Urban Forestry and Tree Canopy: A Pathway to Climate Resilience”

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## Abstract

***Background:*** Urban habitats face many challenges with its environment, infrastructure, and social systems. Urban forests play an important role in urban ecology but continue to face many threats directly and indirectly. Climate change, insects, disease, and urbanization have been found to be the major causes for the decline in urban forests. Tree canopies play a major role in urban forestry and ecosystem services providing the advantages of a natural, cost effective system of green infrastructure, air, and water pollutant removal, regulate energy use, and improve water quality. ***Methods:*** The class collected tree canopy data using the i-Tree tool designed to provide an estimate of ecosystem service benefits and the Tree-Snap tools designed to allow citizens to make observations of trees in local communities and provide these observations to scientists who will catalog these tree observations. ***Results:*** Within the Washington, DC landscape, trees provide a host of benefits that are determine in monetary value. The results further showed the variety of tree species in the Washington, DC area which adds to the biodiversity of our tree canopy and affirms that Washington, DC is moving towards a climate resilient city. ***Conclusion:*** Washington, DC has increased its effort to become a climate resilient city particularly as it strives to attain its place as one of US most sustainable cities. As urban sustainability majors, this project has enlightened our understanding to the real meaning of urban sustainability and a climate resilient city.

## Introduction

Recently, the Environmental Science Senior Project class participated in the development of an urban forestry tree canopy workshop held in Washington, DC on March 10, 2020. While the conference in and of itself was interesting we learned much about how urban forestry and ecosystem services are closely linked, which surprised us. Our class decided to investigate the concepts of urban forestry and tree canopy and determine how this could be a pathway to climate resilience. Most of the students in this course are residents of the Washington, DC metropolitan area where trees are plentiful in number and variety.

At the outset of our semester, we learned that our service-learning involved working with university partner, Casey Trees, as citizen scientists to conduct evaluations and measurements of trees in local neighborhoods. Our opportunity to engage in this project was cut short following Washington, DC Mayor's order to "stay-at-home" as a safety measure from the COVID-19 pandemic. As students we had to comply; nevertheless, our professor found an innovative way for us continue our service-learning project of tree canopy observations by using two internet-based tools; i-Tree tool and Tree-Snap. These tools allowed us to collect data, limited to the trees in our neighborhood and to upload our observations to the tool's websites, and use the data in our final research paper.

With approval from our instructor and an innovative way to collect data, our class made this service-learning component of our senior class project to evaluate Washington DC tree canopy from five different aspects. This paper will evaluate urban forestry and tree canopy from the lens of ecosystem services, human health, mitigation strategies, threats to urban forests, and policies related to urban forests. We begin our discussion by defining urban forestry and the role of tree canopies.

## Background

Current research suggest there is lack of clarity on the definition of urban forestry; however, in this paper we will rely on Lin, Kroll, Nowak, and Greenfield's (2019) definition in that "urban forest contains, trees, shrubs, lawns and pervious soil in urban areas"(2019, p.2). These authors further noted that a better understanding is to see urban forestry as two distinct terms, "urban" and "forestry" suggesting that urban systems are multifactorial that includes environmental functionality, social equity, and economic viability (Lin et al., 2019). Given the complexity of urban forestry concepts, our group chose to stick with Lin's et al, simple definition.

Tree canopies play a major role in urban forestry and ecosystem services providing the advantages of a natural cost-effective system of green infrastructure. Trees capture air and water pollutants, as they provide shade, habitat, and even social organization. These services offer significant value and has been quantified to capture that value (Turner-Skoff and Cavender, 2019). From an ecosystem services perspective, urban forestry reveals that the very existence of the character within the urban areas occurs as both a conceptual and a physical construct.

