ABSTRACT

Title of Thesis:	IMPROVING TREE CANOPY COVER WITHIN SINGLE FAMILY RESIDENTIAL FRONT YARDS AND THE CASE FOR NEIGHBORHOOD TREES CASE STUDY: GALWAY ELEMENTARY SCHOOL DISTRICT
	Daniel Bentley, Master of Landscape Architecture, 2023
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Trees contribute to many social and health benefits for citizens when trees are planted appropriately and maintained into maturity. A healthy tree canopy cover layer should be enjoyed by all residents no matter their location or income level. While many communities and organizations have developed robust tree program and provide free trees, homeowners have difficulty imagining what mature trees might look like and what the benefits of the trees would be to them. This thesis strives to develop design methods to support homeowner decision-making for tree planting. A case study focused on the selected front yards of residential homes in the Galway Elementary School walk zone will be used to document these methods. The research is focused on how to demonstrate tree placement to homeowners, tree benefits and but also bring to their attention the opportunities offered to make the process simple and rewarding for the future of their children and the neighborhood.

IMPROVING TREE CANOPY COVER WITHIN SINGLE-FAMILY RESIDENTIAL FRONT YARDS AND THE CASE FOR NEIGHBORHOOD TREES: CASE STUDY: GALWAY ELEMENTARY SCHOOL DISTRICT

By

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Dedication

This thesis is dedicated to my children, who love the forest. May the delight they get from the presence of trees be accessible to all children, near and far. To my wife, for without her love and support, this never would have been possible.

Acknowledgements

David Myers, my committee chair, and inspiration for this big idea. We share a love of trees. I am eternally grateful for his help in maintaining my focus and for having confidence in my abilities as a writer and researcher.

Dr. Kweon who was part of my committee and helped me to focus on the small but most important things that make this idea work. Thank you for sharpening my gaze.

Dr. Ruggeri was also part of my committee. Thank you for helping me to see the gaps and how to fill them for the greater good of both people and trees.

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List of Abbreviations

FARMS - Free and Reduced Meals Program

FBCMP – Fairland Briggs Chaney Master Plan

MCDEP - Montgomery County Department of Environmental Planning

MCDNR – Montgomery County Department of Natural Resources

MCPD – Montgomery County Planning Department

MCPS – Montgomery County Public Schools

MDOT – Maryland Department of Transportation

MNCPPC – Maryland National Capital Park and Planning Commission

MOCO TCL – Montgomery County Tree Canopy Law

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Chapter 1: Introduction

This thesis explores how tree canopy cover can be maximized in front yards of single-family homes within underserved communities, specifically in elementary school walk zones. Research suggests that a healthy tree canopy can lead to better environmental health, physical health, and better educational outcomes for children. In addition to social benefits for humans, trees and other vegetation also provide many environmental benefits and ecosystem benefits such as air pollution reduction, stormwater mitigation, and an increase in biological diversity. However, tree canopy cover is inequitably distributed across geographic areas, with poorer communities typically having less tree canopy than richer ones. Thus, there is a need to increase tree canopy in these neighborhoods. Governments, such as Montgomery County, Maryland have developed a variety of tree planting programs to increase tree canopy, and in particular front yards, to address both these social inequities and to increase environmental benefits afforded by trees to meet overall environmental goals. This thesis addresses how to increase tree canopy in front yards to maximize the benefits for children. It uses selected properties within the case study area of Galway Elementary School to demonstrate a method for both 1) documenting the benefits of tree canopy cover and 2) persuading homeowners to take advantage of county tree planting programs.

The case study area is the school walk zone within a half mile of Galway Elementary School in Silver Spring Maryland. Tree canopy cover is inequitably distributed throughout Montgomery County, Maryland. Located in the western portion of our county, this area has lower tree cover and tree health is poorer overall in these areas. The children attending the schools in these areas deserve to have a healthy tree canopy within their neighborhoods that can lead to better environmental health, physical health, and educational outcomes for not only them but amongst all the residents within the walk zone and throughout the extended community as well.

The overall application of this research is a desktop design method that can be used to reach residents in these areas and to facilitate healthy tree plantings for the future of these elementary school walk zones. Using tools such as ArcGIS Pro, I-Tree, and Photoshop, we can use data analytics and virtual proposals to document for residents the opportunities for front yard tree plantings but also the long-term benefits of planting these trees now. There is a gap between the available trees and the long-term success of these plantings within these underserved areas. This thesis strives to fill that gap and move forward with a plan to increase the frequency with which trees are planted in these communities. This desktop design method and brochure can then be applied to other areas of the county and throughout the country as well.

This thesis is organized into five chapters. This first chapter serves as an introduction to the topic and acts as a roadmap. The second chapter discusses the literature surrounding precedent projects abroad, existing programs in our area, and the benefits of increased tree canopy cover. The third chapter introduces site selection, inventory, and analysis for the selected neighborhood and the elementary school. The fourth chapter introduces the design interventions and proposed steps to build a successful tree-planting plan for the proposed residential yards. The fifth chapter is a discussion and conclusion of the proposed changes and further steps that can be taken to ensure tree canopy health for years to come.

Chapter 2: Literature Review

Chapter 2 is divided into three sections. Section one discusses selected Montgomery County existing tree programs that are focused on increasing tree canopy cover in the county. Section two identifies representative precedent projects and canopy cover solutions applied in other cities and townships across the country. The third section discusses the benefits of trees from an environmental, health, social, and educational aspect. These four areas of benefit were most relevant to this project and were chosen as specific areas of focus.

Existing Montgomery County Tree Programs

Within Montgomery County there exist several programs for helping citizens achieve tree canopy goals within their private lots but also within the right-of-way properties adjacent to their front yards. These programs strive to increase tree canopy in urban and urbanizing areas of Montgomery County. Properties in Montgomery County's priority funding areas are eligible to apply for free trees from Reforest Montgomery. Priority funding areas are home to 98% of the county's residents, but just 36% of the county's tree canopy. By working together to plant trees in these urban areas, they can cool buildings, prevent flooding, reduce stress, and improve the quality of life for all the county's residents. (Reforest Montgomery, 2023) They offer property owners a wide array of incentives to simply plant trees within the county as well. From free shade trees, discounts on native trees, free reforestation, and guidance on all aspects of tree plantings they work with the community to increase canopy coverage in a variety of ways and in a variety of locations from private lawns to parkland.

