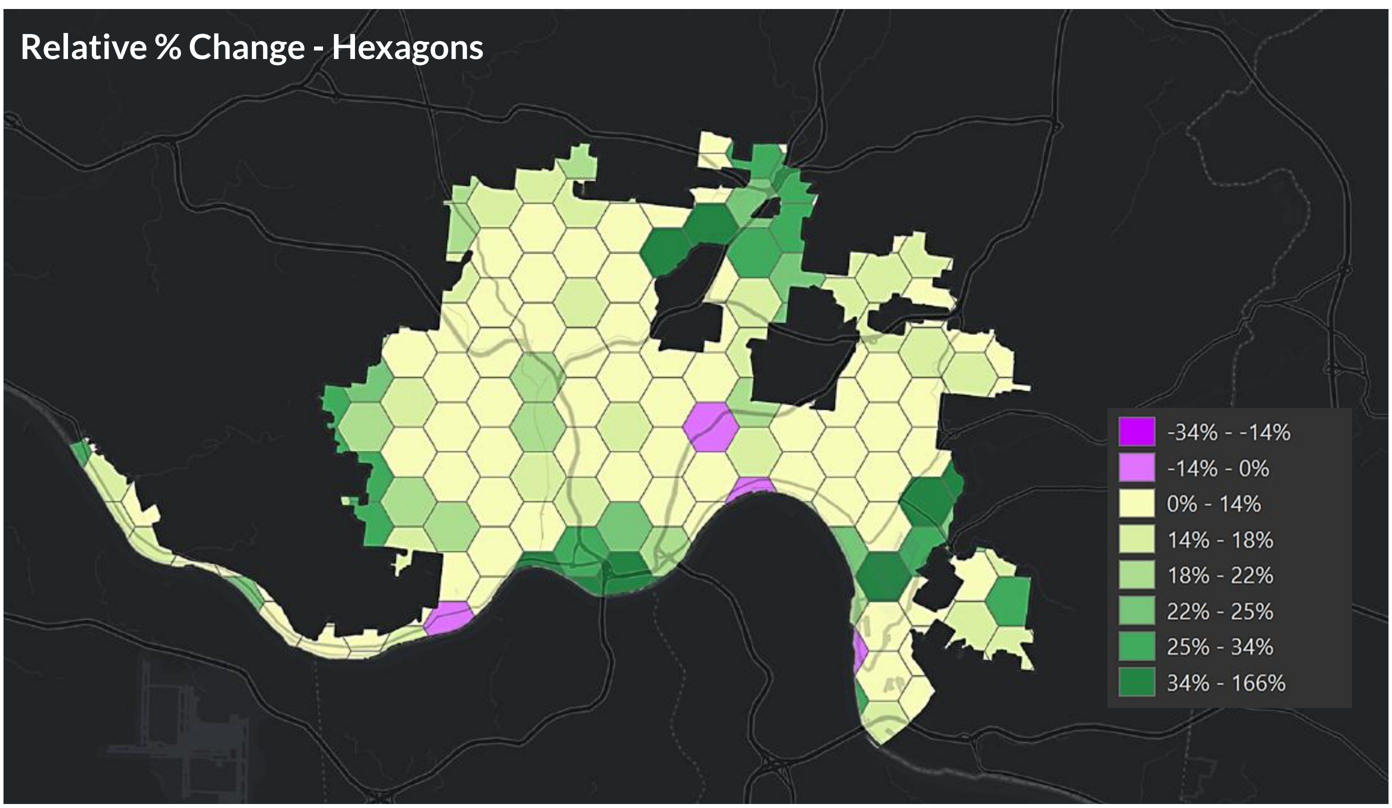


Figure 7: Tree canopy change metrics summarized by 20-hectare hexagons. Relative tree canopy is calculated by using the formula (2011-2020)/2020. Colors are categorized by data quantiles. Darker greens indicate greater relative gain, while darker purple reflects a higher magnitude of loss.

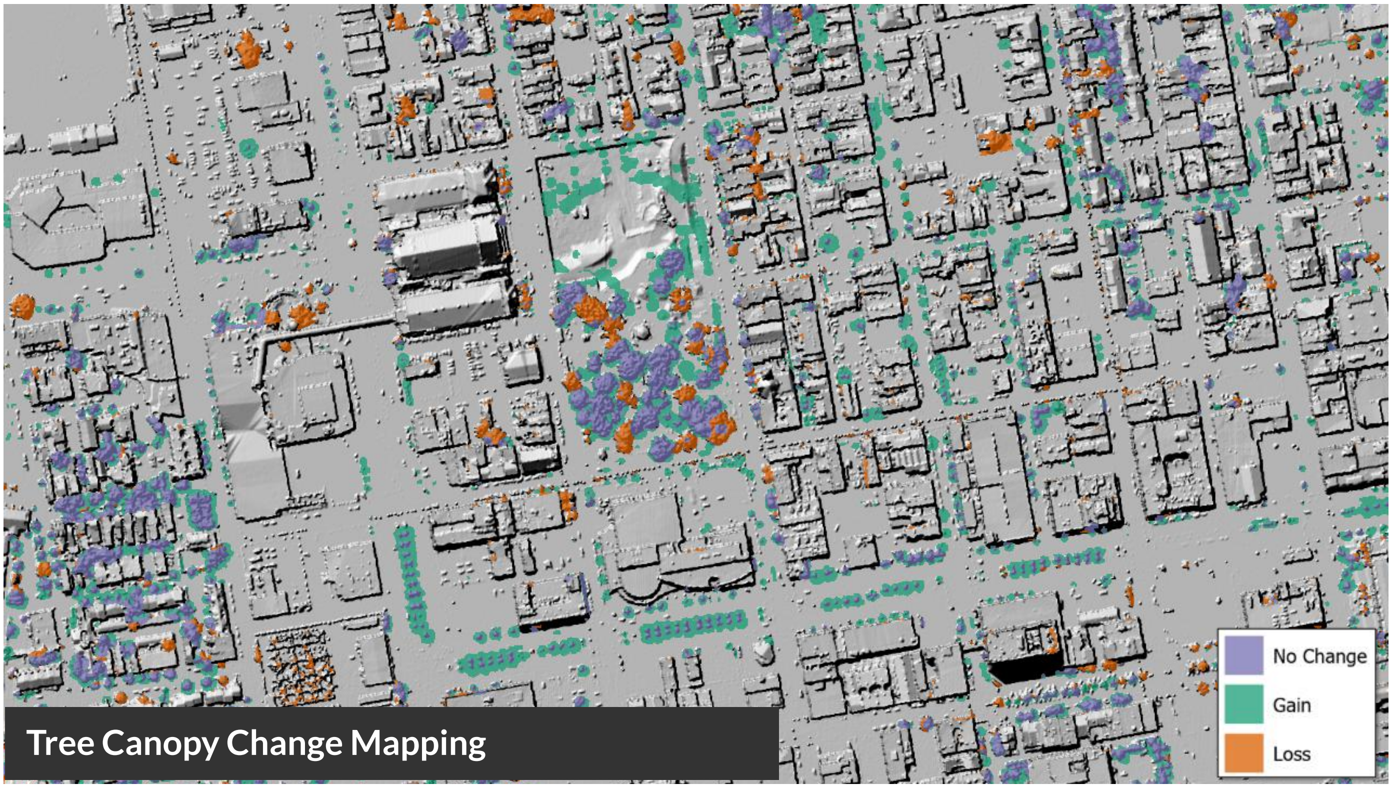


Figure 8: Tree canopy change mapping for the area surrounding Washington Park overlaid on 2011 LiDAR. This area experienced a mix of gain and loss, but the rapid growth of trees planted prior to 2011 resulted in overall growth.