*Ecosystem Services*

Ecosystem Services as proposed by Boyd and Banzhaf (2007) as cited in the working paper of Fisher, Brendan, Costanza, Robert, Turner, Kerry and Morling (2007) is defined as services or organizations, processes or functions that are consumed by humans either directly or indirectly that benefits humans. Ecosystems are characterized as public-private goods that are open access that directly impact the health and well-being of local citizens in communities. The role of tree canopy in ecosystem services contribute significantly to air purification and soil remediation. Ecosystem services play an essential role in urban forestry in alleviating local challenges in a city environment. Specifically, in Washington, DC where the increase in tree canopy has improved stormwater control and mitigating flooding in many parts of the city. On the other hand, improper maintenance of urban tree canopy can be costly to a city's budget.

Municipalities play a big role in urban ecosystem services. Cities that embrace greening initiatives as the main strategy for improving urban sustainability and mitigating the environmental impacts of rapid urbanization (Smith, et al, 2019). The ecosystem service of forests cannot apply to the urban environment; there are different factors that affect them urban forests compared to forests in general. Decreasing mortality rates of mature trees is an effective strategy than planting more trees to improve a carbon balance in urban tree canopy (Smith, et al, 2019). Municipalities who use greening strategies like adding greenspaces and urban tree canopy can combat the negative impacts to the urban environment such as the urban heat island effect, air pollution, and soil erosion (Jike, et al., 2020). Further, adding greenspaces, additional trees, and maintaining existing tree canopy has protective benefit to human health and well-being.

*Human Health*

Exposure to extensive forests has been found to improve human health and certain cognitive functions (Karjalainen at el 2010). The benefits of urban forestry to humans includes, 1) improvement of academic performance, 2) social cohesion, 3) cognitive health, 4) and reduced air pollution. Salmond et al., 2016) noted that some of the ecosystem services from urban forestry that benefits human health are in four categories, provisioning of services (food supply, water supply), regulating services and related health benefits (temperature regulation, noise reduction, air quality improvement, moderate climate extremes, mitigate stormwater runoff, waste treatment, pollination, pest regulation, seed dispersal, global climate regulation). Supporting (habitat) services (biodiversity), and cultural services (recreation, aesthetic benefits, cognitive development, place values, and social cohesion) (p.97).

Health impacts are unforeseen factors such as air pollution), which can have a negative effect on human health. While many believe that climate change is linked to human activities, urban environments are noted to be hotter in the city than in the rural areas surrounding the city, called the urban heat island effect. Cao et al. (2016) provided evidence that urban aerosol or haze pollution contributes to urban heat island in urban areas (p.1). Barron et al. (2019) noted that urban tree canopies are important factors for increasing resilience among local residents because tree canopies improve air quality. Trees improve water quality, slows the flow of stormwater, absorb water, and increases groundwater recharge. These authors further noted that particulate matter if not alleviated can contribute to an increase in lung and heart disease, decreased lung function and heart attacks. Finally, Ebi et al. (2018) noted the plethora of health benefits, but they also noted the positive emotional response in tree canopies connected to urban forestry. As more people move to urban environments, the benefits of urban forestry are many and can support mitigation efforts to decrease the effects of climate change.

*Mitigation Strategies*

Urbanization, deforestation, and use of fossil fuels has been shown to increase temperatures all over the globe by releasing excess carbon dioxide into the atmosphere. Research shows that planting trees and other plants in urban environments increases biodiversity, reduces urban heat island effect (UHI), and mitigate the effects of climate change (Salmond et al., 2016). Carbon sequestration, heat-stress mitigation, noise reduction, air and water quality have been shown to improve neighborhood health and well-being of cities (Chuang et al., 2017, p.363).

These researchers compared tree canopy of Washington, D.C. and Baltimore and found that tree planting alone does not constitute an effective urban tree canopy plan; in fact, cities must account for social and economic influences of tree canopy distributions (Chuang et al., 2017, p.363). Collazo-Ortega, et al. (2017) noted, “vegetation plays a crucial role in urban ecosystems, by sequestering carbon excess, storing carbon as biomass, and releasing oxygen and water vapor through evapotranspiration. Climate change and UHI can adversely affect the populations health. These factors also affect how well a mature tree can perform its ecosystem service of carbon sequestration. Urban heat island is known to reduce carbon sequestration by 12% due to the direct effects of warming on trees (Meineke, et al., 2016). Mitigating the effects of UHI would benefit the inhabitants, as well as the trees and vegetation for carbon sequestration.