Figure 1: Reforest Montgomery Logo

The fund that supports these programs is the Forest Conservation Fund, which is generated by certain development projects that need to meet the requirements of the Forest Conservation Law. In 1991, the state of Maryland passed the Forest Conservation Act to regulate the removal of forests by certain types of projects and also to grow new forests in the state. In 1992 Montgomery County passed its own Forest Conservation Law. The primary requirement of this new law was that developers set forth a forest conservation plan which settles a forest mitigation requirement for an existing development project. Some development projects meet the requirement by paying a “fee-in-lieu payment” which generates funds to be used in the Reforest Montgomery program. The fund charges $1.30 per square foot of developed space and uses these funds to increase plantings in much-needed areas throughout the county. To date, they have collected funds to reforest 68 acres of forest within the county. By working with partners of the program they have been able to stretch that amount to plant 90 acres of reforested property. In 2020 they incorporated preexisting programs such as “Shades of Green” and “Leaves for Neighborhoods” into Reforest Montgomery. These programs now lie under the umbrella of Reforest Montgomery and all their resources have been used to advance this new program. The program recently set a new goal of "No Net Loss of Forest" in Montgomery County which strives to see the amount of forest planted be greater than the amount of forest acres cleared. They passed the No Net Loss of Forest amendment in April 2023 to strengthen the Forest Conservation Law to help achieve the goal in the coming years.

A resource that Montgomery Planning uses to project changes to forest cover within Maryland is the Maryland Forest Study released in 2022 by the Hughes Center for Agro-Ecology. The University of Maryland's School of Agriculture and The Chesapeake Conservancy contributed to the report, which strives to lay out strategies and goals for monitoring forest canopy cover within our state. With this, they can underscore the importance of planting and protection efforts across the state with the goal of achieving no net loss of forest cover in the very near future. The report found that significant canopy loss took place between 2013 and 2018 across the state specifically in areas of high development. They also mention invasive species spread and fragmentation from over-development as key concerns.

Another important program within Montgomery County is Tree Montgomery. Tree Montgomery is a free program to plant shade trees across Montgomery County, Maryland. The goal is to plant shade trees and increase tree canopy to provide a wide array of benefits for the community. They strive to focus on planting shade trees specifically on private property within the county. To date, they have planted more than 7,500 trees with a growing number being planted every year. By simply filling out an application, visiting with a properly trained urban forest technician in their yard, and selecting trees they can receive shade trees at no cost. Most importantly they provide follow-up inspections to consult with homeowners on tree health, maintenance techniques, and suggestions for a healthy tree moving forward. The program, which is run by the Maryland Department of Environmental Protection, is a very successful one and even has a slight wait for new customers desiring shade trees.

Figure 2: Tree Montgomery Logo

<u>Right Of Way Programs</u>

Trees that are growing in the Right of Way in Montgomery County are the property of the county and the agency in charge is the Montgomery County Department of Transportation. The county is responsible for the health and maintenance of these trees. MCDOT maintains over 250,000 trees in the dedicated county right of way and another 200,000 in rural areas. The county plants approximately 2,000 trees per year and it is done so on a request basis. Citizens can call and request a planting and a county arborist will inspect the property for appropriate species and location. Acceptable major trees shall be 8' to

12' tall and have a minimum trunk caliper of 1 3/4" - 2" as measured 6" above ground level. They shall be branched at a point approximately 60% of the total height of the tree above ground. Major tree species will grow to a minimum of 40' at maturity. Acceptable minor trees shall be 8' to 10' and have a minimum caliper of 1" - 1 1/2" measured 6" above ground level. Minor tree species grow to a maximum of 35'. Minor species are only planted directly under power lines. (*MCDOT* - 2023) The size and species of the trees in these cases are important to distinguish. "Right tree right place" is an important concept when planting beneath power lines or in certain right-of-way conditions.

Figure 3: Montogomery County Dept of Transportation

Figure 4: Pepco Logo

Montgomery County's right of ways are important to this thesis topic in that they make up such a large plantable area of the lots we are choosing to focus on. Some of these lots have over 1,000 sq. ft. of ROW in between the private lot and the street. In some cases, these areas represent the best possible location for new plantings. In other cases, they already contain large healthy trees that can be further prioritized and possibly worked into a sidewalk layout for the neighborhood further down the line.

As previously mentioned, certain considerations should be taken concerning power line location and new tree plantings. Although these areas of open lawn are plantable, we must take care to consider utility infrastructure when planning for the future expansion of the tree limbs and roots. Furthermore, PEPCO has full decision-making power when it comes to determining how to maintain and trim the trees near energized lines. This activity is not regulated by Montgomery County so communicating with PEPCO during initial planting plans would be ideal to avoid unnecessary removal or limb cutbacks in the future.

Other Programs

These three aforementioned programs are specifically important to this thesis. However, other programs exist within Montgomery County and Maryland for tree plantings as well. They include Marylanders Plant Trees and Tree-Mendous, programs run by the Maryland Forest Service, Backyard Buffers, a streamside buffer-focused program handled by MCPD, Raincapes, operated by the Montgomery County Department of Environmental Protection which focuses on stormwater mitigation plantings, and the Maryland Urban and Committee Forest Grant, which is a volunteer group of citizens, professionals, and government officials united to protect and enhance Maryland's forest ecosystems through plantings on public land. Each of these programs serves a different purpose and can also be appropriately applied to increase canopy in special situations. For this thesis, the first three programs are of special importance.

Precedent Projects

Across the country, many cities are beginning to see the benefits of planting more trees, both in urban environments but also in the suburban sprawl surrounding their inner-city areas. Through overdevelopment, many of these cities have lost considerable tree canopy cover and it is noticeable when looking at map data as well as viewing properties from the ground. This has had a drastic effect on many aspects of city and suburban life such as increased heat extremes, less biodiversity, and an increase in issues with overworked urban stormwater systems. These city planting guides and plans vary in many ways and serve only to begin the process of solving the multi-faceted issue of lost canopy cover within these cities. Many cities have plans in place, but where they do exist, many of those plans fall short in one way or another. Policy, funding, and maintenance issues can all play roles in slowing the development of these tree canopy programs. These guides are designed primarily to help municipalities assess the state of their urban forest, identify management concerns, and chart a path forward, step by step, toward long-term sustainability. (Leff, 2016)

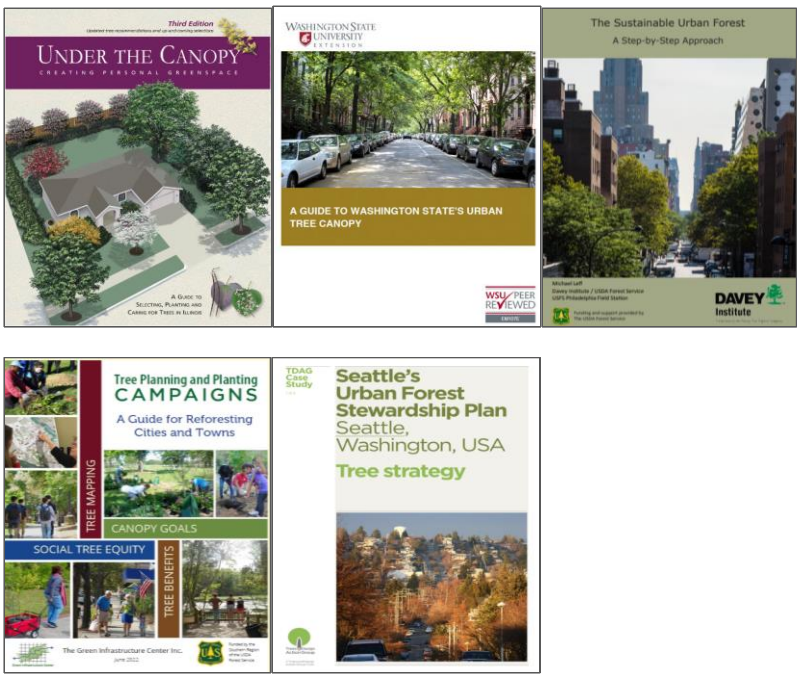

Figure 5: Tree Planting Guides from various cities and municipalities.