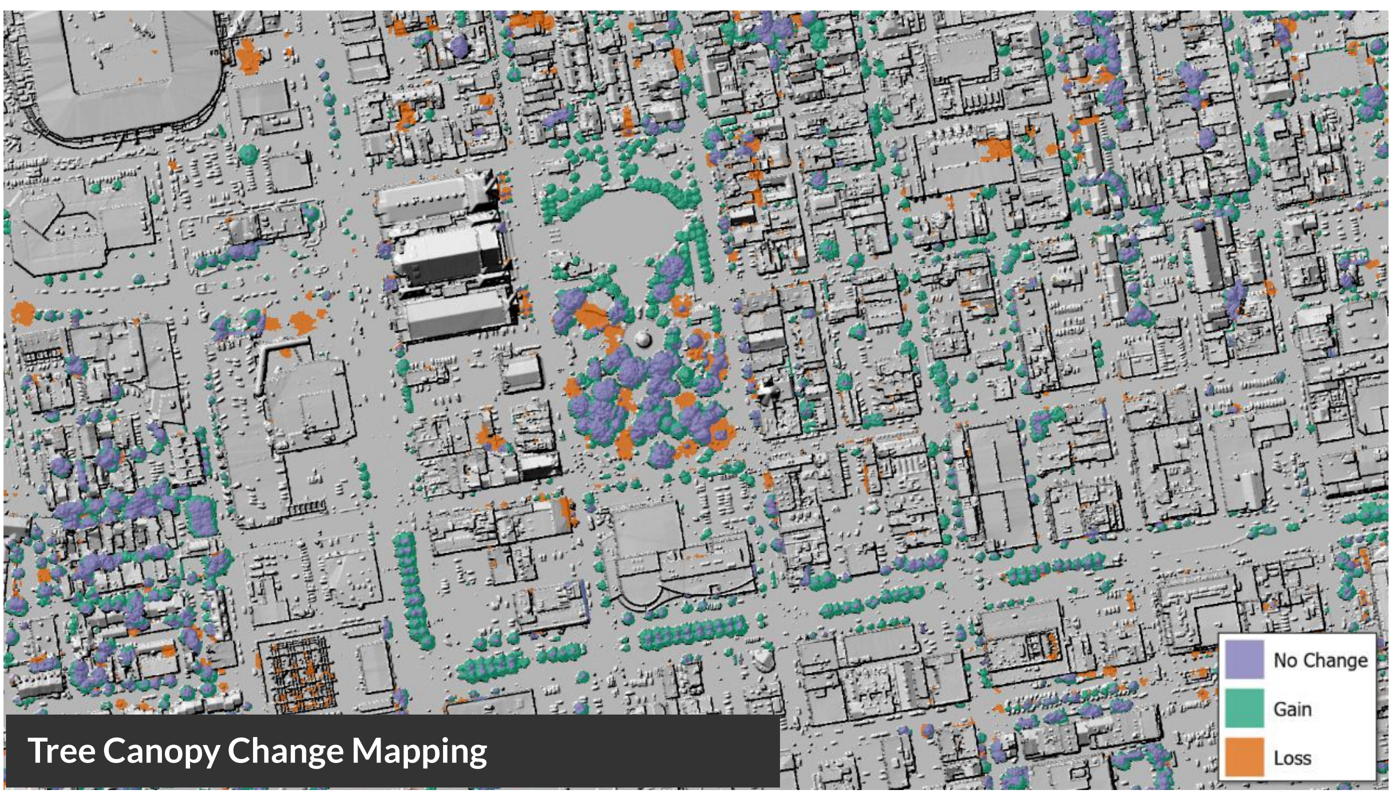


Figure 9: Tree canopy change for the same area above but overlaid on the 2020 LiDAR. The areas of gain appear rough now that tree canopy is present, and the areas of loss appear smooth due to the absence of tree canopy.

Neighborhoods

In Cincinnati, neighborhoods are areas that most residents can easily relate to, especially the neighborhoods in which they live, work or visit most often. The city's official neighborhood geographic boundaries are a useful way to summarize tree canopy and draw comparisons between neighborhoods.

Downtown had the greatest relative gain of over 50% despite having amongst the lowest existing tree canopy of less than 10%, which is the result of renovations and replanting efforts of Smale Riverfront Park. The neighborhood of Mt. Washington had the greatest absolute change with nearly 8% gain and an existing canopy of nearly 60%. The differences in canopy is the result of land use history and changes to the built environment. Neighborhoods with large parks and open space or those that have lower density development tend to have more canopy, while neighborhoods that are more dense with commercial or industrial use tend to have less tree canopy. All neighborhoods experienced both gain and loss within their boundaries, but overall gain outpaced loss across Cincinnati, amounting to an overall gain in canopy from 2011-2020.

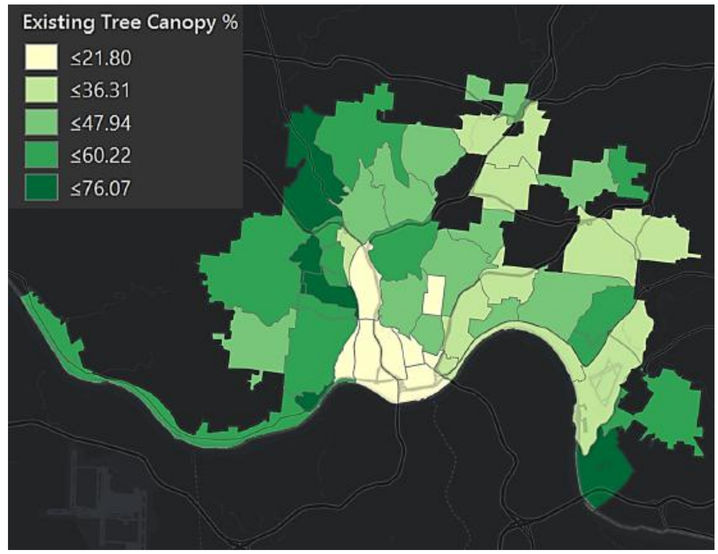


Figure 10: Existing tree canopy percentage for 2020 conditions summarized by neighborhood.