Taillardat, Friess and Lupascu (20180 suggested mangrove blue carbon strategies are effective at mitigating climate change at the national level. Blue carbon ecosystems are saltmarshes, seagrasses, and mangroves characterized as large organic carbon storage that have high carbon sequestration capabilities (p.1). Other more local strategies such as green roofs, bioswales, green spaces add to biodiversity and improves ecosystem functioning overall (Oberndorfer et al., 2007; Williams, Lundholm, and MacIvor, 2014).

Green roofs are becoming increasingly common in cities however, while their water and energy cost savings benefits are known, they have contributed significantly to biodiversity as other authors have discovered in their studies. On the other hand, urban development and peri-urban agriculture contributes to mitigating food insecurity, mitigating climate change, adding biodiversity and ecosystems services, sustainable agricultural, resource efficiency, urban regeneration, land management, public health, social cohesion, and economic growth (Artmann and Sartison, 2018).

Nowak, et al. (2018) found that urban park characteristics (area, perimeter, shape) are important when mitigating climate change and designing future urban parks. An increased park cool island (PCI) effect can be achieved by designing rounder and bigger (minimum 0.3 ha) urban parks. In addition to park size, park complexity is another important factor. When a park’s shape is too complex, the cooling effect decreases. Nowak et al. study also found that in order to mitigate UHI effect, parks also need substantial number of trees, a small number of trees is not enough for reducing air temperature. The size and health of the trees also matters when it comes to mitigation strategies: large, healthy trees with big crowns (leaf area and leaf biomass) have a bigger shading, cooling, and humidifying effect.

## Threats

Urban forest ecosystems have special characteristics that distinguish them from other forest types. Urban forests that are near large or dense human populations, have high diversity of species, and multiple public and private ownership. Because 80 percent of the U.S. population lives in urban areas, urban forests have a huge influence on the day-to-day lives of most Americans (United Nation (2018). Many do not think about the health of the trees around us until it is too late. Often, trees, including the ones in our backyard, get sick, are attacked by pests, and are constantly being damaged due to infrastructure expansion. The future survival of our urban forests is constantly at risk (Veach, Moilanen, and DiMinin, 2017). Sustaining our forests requires us to analyze the threats trees face while trying to provide resolutions to limit those threats. Threats are categorized as the following: disease and insect infestation, deer damage, and urban housing development

### *Pest Infestation*

Urban warming and drought stress have been found to be directly correlated to diseases and insect infestations attacking urban forests. An example of this is the Macquartia tenevricosa (M. tenebricosa), also known as gloomy scale, is an insect that lives and feeds on the trunk and branches of certain trees. When M. tenebricosa heavily infects a tree, it causes the tree to die. Increased temperature exacerbates the effect of warming such that M. tenebricosa produced over 17% more embryos on the warmest un watered trees than the warmest watered trees, and over 65% more than the coolest watered trees in Raleigh, NC (Dale & Frank, 2017).

### *Deer Damage*

Increased deer populations in North America decrease diversity and productivity of forests as well as facilitates local plant extinctions. Lack of hunting and predators make human communities prone to high deer abundance. Through selective grazing, deer affect the number of plant species in an area, impair the growth of new trees, and alter the overall structure of forests (Dobson & Blossey, 2015). Deer prefer to eat certain plant species which reduces the native biodiversity in a forest. When the species in a specific forest changes, the way the forests ecosystem functions changes as well (Dobson & Blossey 2015).

*Developers and Homeowners*

The transition from rural to urban has been ongoing with many individuals globally moving to city centers (United Nation, 2018). Washington, D.C, is a good example and have erected many new developments across the city welcoming incoming residents. Increasing the number of residents has a multiplier effect where cities can increase the tax base that support additional city services. However, there is a fine balance between development and green/blue space necessary for the overall wellbeing of citizens involved in the flow of energy within its environment. Population growth leads to a cycle of consumption that directly leads to increased extinction rates, which undoubtedly place undue pressure on ecosystem services. For instance, in Changchun, China, rapid urbanization led to increased temperature, which in turn affected the urban forest; ultimately affecting the health and wellbeing of the citizens (Wang et al, 2018).