These plans often outline more than just the physical tree plantings. They include steps to create neighborhood and national awareness, increase volunteerism, cultivate partnerships between municipalities, create multi-jurisdictional natural resource plans, integrate federal agency goals, support collaborative research, and establish open-access tools for community members. Furthermore, they stress that in addition to trees on public land, these guides also cover trees on private property, which represents the majority of land area in most communities and, as such, are a critical component of the urban forest. (Leff, 2016) This is crucial to the development of my thesis as I am focusing on these private property front yards. They make up a large amount of the plantable area within my project scope and thus are crucial to maximizing tree canopy in western Montgomery County moving forward.

One important aspect of these urban forestry guides is to recognize the inequitable distribution of current tree canopy cover and strive to make reparations for past policy decisions and funding shortcomings. The city of Seattle's Urban Forestry Core Team recognizes that not all residents in Seattle experience environmental progress equally. People of color in their city are more likely to live near polluted sites, suffer from environment-related health problems, and have less access to healthy fresh food and open space. They continue to work to create a city where all residents benefit equally from their environmental achievements. (Seattle 2020 UFMP) This is the case in many U.S. cities and is also a focus topic of my thesis. The neighborhood scope in my project is one that has been historically underserved. I chose my site specifically to align with Montgomery County's efforts to implement structural and environmental changes in this Calverton neighborhood through the Fairland Briggs Chaney Master Plan. These changes are long overdue and should make progress towards not only increasing canopy coverage but providing citizens in this area with much-needed improvements in access, connectivity, and enhanced comfort and safety. Within the FBCMP there are recommendations provided for improvements in land use, zoning, housing, transportation, community health, parks, trails and open space, the environment, community facilities, and historic preservation. (FBCMP, 2023)

Most of these cities have similar goals when planning for an increase of the canopy cover within the urban and suburban scope. Along with increasing canopy, they can include reducing greenhouse gas emissions, enhancing green infrastructure, reducing citywide building energy use, improving air quality, and creating green jobs for the future. Not surprisingly by increasing tree canopy coverage to above 30% these other goals are met simultaneously. Meeting that single target would help advance half of all the other targets in all five of the other categories mentioned. (Leff, 2016) The benefits of trees are numerous and well-documented. Both environmentally and socially, trees can positively affect the lives of citizens in many, many ways.

Tree Canopy Benefits

The benefits of trees are numerous. From human health and biodiversity to improved water quality and increased property values, the benefits can be measured in a myriad of ways. Trees also benefit people in ways that cannot be measured, such as a sense of community in a neighborhood and eco-education for school-age children who can learn to plant trees, harvest acorns, and build birdhouses. Trees build relationships with the land we inhabit and provide a bit of green in an often-endless concrete skyline. Therefore, maintaining a healthy tree canopy within the suburban sprawl is essential for a healthy population and a bright future.

Figure 6: Benefits of Trees

Environmental Benefits

The environmental benefits of trees have been well-documented in recent years. Green infrastructure in urban areas provides goods and services and supports resilience in the system. They also form a connected network of multi-functional, predominantly undeveloped land that supports ecological and social activities and processes Green school areas can amplify the connectivity of the major green infrastructure by acting as steppingstones for species flow. (Iojă et al., 2014) Trees maintain healthy biodiversity when moving through the mosaic of suburban homes that are present in the western portions of Montgomery County. Without these patches of green, animals such as Sitka deer, songbirds, pollinators, and native wildlife would be unable to navigate the patchwork we have created through overdevelopment.

Trees also prevent water pollution through increased stormwater filtration. Urban tree canopy cover offers stormwater control and water quality benefits for municipalities in the Chesapeake Bay watershed and can extend many riparian forest buffer functions to urban settings. They interact with the urban hydrologic cycle by intercepting incoming precipitation, removing water from the soil via transpiration, enhancing infiltration, and bolstering the performance of other green infrastructure technologies. Research has shown that trees can play a substantial role in reducing stormwater runoff via canopy interception loss, transpiration, facilitating infiltration, and by coupling trees with other green infrastructure technologies. (Berland et al., 2017)

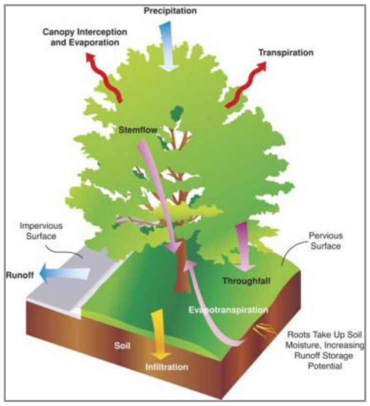

Figure 7: I-Tree graphic depicting tree canopy stormwater benefits.

They also reduce weather extremes in local neighborhoods by shading homes during the summer and blocking winds in the dry Maryland winter. Heat extremes during summer months are an increasing problem in neighborhoods with lower levels of tree canopy coverage. Heat exhaustion and stroke are very serious side effects of exposure to prolonged high temperatures and affect these underserved areas much more often than in wealthy neighborhoods with denser canopy coverage. People who may not have sufficient resources to operate air conditioning in their homes may also live in neighborhoods that lack the cooling benefits of urban trees, thereby compounding their vulnerability to extreme heat events. (Jennings & Gaither, 2015)

Figure 8: Calverton neighborhood canopy. Galway Elementary School is shown as a white logo

Figure 9: Calverton neighborhood canopy heat island maps. Galway Elementary School is shown as a white logo