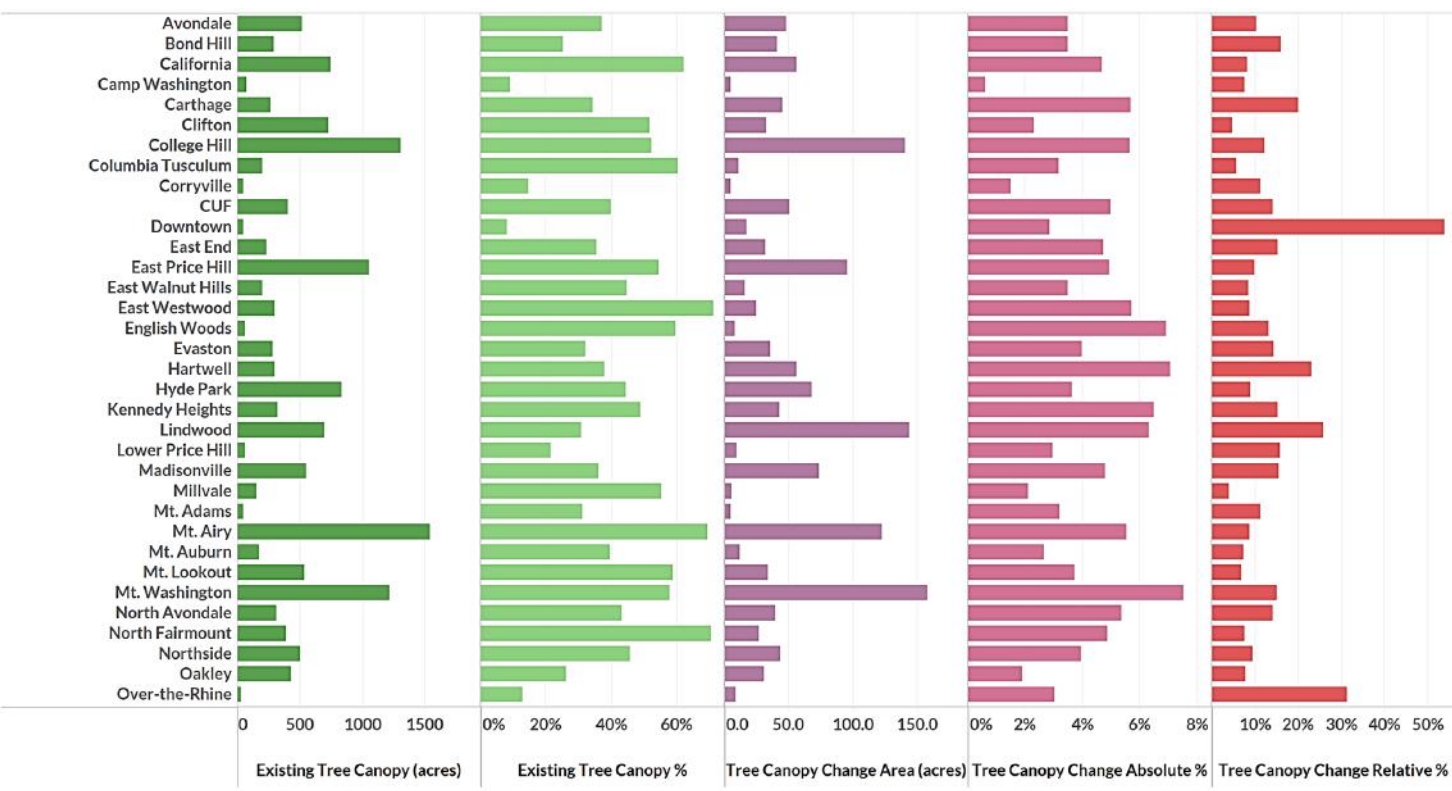


Figure 11: Tree canopy and change metrics by neighborhood.

Land Use

Land use is how humans make use of the land including the economic and cultural activities (e.g., agricultural, residential, and commercial) practiced in the city. Land use is not to be mistaken by land cover which refers to landscape features, such as trees, buildings, water and other classes mapped as part of this study. For example, residential land use can contain trees, buildings, impervious ground cover, grass, and other land cover features. Land use can significantly influence the amount of tree canopy and the room available to establish new tree canopy.

Residential land controls the majority of tree canopy (over 9,000 acres), followed by publicly owned land (about 6,800 acres) and the right-of-way and commercial (both have about 2,300 acres). In general, Cincinnati's residential land has excellent tree coverage, with over 50% of the land covered by tree canopy. The amount of loss on residential land is cause for further monitoring. Over 900 acres of tree canopy were lost in the 9 year period. While loss was offset by 1,900 acres of gain, resulting in a net gain of nearly 1,000 acres, watching to see if this trend continues in the long range is important. Gain outpaced loss on all land use categories.

Street trees not only make roads more aesthetically pleasing, but they also play an important role in reducing stormwater runoff and decreasing the urban heat island effect. The ROW gained nearly 800 acres of canopy in 9 years. Trees in the ROW face inhospitable conditions associated with their close proximity to roads. Regular salting, compaction, limited space, clearance pruning, and vehicular collisions are some of the challenges that limit canopy establishment and growth in these harsh environments. Car crashes are a major issue in Cincinnati and have claimed pedestrian lives in recent years. In some places, trees can act as visual cues to slow cars down, and can be explored as the city conducts studies on traffic calming in business districts. The gain in the ROW is a sign of the city's effective tree management, investment in the urban forestry assessments, and continued funding that are appreciating over time.