*Urban Forestry Policies*

Managing urban forests and natural resources is an important issue. Communities can regulate the urban forest through a variety of legislation. Tree ordinances, and authoritative rule are laws that mirrors the values of a community and the worth of a community’s trees or urban forest. Urban Forestry Policy or tree ordinances encourages tree planting and tree maintenance to secure; tree wellbeing and the public health and safety benefits that trees provide.

However, despite some examples of coordination of research and actual policy making, the current practices are still insufficient in decreasing the negative impact on urban forests. It is quite evident the purpose of policy is to be the voice of the people in local jurisdiction to express concerns regarding their needs in the communities. Policies that do not respond to the needs of the community are counterproductive and negatively impact the health and well-being of the environment and its residents. Policies should be enacted to protect the environmental and support economic development.

## Methods

To collect tree canopy data, half of the class would use the i-tree tool and the other half of the class would use the Tree-Snap tool. Since we were limited to collecting data in our own neighborhoods, these tools would provide us useful information. We describe the tools below:

> i-Tree tool is a combination of science and free tool designed to quantify the benefits and values of trees around the world. It aids in tree and forest management and advocacy. It shows the potential risk to trees and forest health. This tool was developed and is based on peer-reviewed research conducted by the United States Department of Agriculture (USDA) Forest Service Research (https://www.itreetools.org/).
>
> Tree-Snap was developed by a collaboration of scientists at the University of Kentucky and the University of Tennessee to help our nation's trees! Invasive diseases and pests threaten the health of America's forests. Scientists are working to understand what allows some individual trees to survive, but they need to find healthy, resilient trees in the forest to study. Individual citizens are able to locate trees in their community and collect data for direct submission to the tree-snap website.  Scientists will use the data collected to locate trees for research projects like studying genetic diversity of tree species and building better tree breeding programs.

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The group using i-tree tools captured data on removal of harmful pollutants and the monetary benefits that trees provide to the ecosystem services in Washington, DC.

The group using Tree-Snap took pictures in their respective communities of the various species of trees in many Washington, DC neighborhoods and uploaded this data to the Tree-Snap web portal. Because this was an actual assignment, each of us had to upload our results to Blackboard, our Learning Management System so that our professor had this information.

## Results

The i-Tree tool captured the following information for Washington DC, landcovers as trees, and shrubs (see appendix 1 for a sample of the i-Tree tool report). The report provided

1) Tree benefit estimates of Carbon:
    a. Annual sequestration of carbon in trees
    b. Amount of carbon stored in trees (not an annual rate)
2) Tree benefits estimates of Air Pollution
    a. Annual amount of carbon removal and the estimated value of removal
    b. Annual amount of Nitrogen Dioxide removal and estimated value of removal
    c. Annual amount of Ozone removal
    d. Annual removal of Particulate matter greater than 2.5 microns
    e. Annual removal of Particulate matter less than 2.5 microns
    f. Annual removal of Sulfur Dioxide removal
3) Tree benefits estimates of Hydrological
    a. Avoid Water Runoff

The Tree-Snap tool group captured a variety of tree species common to many areas within Washington, DC neighborhoods (appendix 2 for a sample of the Tree-Snap report). Observations of tree species in various neighborhood provided a holistic view of the Urban Tree Canopy in our local neighborhood. Several prominent types of trees included the Purple Leaf Sand Cherry Tree, White Oak, Bur Oak, Maple Oak, and Chestnut Oak to name a few of the varieties were evident in our data set.