The benefits that trees provide can help cities and countries meet 15 of the 17 internationally supported United Nations Sustainable Development Goals. (Turner-Skoff & Cavender, 2019) They are one of the best and simplest solutions to climate change and the aesthetics and beauty provided are an added bonus. Trees also remove a tremendous amount of air pollution. It is estimated that from the contiguous United States, urban trees remove 711,000 metric tons of air pollution each year. Air pollution is a major environmental concern in most major cities across the world. Urban trees and shrubs offer the ability to remove significant amounts of air pollutants and consequently improve environmental quality and human health. (Nowak et al., 2006) Previous research has demonstrated that many woody species accumulated particulate matter and suggested that $PM_{2.5}$ accumulation capacity increases as a tree matures, and a diverse planting of species augments the trapping of particulate matter. (Turner-Skoff & Cavender, 2019) A genetically diverse mature tree canopy in the Calverton neighborhood would have a very profound effect on the amount of particulate matter cleaned from the air. Front yards are a perfect location for these future mature trees. Even one mature tree in each yard would have a great impact, and we have the opportunity to do much more than that. Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass. The net long-term CO_2 source/sink dynamics of forests change through time as trees grow, die, and decay. Urban forests can play a significant role in helping to reduce atmospheric carbon dioxide levels. Urban forests likely will have a greater impact per area of tree canopy cover than non-urban forests due to faster growth rates, increased proportions of large trees, and possible secondary effects of reduced building energy use and consequent carbon emissions from power plants. (Nowak & Crane, 2002) This combined with the stormwater mitigation, surface cooling, and biodiversity maintenance that urban trees provide makes them a necessary tool in improving the environment for the long term.

Social Benefits

Trees play a critical role for people and the planet. Numerous studies have demonstrated that the presence of trees and urban nature can improve people's mental and physical health, children's attention and test scores, property values in a neighborhood, and beyond. Trees cool our urban centers. Trees are essential for healthy communities and people. (Turner-Skoff & Cavender, 2019) People feel more comfortable and at ease when in shaded, open areas of trees as compared to areas of hardscapes and non-living things. Values are realized by the people that own the trees, by people nearby, and by society in general. People plant, maintain, conserve, and covet trees because of the values and benefits generated. (Coder, 2011) Simply put, a majority of people love trees.

Other important social benefits are significant but not ones that come to mind quickly when thinking of canopy benefits. Trees reduce wind speed and thus heating costs in winter. By also shading homes in the intense heat of summer it can reduce air conditioning usage by huge amounts. Tree canopy is typically more effective at reducing land and air temperatures than grass or other vegetative cover. (Jenerette et al., 2016) Controlling unnecessary energy usage from these utilities is another side effect of trees being placed near homes. We can substantially reduce the imprint this neighborhood has on the electrical grid by properly placing these canopy trees near homes.

Trees also buffer pedestrians from traffic. In the case of the Calverton neighborhood, this is very true for the front yards of the homes within this study. Children playing in the front yards can have another important feature to block them from unsafe traffic and the noise and pollution that come along with that. The beauty and aesthetic value of the trees also go without saying. The trees proposed in this thesis will simply make the neighborhood a more beautiful place to live. With beauty and added aesthetics comes one of the most significant benefits for homeowners, increased property values. Studies about trees and residential property values have evaluated a range of urban forest and landscape conditions in single-family homes. Although there have been a few exceptions, homes with trees are generally preferred to comparable homes without trees, with the trend across studies being a price increase of about seven percent. Decades of research findings indicate that property values are consistently higher with the presence of trees. There are a few studies that show modest or no results, but even fewer show any negative price effect for city trees. In studies where distance effects can be measured, properties closest to naturalistic parks and greenspace have the greatest value. (Wolf, 2008) The effect of increased tree canopy within the Calverton neighborhood over the next 25 years could have far-reaching benefits for homeowners within the project scope. However, one important note to consider is that by raising property values in the area, we could see detrimental effects as well. Gentrification is a real problem in this area moving into the future. As property values increase closer to urban centers, buyers could see the value of these neighborhoods within close driving distance to huge urban hubs, like

Baltimore and Washington D.C. Urban planners must attempt to reduce gentrification by offering these benefits to current homeowners and the existing community.

Health Benefits

Green spaces provide ecosystem services that are vital to public health. Studies across the U.S. show beneficial results related to coping with stress, improving resilience, enhancing self-discipline, and reducing symptoms of depression. For example, natural features (e.g., vegetation) around homes showed a significant positive relationship with strategies to cope with stress for mothers of children, suggesting that participants may find relief in aesthetic surroundings. (Jennings & Gaither, 2015) Implementing trees as a health intervention in a community is a long-term, even multi-decade, investment. Urban forestry and health professionals could work together to better integrate human health outcomes into urban forestry best practices. (Wolf et al., 2020) Activities in natural outdoor environments are intuitively known to be good for mental and physical health. These health benefits are obvious to those who live in well-canopied neighborhoods. The air is cleaner, cooler and promotes physical and mental healing. There is a very long-established view that personal contact with plants, animals, and natural green surroundings can benefit human health and well-being. The value of this is being seen as increasingly important as the human habitat becomes more urbanized. They also help to moderate the effects of other physical environmental factors by acting as a biological buffer. Contact with nature and contacts with animals and plants can have a powerful -therapeutic or preventative effect on many people, by reducing stress and helping to improve both mental and physical ability. Moreover, access to natural green spaces, particularly if they are conveniently close to work or home, may provide a supportive setting for physical exercise and restorative relaxation. (Nilsson et al., 2011) An increased sense of community and well-being is a beneficial side effect of these health benefits. When people feel better outside, they go outside more often. When neighbors are in their front yards more often, interaction, conversation, and recreation are guaranteed by-products.

These landscapes can also heal the community over the long term. Horticultural therapy has its origins in the -rehabilitation of British and American soldiers returning from the Second World War. Distinct values of horticulture to support the healing process include people's physical dependency on plants (related to harvesting crops for food), observing beauty, nurturing life, and social interaction. (Nilsson et al., 2011) Overall health benefits of greener communities are well documented and something to invest in for the future of equitable landscapes.

Educational Benefits

In the United States, schools serving urban, low-income students are among the lowest performing academically. Previous research in relatively well-off populations has linked vegetation in schoolyards and surrounding neighborhoods to better school performance even after controlling for important confounding factors, raising the tantalizing possibility that greening might boost academic achievement. We also must look a bit at types of cover since this thesis is strictly determining benefits of planting trees within already grassed lots. In recent studies, trees show significant positive relationships with achievement, but grass and shrubs show null or even negative relationships. (Kuo et al., 2018)

Trees are an essential part of healthy living, and we are finding this is true in how children perform at school. A recent study found that schools with more trees had a higher percentage of proficient or advanced scores in Mathematics and Reading standardized tests after controlling for school size, student teacher ratio, and free lunch enrollment. However, not all types of landscapes have the same beneficial properties. Large expanses of land, "featureless landscapes," including large areas of campus lawns and athletic fields have negative effects on academic performance. These results may help to guide the decisions made by landscape architects on the basis of evidence when they plan new and renovate existing schools. (Kweon et al., 2017) The benefits of an extended suburban tree canopy into the surrounding neighborhood would hopefully have the same effect for the children who walk or bike to school on a daily basis. The more time they spend in a green environment before and after school, the better.