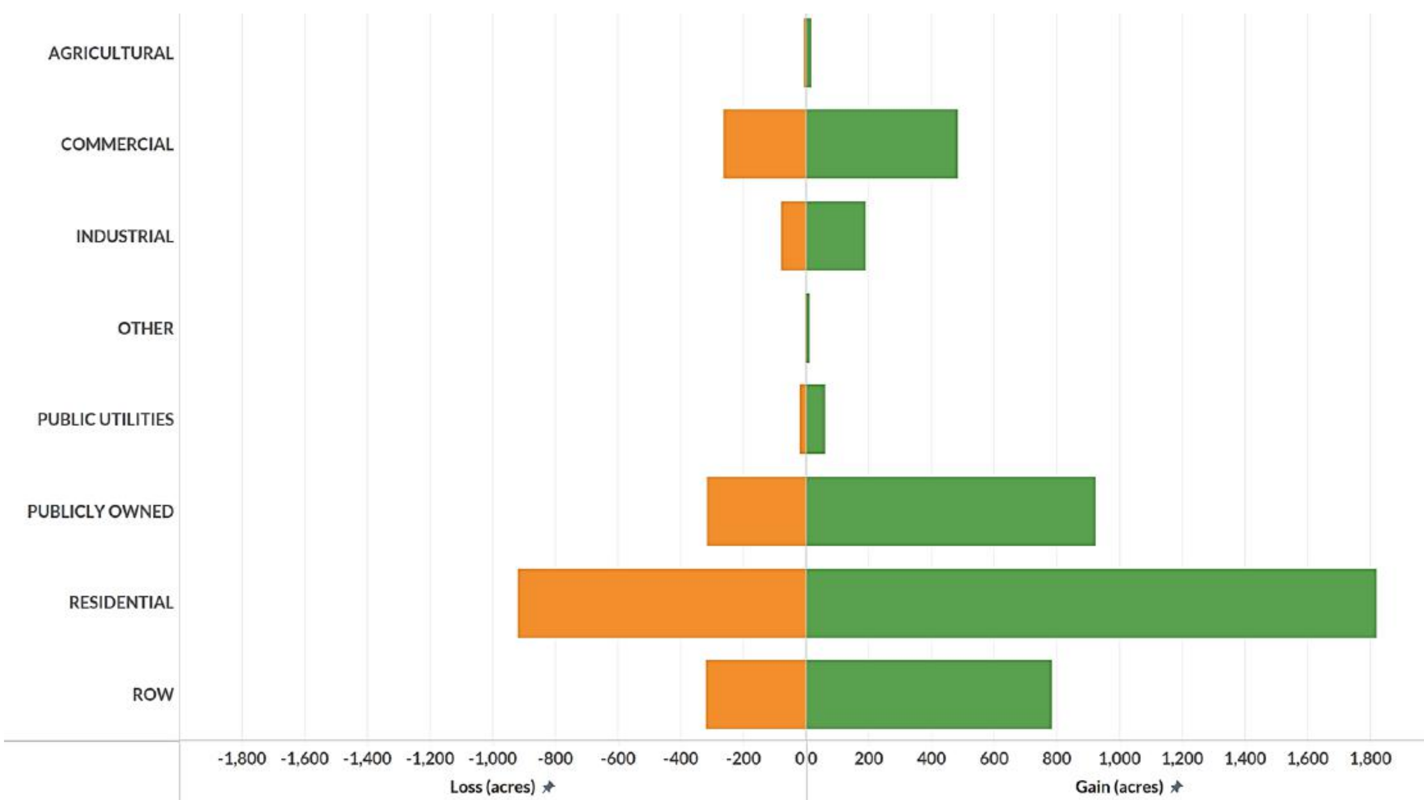


Figure 12: Tree canopy and change metrics for generalized land use categories.

Land Use (continued)

The most opportunity to establish new canopy (possible-vegetation) is on residential and publicly owned land. While the city does not have direct influence over residential land, establishing trees on publicly owned land can be achieved through collaboration and partnerships with different public land owners. Establishing new canopy in the rights-of-way (ROW) will be costly due to potential hardscape modifications needed to create more space, but are worthwhile investments given the critical ecosystem services that street trees provide. In order for Cincinnati to maintain and grow its tree canopy into the future, government, institutions, businesses, and residents must all be involved and see the value in this crucial green infrastructure asset.

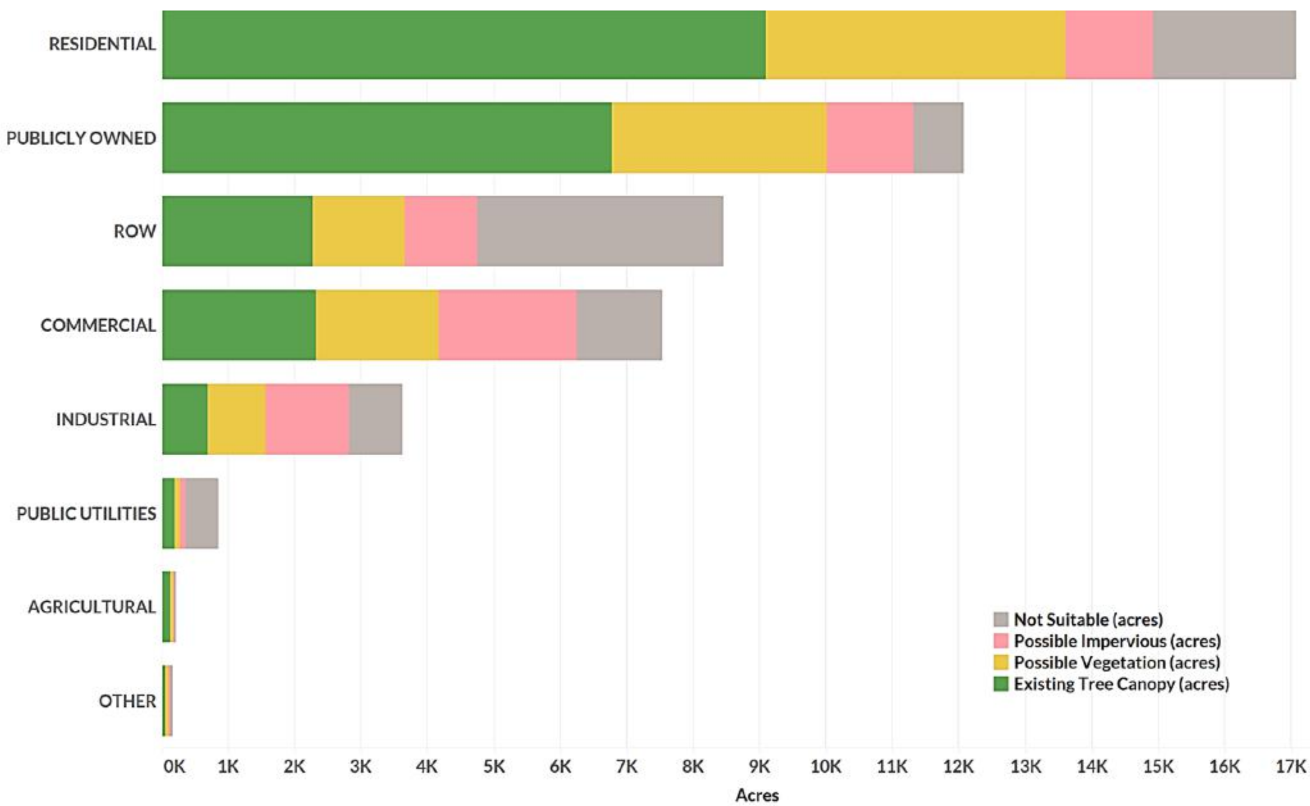


Figure 13: Acres of Cincinnati land broken down by Existing Canopy, Possible-Vegetated, Possible-Impervious and Not Suitable for each generalized land Use class. Residential land has the most tree canopy and the most room for establishing new tree canopy.