## Discussion

As students studying urban sustainability issues, understanding urban forestry and the benefits of trees was quite intriguing. It appears that none of us had given serious considerations to trees in our neighborhood, nor did we understand the benefits of a healthy tree canopy. Collecting both sets of data provided a new appreciation for what benefits trees provides to a community. For example, a quote from one of the students who used the i-tree tool sums it up this way:

> The i-Tree Canopy tool is useful for seeing the benefits of the tree canopy for a chosen area, here being the benefits of the tree canopy in Washington, D.C. The points generated within my report estimate the benefit of the tree canopy to be quite significant; removing 24.74 tons of carbon monoxide, 136 tons of nitrogen dioxide, 1,055 tons of ozone, over 300 tons of particulate matter, and 67 tons of sulfur dioxide annually. The report also estimates that the tree canopy also provides hydrological benefits, reducing storm water run-off by 362 Kgal, evaporation by 8,147 Kgal, interception 8,200 Kgal, transpiration 7,714 Kgal, potential evaporation by 52,397 Kgal, and potential evapotranspiration by 43,214 Kgal per year. Overall this report shows that the quality of human life on Earth would not be the same without trees; they are essential for maintaining decent air quality and play a major role in the circulation and distribution of the waters on Earth and in the atmospheres.

Two other quotes from students who used the Tree-Snap tool, marveled at their findings

> "Royal Japanese Cherry Trees are all over the Washington, DC, Maryland, and Virginia and it is the prettiest tree in my neighborhood by far." (pers communication NR, 2020).

> “I observed in my neighborhood Ward 3 about thirty trees, from 12 different species. Biodiversity and planting native and adoptive plants are very important tools to build resilience. I am eager to continue learning more about different species of trees in Washington, DC” (pers communication, LS, 2020).

Collecting tree data was a useful activity for our environmental senior project and it brought the reality of urban forestry and tree canopy to life. While many of us will graduate this spring, understanding and using these tools to evaluate other neighborhoods supports our preparation as informed citizens. We are better prepared to assess the value of a community considering ecosystem services as a primary decision factor in determining whether this would be a great neighborhood to live.

## Conclusion

Tree canopies play a major role in urban forestry and ecosystem services provides the advantages of a natural, cost effective system of green infrastructure. Trees capture air and water pollutants, as they provide shade, habitat, and even social organization. In this paper we discussed that tree canopy play a role in mitigating stormwater runoff and soil amendment (Berland et al, 2017). Our research examined urban forestry from the lens of ecosystem services, human health, mitigation strategies, threats to urban forestry, and urban forestry policies. Our findings from both the i-Tree tool and the Tree-Snap tool confirmed that urban forestry and tree canopies are worth investments from city governments as trees provide significant benefits to the health and well-being of its citizens. Washington, DC has increased its effort to become a climate resilient city particularly as it strives to attain its place as one of US most sustainable cities. As urban sustainability majors, this project has enlightened our understanding to the real meaning of urban sustainability and a climate resilient city.

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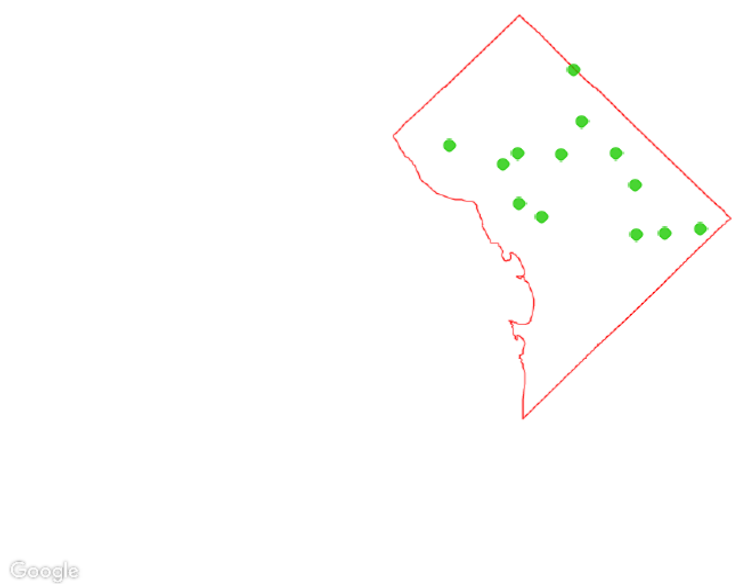
*Appendix 1 i-Tree Tool*