Literature Review Summary

The following is a listing of important takeaway principles that are useful for the implementation of the case study.

- Green school yards provide a better learning environment for all children. (Kuo et al., 2018)
- Social and environmental context is important in mediating relationships between vegetation and academic achievement and the need to consider these disparities in supporting academic success through urban vegetation management. (Hodson & Sander, 2021)

- There are beneficial associations between longer time spent in green spaces and behavioral indicators for attention deficit and hyperactivity disorders. (Amoly et al., 2014)
- “In between spaces” and “out of bounds” areas are key in allowing children to engage in self-directed play and can help deal with overcrowded school yards. (Aminpour et al., 2020)
- There is clear research pointing to the positive correlation between greater amounts of trees on campuses and higher academic performance. (Kweon et al., 2017)
- Positive correlations were found between green classroom views and positive feelings of comfort and acceptance. (Lindemann-Matthies et al., 2021)
- There are different perceptions of trees amongst several demographic groups within different Washington D.C. communities. (Leets et al., 2022)
- Findings indicate that the spatial distribution of street trees in the immediate vicinity around the schools in certain cities studied closely mirrors the pattern of socioeconomic distress in those same cites. (Paddle & Gilliland, 2018)
- Neighborhoods with lower socioeconomic status and larger populations of underserved race/ethnicity residents had less tree canopy cover overall. (Zhang et al., 2022)

In summary, the literature review documents 1) the existing Montgomery County tree program 2) precedent tree programs in cities 3) benefits of trees including environmental, health, social, and educational aspects.

Chapter 3: Case Study

Chapter 3 is divided into four sections. Section one discusses the site selection process and how that process shaped the direction of the thesis. Section two discusses the site inventory. Abiotic, biotic, and cultural inventories were completed at a broad scope to understand the context of the final case study area. The third section analyzes this inventory and introduces the interventions and measures that will be discussed in Chapter 4. Section four outlines the method of selecting twenty sample single-family lots for determining metrics and design interventions . ArcGIS Pro was used for the mapping and analysis for these site inventory sections with some data being collected from Montgomery Planning and other sources.

Site Selection

The initial goals were to select a topic around tree canopy and children's access to green spaces. Initially, I wanted to design tree canopy cover solutions for an elementary school yard and grounds. As a father, a child's access to healthy trees is something I value for my own kids but also recognize as being important for all children no matter the age, demographic, or geographical location. As I began to investigate area schools and their tree canopy coverage, I inevitably ended up researching ongoing projects and plans for Montgomery County. As a former MNCPPC employee, I contacted several people at Montgomery Planning to get further information about several projects. The one that stood out to me the most was the Fairland Briggs Chaney Master Plan. This multi-dimensional plan, which is taking place in western Montgomery County, focuses on enhanced transit service and its connectivity with community uses, enhanced comfort and safety for all users living, working, or visiting the plan area, and strategic redevelopment opportunities to strengthen existing neighborhoods and amenities. Recommendations are provided for land use, zoning, housing, transportation, community health, parks, trails and open space, the environment, community facilities, and historic preservation. (FBCMP, 2023) During this search process, I was simultaneously investigating low-income school areas and those with high numbers of children enrolled in the county's free lunch program. I hoped by using these criteria I could find the schools with the children most in need of help. It led me to several schools close to the Prince Georges' County border but still lying in Montgomery County. When matched up with the FBCMP, four schools with FARMS enrollment over 60% stood out. Burnt Mills Elementary, Fairland Elementary, Greencastle Elementary, and Galway Elementary.

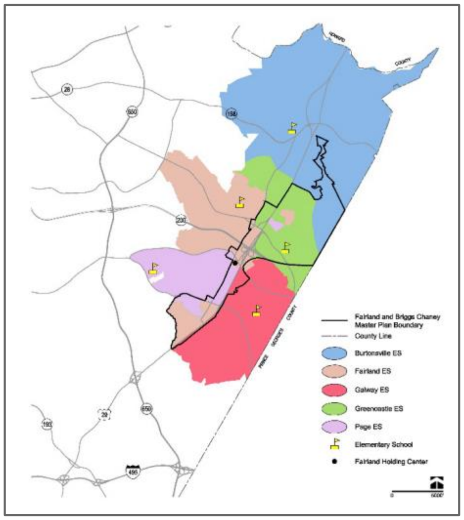

Figure 10: Fairland Briggs Chaney Master Plan

(FBCMP, 2023)

Of these four schools, Greencastle was the only elementary school residing within the FBCMP boundary. However, all four schools were close enough to the plan outline to use some research from the FBCMP. Initially, Greencastle Elementary was my choice for the planned schoolyard design and intervention.

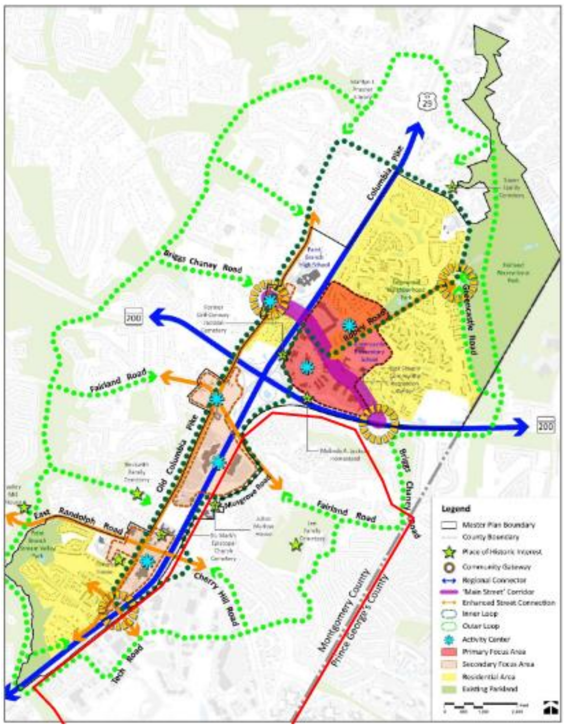

Figure 11: FBCMP Scope and Interventions

The Fairland Briggs Chaney Master Plan includes several overarching goals to improve the lives of the community within their plan scope. They include,

- Establish an emphasis on community gateways and activity centers as compact, high-density mixed-use centers focused on: frequent transit service; safe pedestrian movement; greater tree canopy and 'cool' surfaces at summer hot spots; and attractive community gathering spaces.
- Transition Briggs Chaney Road into a compact, mixed-use 'Main Street' corridor that serves as a community gateway focused on transit service, expanded housing and shopping choices, community gathering spaces, and

cultural and historic landmarks.