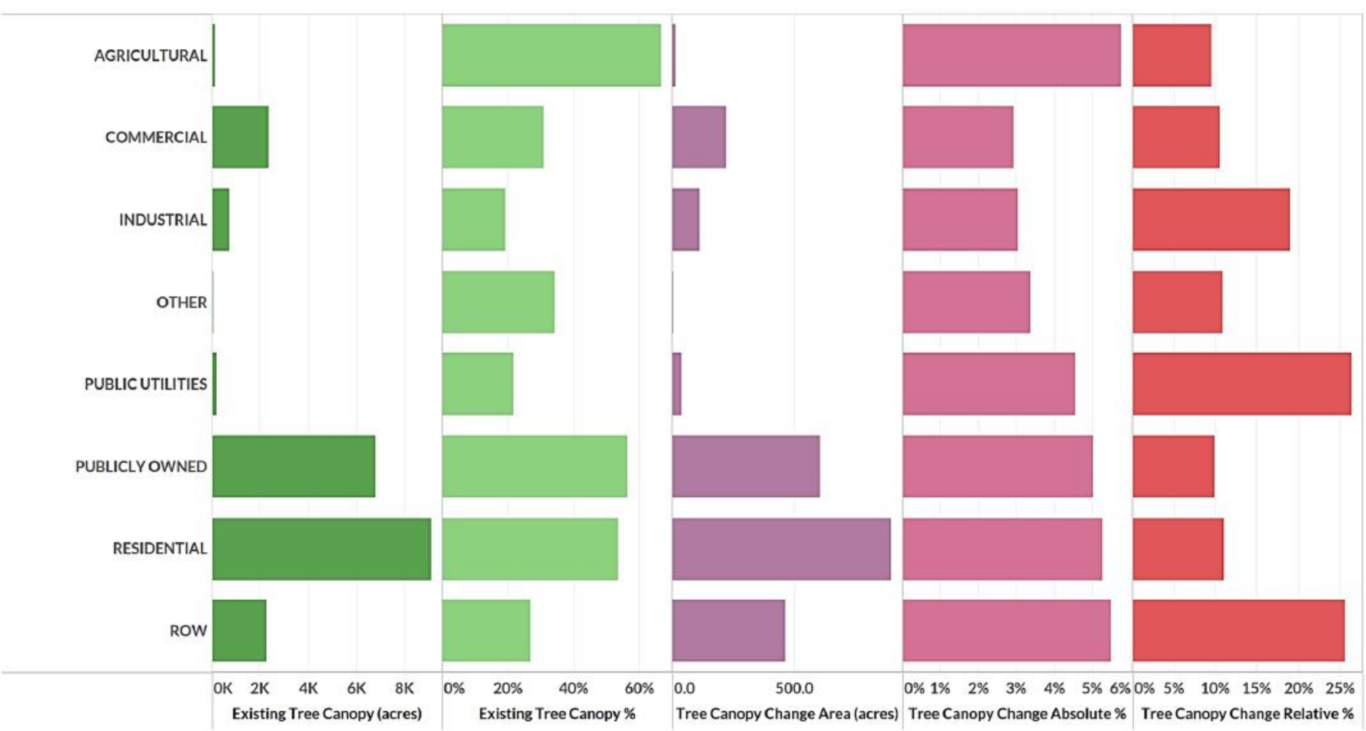


Figure 14: Tree canopy and change metrics for generalized land use categories. Residential land has the largest area of tree canopy change but the relative change was comparatively low to other land uses. The greatest relative change occurred on utility land and within the rights-of-way.

EQUITY & ENVIRONMENTAL JUSTICE

Environmental Equity & Urban Resilience

Like many cities in the United States, Cincinnati faces environmental risks and challenges relating to the urban environment. Trees, when properly cared for, can serve as a solution to create a sustainable and more resilient city. However, resiliency requires preparedness to overcome shocks to the city and community, and a crucial component of city resilience are its residents.

Thus, to enhance urban resilience, we recommend Cincinnati targets neighborhoods lacking access to tree canopy cover, and for tree planting prioritization to be further informed by the distribution of demographic groups that are typically more susceptible to environmental risks. These include historically marginalized populations like racial and ethnic minorities and residents living in poverty.

In Cincinnati, distributions of census blocks with greater presence of Black residents and little tree canopy cover closely resemble the distributions of census blocks with greater presence of low-income residents and little tree canopy. It is likely that these demographics, which are typically interrelated, are also more exposed to environmental challenges due to a lack of trees available to provide important benefits that mitigate them.

SUCEPTIBILITY AND INEQUITY

-

VARIOUS DEMOGRAPHICS* ARE AT GREATER RISK AGAINST ISSUES THAT IMPACT CITIES

*Other demographics at risk besides those illustrated include:

- Hispanic population
- Individuals that had strokes
- Children younger than 5
- Adults older than 65
- Individuals exposed through daily commuted (walking or public transportation)
- Individuals living in areas with hazard risk like sewage overflows

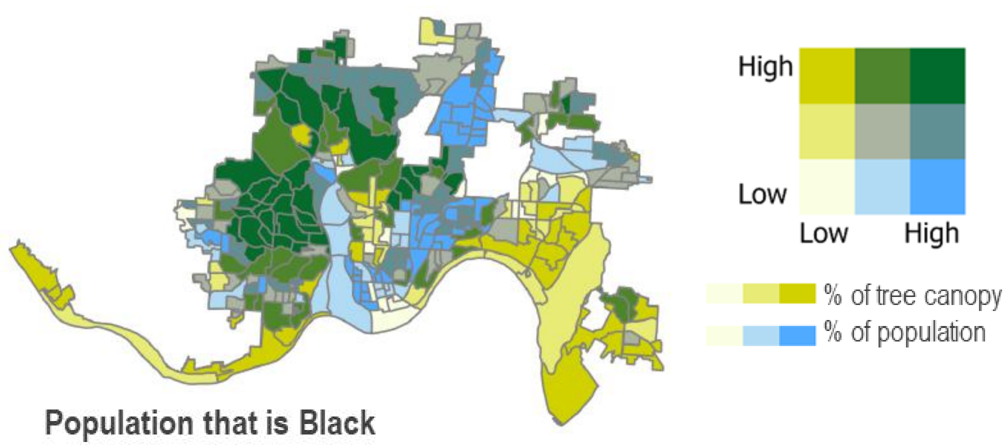


Figure 15: These maps show tree canopy cover in relation to two demographic groups that are highly interrelated and that typically are within the most susceptible groups against environmental challenges. Shades of green indicate tree canopy percentage by block group, with the darkest shade indicating higher percentages. Meanwhile, shades of blue indicate percentage of residents within each of the demographic groups, with the darkest shade indicating higher percentages.