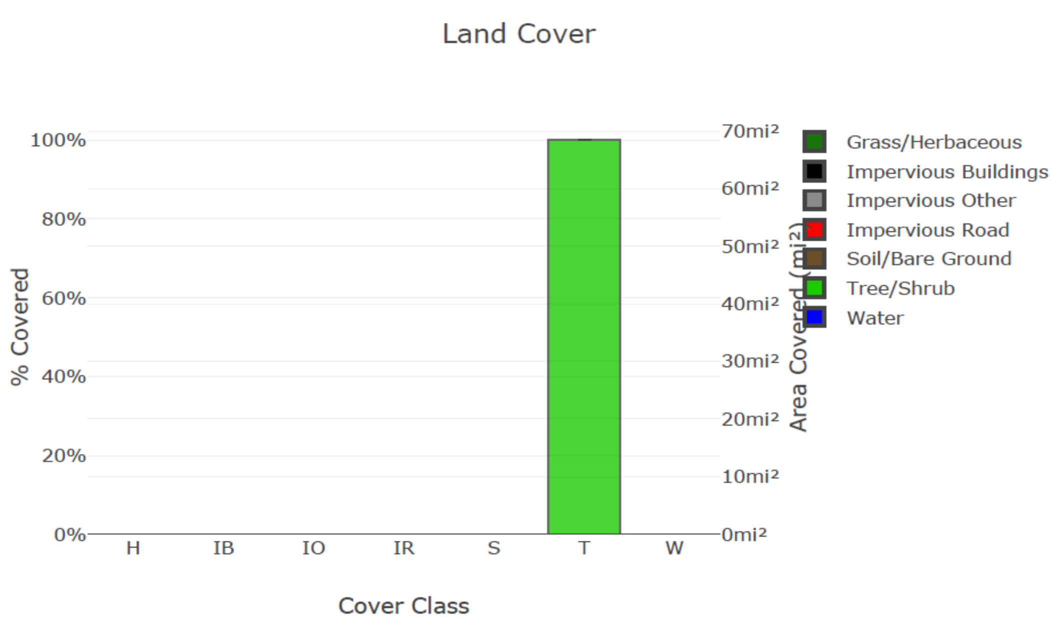


# i-Tree Canopy v7.0

**Cover Assessment and Tree Benefits Report**

***Estimated using random sampling statistics on 4/19/2020***



| Abbr. | Cover Class | Description | Points | % Cover ± SE | Area (mi²) ± SE |
|---|---|---|---|---|---|
| H | Grass/Herbaceous | | 0 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| IB | Impervious Buildings | | 0 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| IO | Impervious Other | | 0 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| IR | Impervious Road | | 0 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| S | Soil/Bare Ground | | 0 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| T | Tree/Shrub | | 13 | 100.00 ± 0.00 | 68.44 ± 0.00 |
| W | Water | | 0 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| **Total** | | | **13** | **100.00 ± 0.00** | **68.44 ± 0.00** |

## Tree Benefit Estimates: Carbon (English units)

| Description | Carbon (kT) | ±SE | $CO_2$ Equiv. (kT) | ±SE | Value (USD) | ±SE |
|---|---|---|---|---|---|---|
| Sequestered annually in trees | 59.79 | ±0.00 | 219.23 | ±0.00 | $10,196,999 | ±0 |
| Stored in trees (Note: this benefit is not an annual rate) | 1,501.52 | ±0.00 | 5,505.56 | ±0.00 | $256,084,907 | ±0 |

Currency is in USD. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Carbon sequestered is based on 0.874 kT/mi²/yr. Carbon stored is based on 21.940 kT/mi². Carbon is valued at $46,513.84/kT. (English units: kT = kilotons (1,000 tons), mi² = square miles)