- Prioritize US-29 (Columbia Pike) as a ‘transit-first’ corridor that provides frequent, convenient regional connections from the plan area to Silver Spring, Washington D.C., Columbia, and Baltimore.
- Complete a network of greenways with a continuous inner and outer loop of trails and paths connecting parks, open spaces, community facilities, and bus stops, with neighborhoods both within and beyond the master plan area.
- Establish an East County Resilience Hub as a community center for daily community needs and a destination for reliable electricity, water, temporary shelter, food, indoor heating and cooling, social services, and fellowship during public emergencies.
- Support a healthy community food system that includes healthy grocery and dining destinations, farmers' markets, community gardens, and an Agricultural-Technology Park for agricultural education and demonstration.

One additional note is that for convenience, I chose this area because I live about fifteen minutes from the location, making research, site photos, and documentation much easier. Upon visiting the schools I singled out as possible choices, I began leaning more toward Galway Elementary as a final choice. Its location on top of the hill, lack of trees throughout the site, and location near single-family homes made it a strong contender. However, something very unexpected happened as I drove around the neighborhood after visiting the school grounds. I saw that the lack of tree canopy was present at the school but also became very aware that the lack of tree cover in the front yards of those single-family homes near the school was even more striking. A vast majority of these single-family home front yards had little or no trees to speak of, and this includes understory plantings. I began to realize that this could potentially be a very interesting thesis topic. Why was the tree canopy level so low in these front yards? What could be done to increase the tree canopy level? And…what were the steps for making these changes for the overall benefit of the children within this neighborhood? I began to shift my scope to these single-family front yards and to develop a plan to persuade homeowners to take advantage of county tree-planting programs that I knew were already present within Montgomery County. Dr. Myers was kind enough to share prior research into a project that looked at decreasing lawn and increasing plant coverage within single-family front yards from 2004. I also realized that this type of desktop design intervention could be applied to several neighborhoods along the western edge of Montgomery County. Furthermore, single-family residential yards make up a much higher amount of land use than a single elementary school property, amplifying not only the amount of canopy that could be added to the area but also drastically increasing the number of school children that could benefit from this design intervention. With my thesis design idea firmly rooted and neighborhood scope chosen, I set out to do site inventory and analysis on a neighborhood walk zone surrounding Galway Elementary School.

Site Inventory and Analysis

Galway Elementary School sits in a unique location topographically. It resides directly on the dividing line between Maryland's Piedmont region and the Coastal Plain. This is very evident when walking in the schoolyard and the surrounding neighborhood.

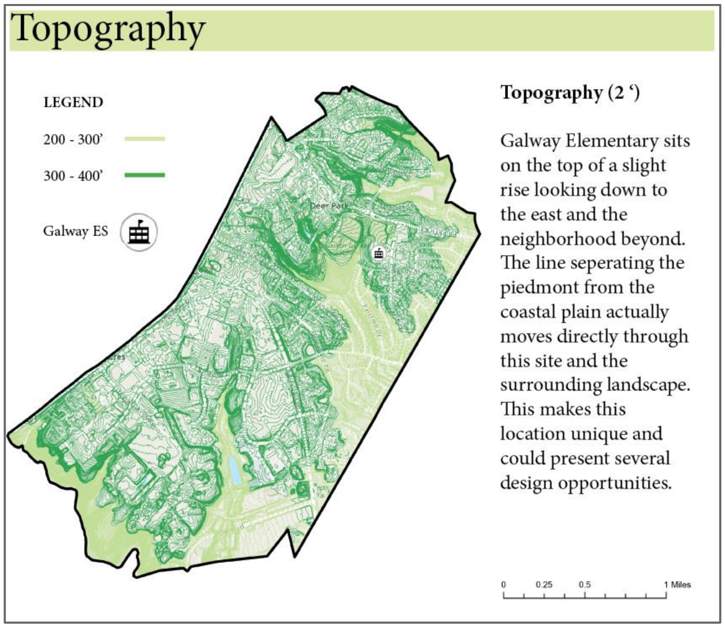

Figure 12: Topography of Galway Elementary and Calverton Neighborhood.

This regional dividing line presented some design opportunities but also some potential issues. Stormwater flowing down into the neighborhood is very heavy at times and it is already a notoriously bad tributary for the Anacostia watershed.

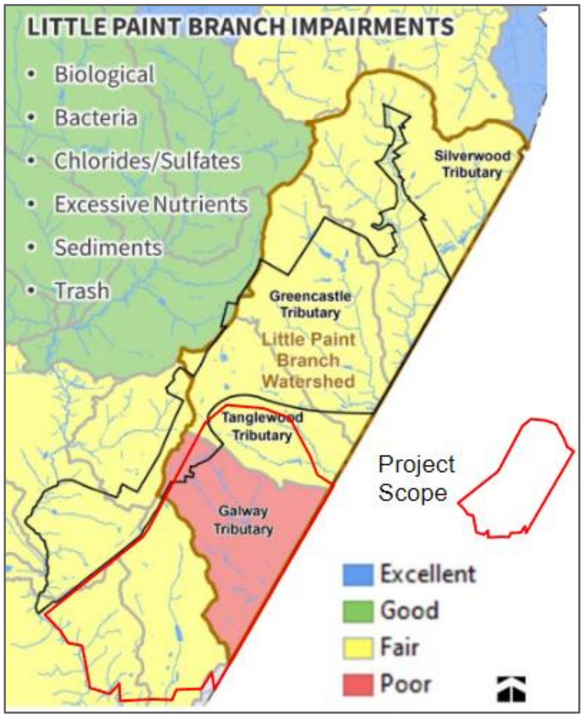

Figure 13: Galway Tributary and Project Scope.

Tree canopy coverage could go a long way towards dealing with many of these pollutants that run down the neighborhood streets and onward to the Chesapeake Bay. The project scope also contained large amounts of impervious surfaces, roads, and driveways, further amplifying the need for some stormwater mitigation techniques, which the trees could help to provide.