Other factors can increase susceptibility of a given population to the environmental issues impacting cities, but many of these additional factors are issue-dependent. For example, residents with a previous history of asthma are at greater risk against air pollution.

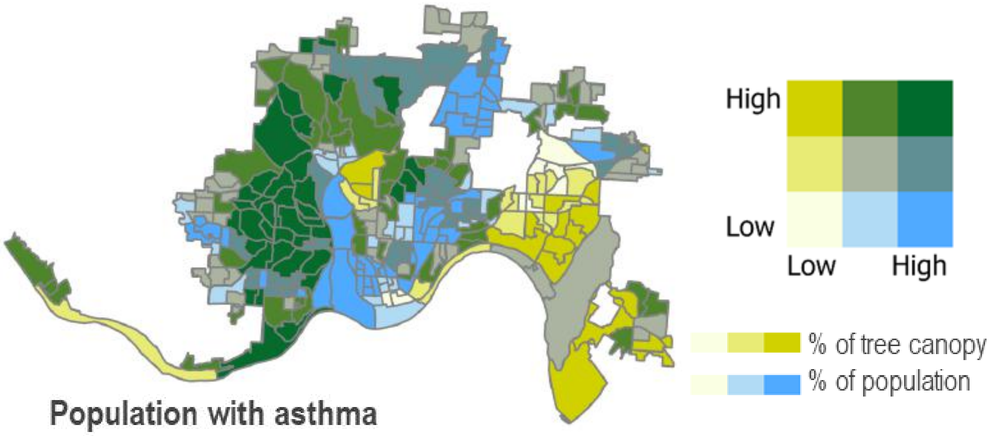


Figure 16: This map shows the relationship between tree canopy cover (%) and residents with asthma (%) by block group. Asthma is just one of many additional factors that can increase risk of residents against environmental issues that typically impact cities. Environmental risk is also greater for residents with other pre-existing conditions like a cardiovascular disease. It is also greater for young children and seniors, and for residents living in areas with hazards like sewage overflows.

To ensure resilience goals are pursued in an equitable and socially just manner, we recommend the City of Cincinnati adopts a tree planting prioritization plan where neighborhoods, at a block group level, are prioritized for tree planting based on their overall sensitivity to key urban issues targeted for management. The overall importance of targeted issues, whether environmental or relating to community susceptibility or inequity, are ranked based on stakeholder input (specific stakeholder rankings shared in page of this report).

Neighborhood Prioritization Workflow

A. Assess targets or challenges that will be addressed through canopy expansion

1. ENVIRONMENTAL TARGETS

- REDUCE FLOOD RISK: *Modeled using InVEST*
- IMPROVE AIR QUALITY: *Represented with PM 2.5*
- MITIGATE HEAT ISLAND: *Modeled using InVEST*
- HOLISTIC: *Targets flood risk, air quality and heat island (mapped as described above)*

2. SUSCEPTIBILITY TARGETS

- TOTAL POPULATION >5 OR >65 YEARS OLD: *From American Community Survey (ACS) data*
- NUM. RESIDENTS COMMUTING BY BUS OR WALKING: *From ACS data*
- EXPOSURE THROUGH OTHER RISKS: *From city health data and data on sewage overflows*

3. SOCIAL EQUITY TARGETS

- TOTAL POPULATION IN POVERTY: *From ACS data*
- RACIAL/ETHNIC MINORITY GROUPS: *From ACS data*

B. Summarize all data types by block groups to prepare for neighborhood prioritization

C. Rank the importance of each type of target in pursuing city-wide resilience

D. Identify neighborhoods to prioritize for canopy expansion based on final weighted sum of ranks

E. Develop tree planting plan based on planting goal (30,000 trees) and neighborhood score

Figure 17: The Neighborhood Prioritization Workflow informs tree planting in an equitable and socially just manner while pursuing city-wide resilience goals that address important issues affecting the City of Cincinnati (e.g., flooding, air pollution and rising temperatures). The workflow suggests how to allocate 30,000 trees across Cincinnati through a multi-step analysis that integrated various data types and stakeholder input to weight the various variables being considered. The suggested tree allocation was tested for feasibility through tree growth projection and potential canopy area from this report. The Neighborhood Prioritization Workflow was adapted from the Shade Equity methodology developed by Esri experts Andrew Makowicki and Lauren Scott Griffin. ACS data refers to data obtained from 2019 American Community Survey.

COMMUNITY NEEDS & TREE PLANTING

Environmental Issues & Neighborhood Prioritization

Flooding, air pollution and rising temperatures are three environmental challenges that impact the City of Cincinnati. Following the Neighborhood Prioritization Workflow, we evaluated community sensitivity to each of these issues, incorporating both susceptibility (including health and hazard data provided by the city, and commuter data from the American Community Survey) and social equity factors (specifically, race, ethnicity and income data from the American Community Survey) to identify the most vulnerable block groups.

These maps can be used to determine tree planting allocation of the 30,000 total trees that the City of Cincinnati is committed to plant in the coming years to strengthen community resilience, and offer an opportunity to evaluate Cincinnati's current ecological performance in decreasing community vulnerability.

Reducing flood risk

Flooding is of great concern for the City of Cincinnati. Surface runoff, as mapped with the Urban Flood Risk Mitigation module of the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) tool, is poorly retained through the city. In addition, when accounting for areas with previous history of sewage overflow along with health vulnerability and social inequity, several risk hotspots are identified (dark-shaded areas in community sensitivity map). The proposed tree allocation suggests distributing trees to relieve exposure of block groups with greater risk of flooding.