## Tree Benefit Estimates: Air Pollution (English units)

| Abbr. | Description | Amount (T) | ±SE | Value (USD) | ±SE |
|---|---|---|---|---|---|
| CO | Carbon Monoxide removed annually | 24.74 | ±0.00 | $32,993 | ±0 |
| NO2 | Nitrogen Dioxide removed annually | 136.68 | ±0.00 | $59,722 | ±0 |
| O3 | Ozone removed annually | 1,055.83 | ±0.00 | $2,742,892 | ±0 |
| PM10* | Particulate Matter greater than 2.5 microns and less than 10 microns removed annually | 299.67 | ±0.00 | $1,878,449 | ±0 |
| PM2.5 | Particulate Matter less than 2.5 microns removed annually | 53.94 | ±0.00 | $5,742,267 | ±0 |
| SO2 | Sulfur Dioxide removed annually | 67.19 | ±0.00 | $8,993 | ±0 |
| **Total** | | **1,638.06** | **±0.00** | **$10,465,317** | **±0** |

Currency is in USD. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Air Pollution Estimates are based on these values in T/mi²/yr @ $/T/yr:
CO 0.362 @ $1,333.50 | NO2 1.997 @ $436.94 | O3 15.428 @ $2,597.84 | PM10* 4.379 @ $6,268.44 | PM2.5 0.788 @ $106,459.48 | SO2 0.982 @ $133.85 (English units: T = tons (2,000 pounds), mi² = square miles)

## Tree Benefit Estimates: Hydrological (English units)

| Abbr. | Benefit | Amount (Kgal) | ±SE | Value (USD) | ±SE |
|---|---|---|---|---|---|
| AVRO | Avoided Runoff | 362.81 | ±0.00 | $3,242 | ±0 |
| E | Evaporation | 8,147.41 | ±0.00 | N/A | N/A |
| I | Interception | 8,200.43 | ±0.00 | N/A | N/A |
| T | Transpiration | 7,714.91 | ±0.00 | N/A | N/A |
| PE | Potential Evaporation | 52,397.54 | ±0.00 | N/A | N/A |
| PET | Potential Evapotranspiration | 43,214.41 | ±0.00 | N/A | N/A |

Currency is in USD. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Hydrological Estimates are based on these values in Kgal/mi²/yr @ $/Kgal/yr:
AVRO 5.301 @ $8.94 | E 119.049 @ N/A | I 119.823 @ N/A | T 112.729 @ N/A | PE 765.624 @ N/A | PET 631.442 @ N/A (English units: Kgal = thousands of gallons, mi² = square miles)

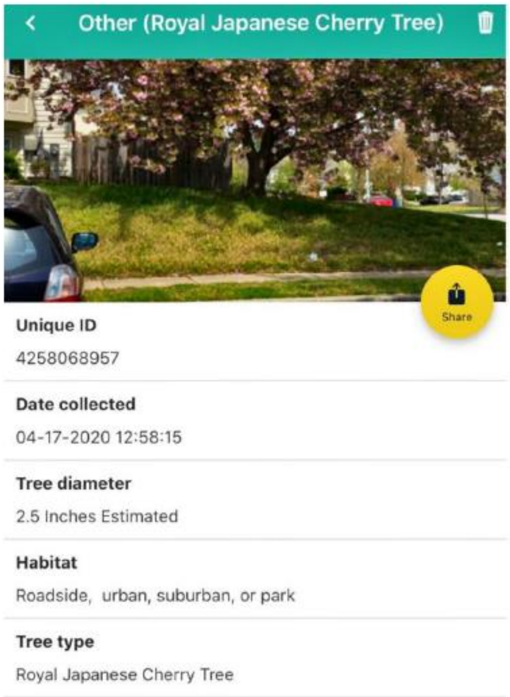
**About i-Tree Canopy**

The concept and prototype of this program were developed by David J. Nowak, Jeffery T. Walton, and Eric J. Greenfield (USDA Forest Service). The current version of this program was developed and adapted to i-Tree by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company)

**Limitations of i-Tree Canopy**

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard error will be too high to have any real certainty of the estimate.

*Appendix 2 Tree-Snap Tool*




**Royal Japanese Cherry Tree**

These trees are all over the DMV, SC is known for its Cherry Trees. The prettiest tree in my neighborhood by far