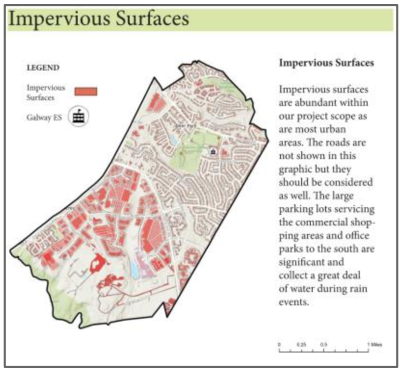

Figure 14: Impervious Surfaces

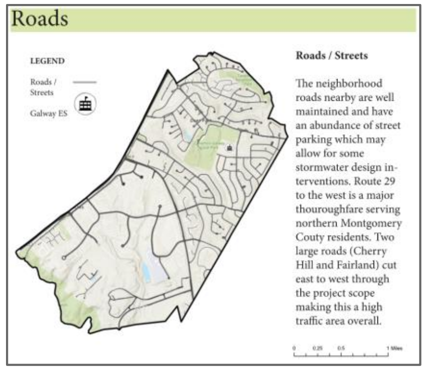

Figure 15: Roads and Streets

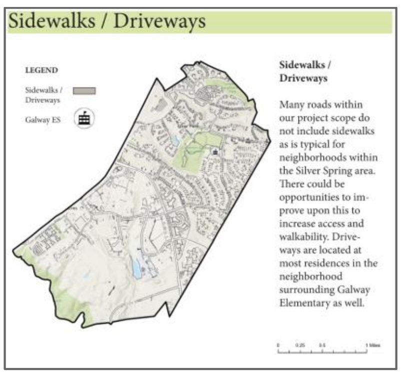

Figure 16: Sidewalks and Driveways

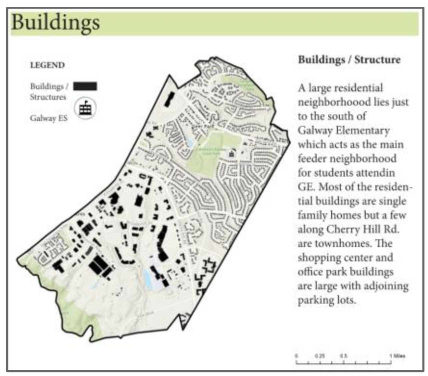

Figure 17: Buildings

Obviously, the tree canopy inventory was a crucial piece of data to be collected and analyzed for this project. However, I also collected data on forest layers (separate from tree canopy) streams, soils, park trails, and existing green infrastructure. All of these proved to be important data sources for analyzing the role an increased tree canopy would play within the project scope. Parks are an important category to mention. Directly behind Galway Elementary and at the center of the school walk zone, is Calverton-Galway Local Park. The park is rather large for the area and is used on a daily basis for its sports fields, playgrounds, and circuitous paved walking trails. It represents a destination for residents of the neighborhood and contains many large canopy trees that act as connectors for the biodiversity within the broken, overdeveloped landscape that surrounds it. An additional network of street trees and front yard canopy additions would serve well to assist in connecting it to the already existing patches of green like Calverton-Galway Local Park.

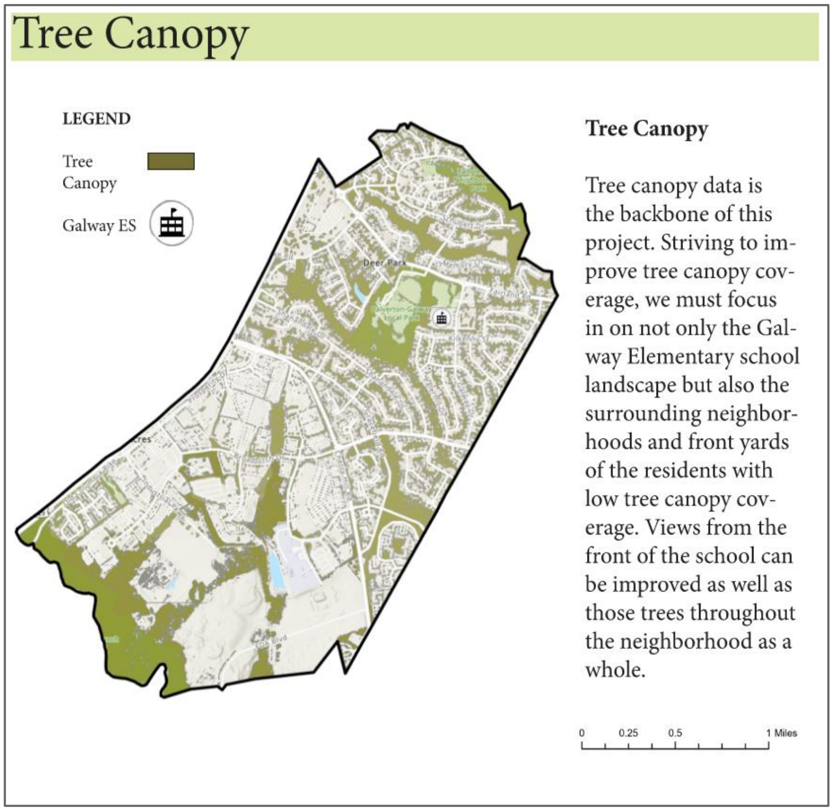

Figure 18: Tree Canopy.

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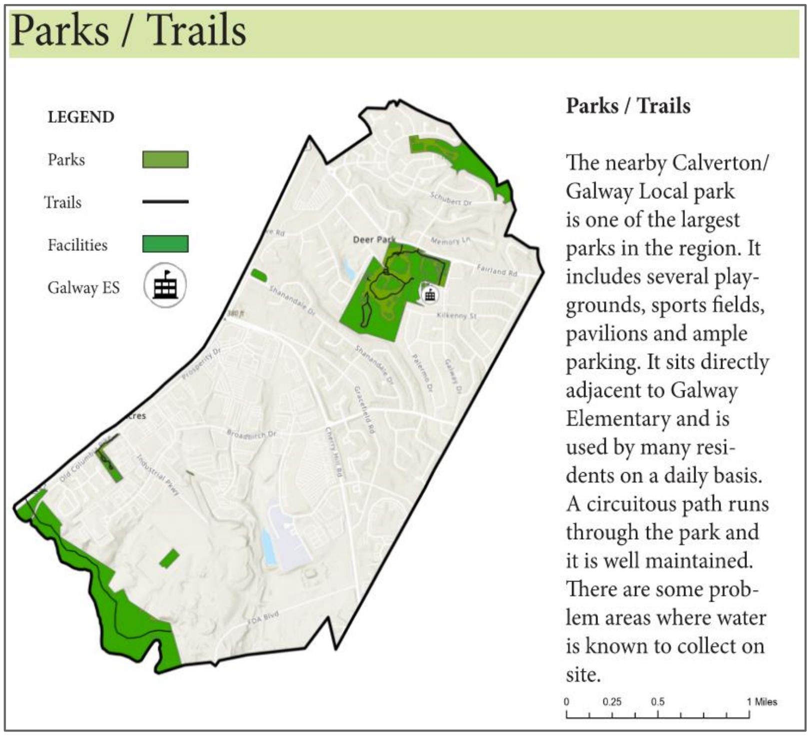