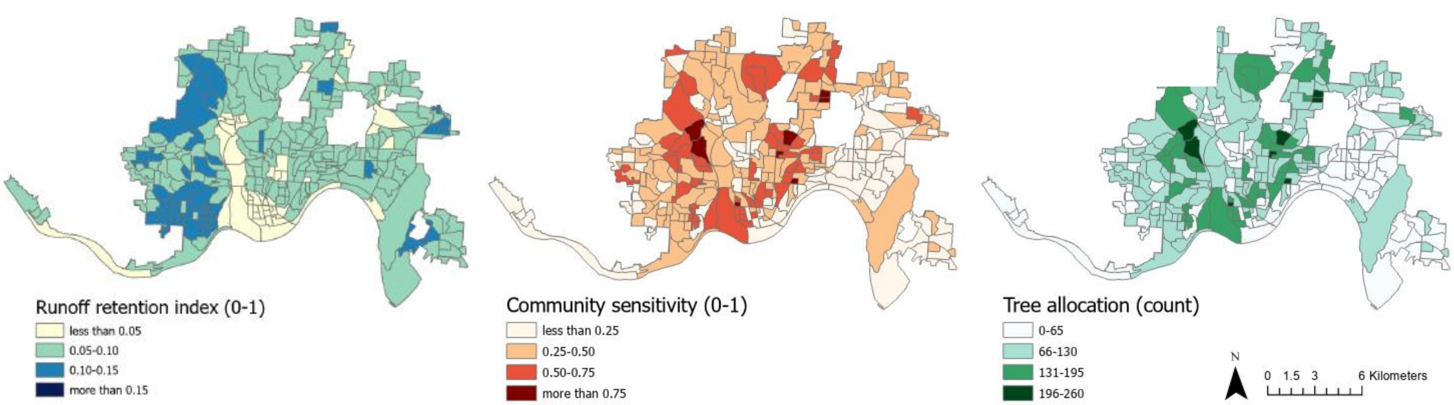


Figure 18: The runoff retention index indicates retention of surface runoff as mapped. The map ranges from zero (indicating low retention of runoff) to one (indicating high retention of runoff). The community sensitivity index shows block group values of risk against flooding, which integrates the runoff retention map, data on sewage overflow, and data on community susceptibility and social equity. The map ranges from zero (indicating low sensitivity against flooding) to one (indicating high sensitivity against flooding). Lastly, the corresponding tree allocation map includes the number of trees from a total of 30,000 that could be planted in each block group to enhance block group resilience against a flooding event.

Improving air quality

Small particles in the air can engrain into our lungs and cause harm. Most of Cincinnati has a 8.4 to 8.5 content of air pollutants that are 2.5 microns or smaller in size. This PM2.5 data was integrated to health and census data, along with other vulnerability data and social equity factors, to assess the sensitivity of residents against air pollution, particularly for those with asthma. Several risk hotspots are identified (dark-shaded areas in community sensitivity map), and a proposed tree allocation suggests distributing trees to relieve exposure of block groups against air pollutants due to the greater risk of its residents to suffer from a pulmonary issue.

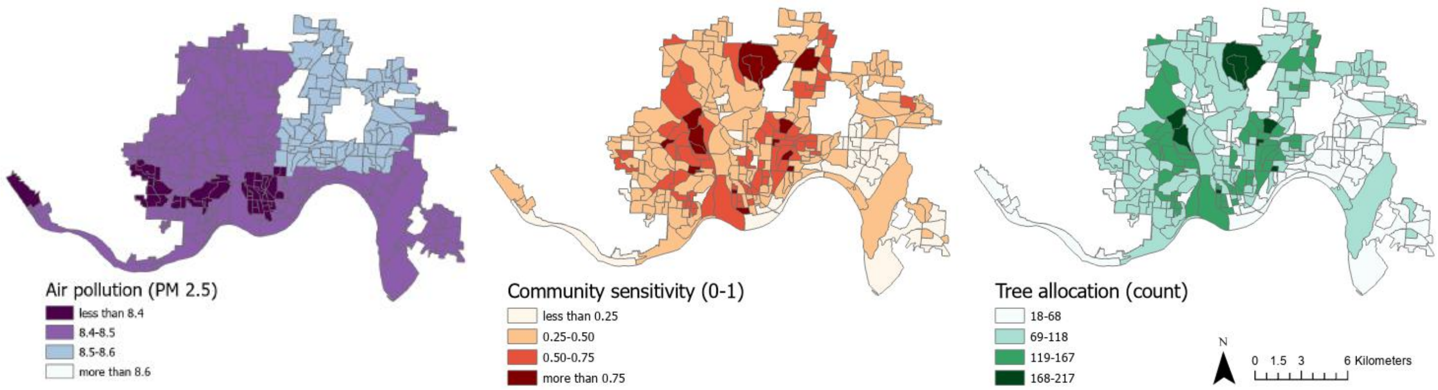


Figure 19: The air pollution map indicates the amount of particles in the air that are 2.5 microns or smaller in size. The air quality priority index has block group values ranging from zero (low priority for targeting air quality susceptibility) to one (high priority for targeting air quality susceptibility). The corresponding Tree allocation map includes the number of trees from a total of 30,000 that could be planted in each block group to strengthen resiliency.

Mitigating rising temperatures

The heat island effect considerably affects cities, and rising temperatures can result in fatalities (particularly among the elderly and those with cardiovascular diseases). The capacity of local vegetation to mitigate rising temperatures varies throughout Cincinnati's urban landscape, but some higher risk block groups can be identified (dark-shaded areas in community sensitivity map) to determine where trees could be allocated to relieve exposure of its most susceptible residents against extreme heat events.

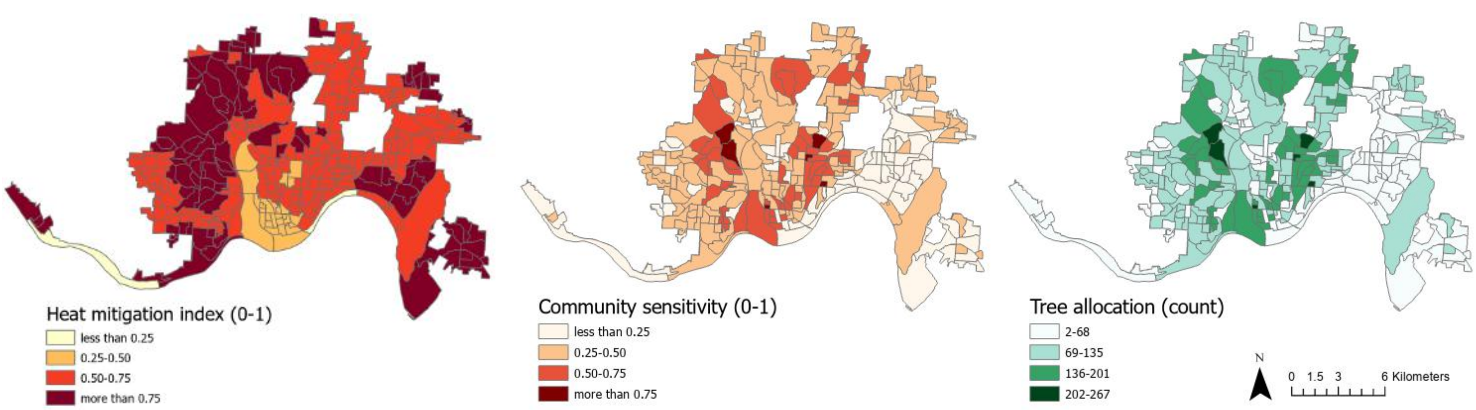


Figure 20: The heat mitigation index ranges zero (low mitigation capacity) to one (high mitigation capacity) and was modeled with InVEST. The community sensitivity index shows block group values ranging from zero (low priority for targeting heat island susceptibility) to one (high priority for targeting heat island susceptibility). The corresponding tree allocation map includes the number of trees from a total of 30,000 that could be planted in each block group to strengthen resiliency.

Targeting All Environmental Challenges Simultaneously

A city needs to be able to overcome different environmental shocks. Achieving urban resilience, thus, entails addressing multiple targets simultaneously. To best represent the City of Cincinnati's priorities in achieving urban resilience goals, stakeholder input was used to rank or weight the three environmental challenges (flooding, air pollution and rising temperatures) in a holistic targeting scenario to inform tree planting. This holistic targeting scenario follows the Neighborhood Prioritization Workflow described in this report and only differs from the individual environmental targets' scenarios (from the previous two pages) in its environmental ranking. Ranking of susceptibility and social equity variables, also determined by stakeholders, remained the same throughout all approaches.

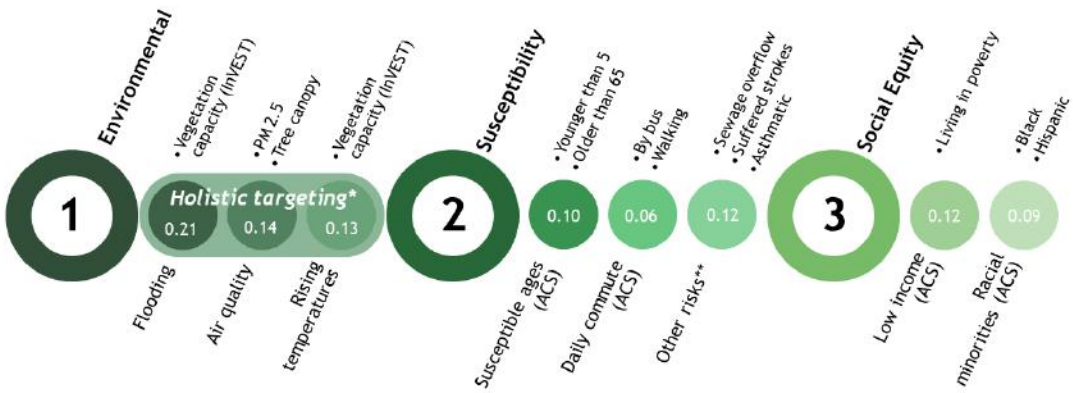


Figure 21: Rankings from stakeholder input. *A "Holistic" approach addresses all three environmental issues simultaneously (holistic ranking is the sum of the individual ranks for each environmental target). The approach was adapted from the Shade Equity methodology from Esri experts Andrew Makowicki and Lauren Scott Griffin. **Other risks vary by the environmental target in question, but all count in the "Holistic" approach.

In the holistic index map below, dark red block groups show high priority for planting trees based on the three combined environmental targets: flooding, air pollution, and rising temperatures. To ensure resilience for the City of Cincinnati, we recommend targeting block groups shaded the darkest (>0.75) first, followed by those ranking less (i.e., >0.5, >0.25, etc.) on a multi-year planting plan. An allocation plan for 30,000 trees is provided in a smaller inset map as example of how this index can be applied in practice.

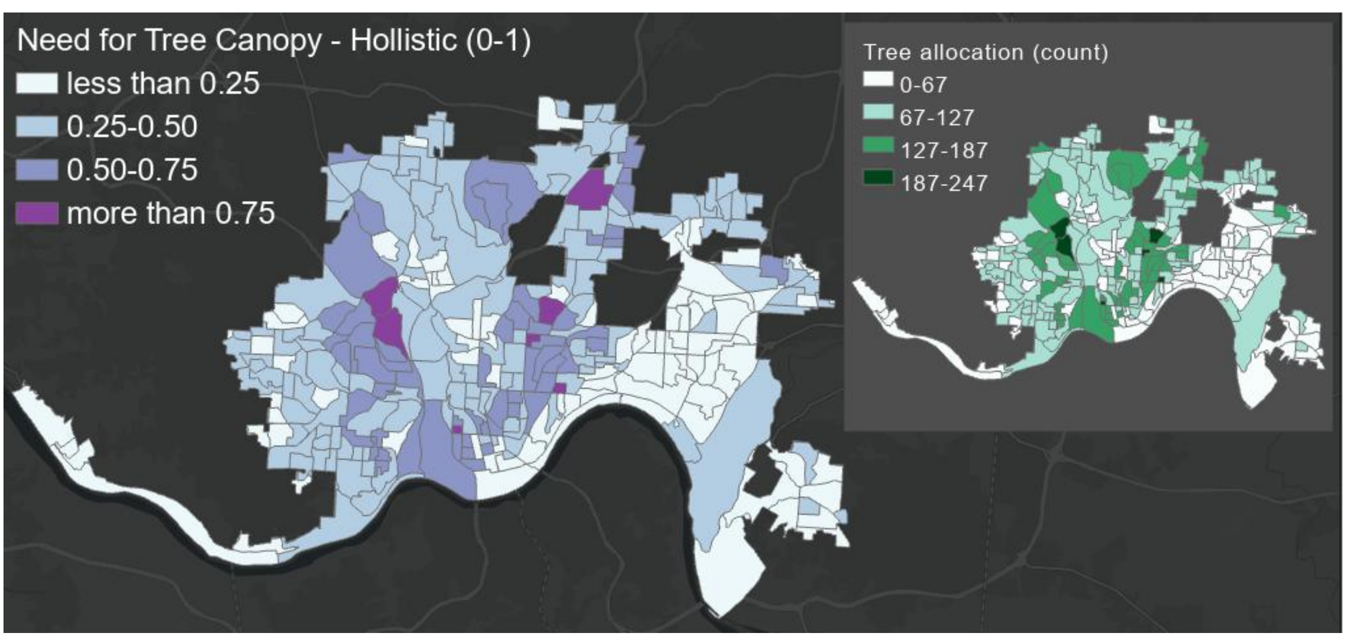


Figure 22: Holistic index map represents block group values ranging from zero (low priority for targeting holistic susceptibility through tree planting) to one (high priority for targeting holistic susceptibility through tree planting). The Tree allocation map on its right is an example of how the holistic index can be used to allocate 30,000 trees to strengthen resiliency at the census block group scale. 30,000 trees was multiplied by the quotient between the index in a given block group and the sum of all indexes.

This assessment was carried out by This assessment was carried out by AppGeo in collaboration with the City of Cincinnati, the University of Vermont Spatial Analysis Lab, Zamin Studio, and SavATree. The methods and tools used for this assessment were developed in partnership with the USDA Forest Service. The source data used for the mapping came from Cincinnati and the USDA. The project was funded by the City of Cincinnati. Additional support for data analytics came from a Catalyst Award from the Gund Institute for Environment at the University of Vermont. Computations were performed on the Vermont Advanced Computing Core supported in part by NSF award No. OAC-1827314.

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