Figure 19: Parks and Trails

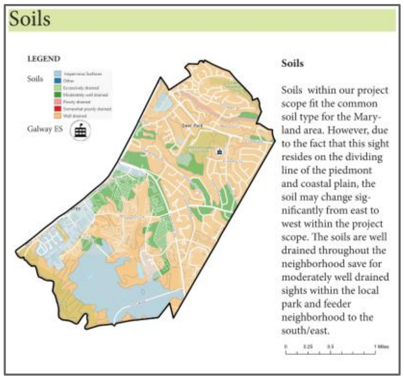


Figure 20: Soils

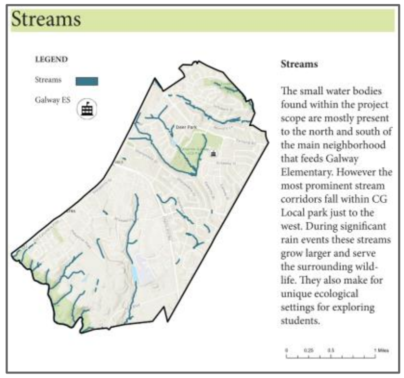


Figure 21: Streams

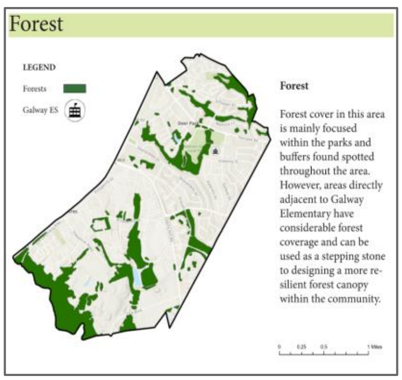


Figure 22: Forest

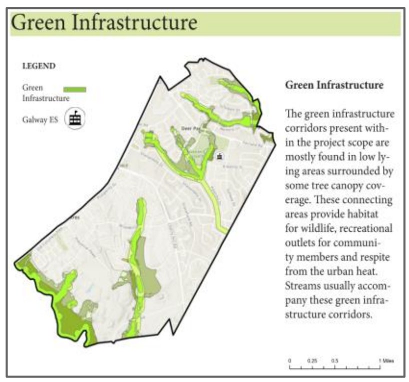


Figure 23: Green Infrastructure

These eleven GIS maps represent the important pieces of abiotic, biotic, and cultural data sets that provide context for the final project scope.

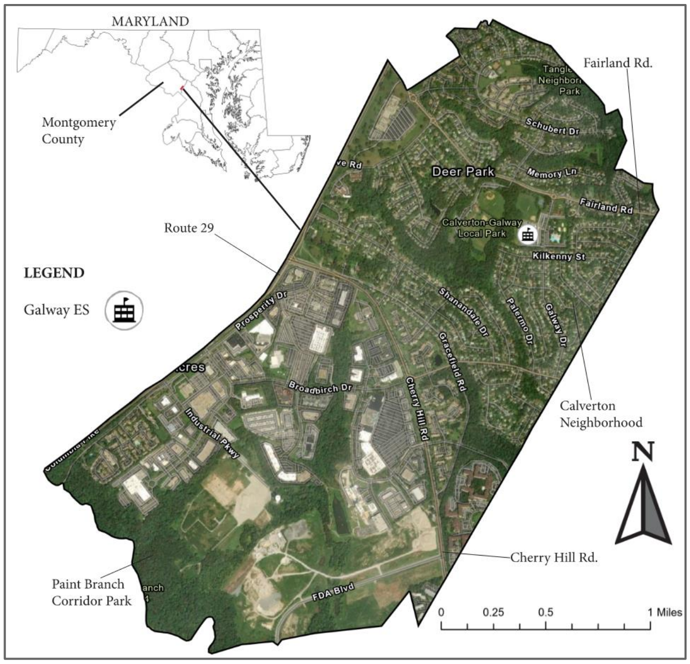


Figure 24: Aerial image of Project Scope.

The Calverton Galway neighborhood is a varied site that contains many individual areas, or yards, within one large project scope. In this study, the author is viewing each single-family front yard as its own site and therefore subject to its own site inventory, analysis, and design intervention.

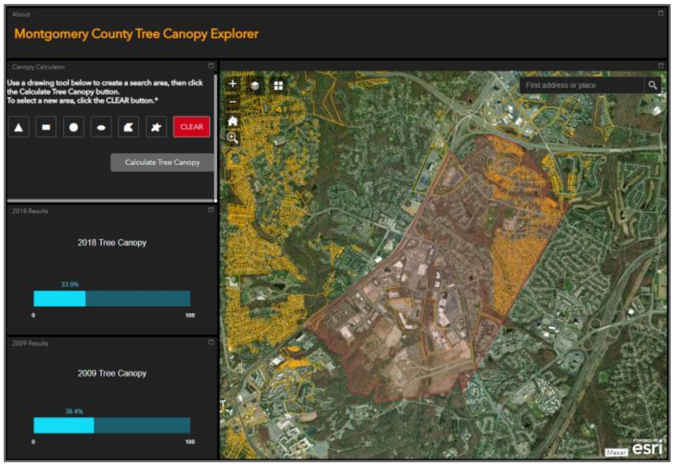


Figure 25: Tree Canopy loss within project scope 2013-2018.

Tree canopy loss within the project scope was up to as high as 5% from 2013 to 2018. In recent years, tree loss has continued due to development, road expansion, and removal by homeowners. This area is due to experience many changes through the Fairland Briggs Chaney Master Plan in the coming years. One of the things that the plan does not directly address in detail is the need for more tree canopy throughout the project scope. Although it is mentioned several times throughout the paper, tree loss is overlooked as a solution to many of the issues in this area.

Front yards in this neighborhood and even beyond the project scope lines are very much lacking in tree canopy overall. These front yards are ideal locations for planting mature trees for future canopy growth. Planting trees could address heat island, stormwater overflow, loss of habitat, and neighborhood aesthetics that have been lost with the removal of older trees.

Methods for Sample Selection of Single-Family Detached Properties

The GIS investigation and documentation of the overall project scope provides overall context . While there are many interventions that could be employed in the area to solve tree cover in the various land uses, the focus of this research is single family detached front yards. Thus the site investigation focus on a smaller area to successfully convey the design interventions. It is intended that they could be replicated throughout the project scope and, also, throughout the western portion of Montgomery County or other similar detached single family house settings.

The initial scope selection was based on the elementary school students attending Galway Elementary School, and the walk zone set aside by MCPS. I then chose to mainly focus on an area within a half mile of the school and then on individual lots of varying tree canopy coverage.

Figure 26: Project Focused Scope and 20 selected lots

Figure 27: Current tree canopy coverage with chosen lots shown.

These lots were chosen to represent varying levels of tree canopy coverage and to be distributed to represent many streets and pockets of the neighborhood. I used ArcGIS Pro to sample many of the lots within the project scope and determine their current tree canopy coverage. The Montgomery Planning data used was part of a 2018 tree canopy study. By checking this data against satellite imagery and street photos I was able to determine that many of the lots had lost trees that were shown as still present within the GIS data. I cross-referenced data to the best extent possible and chose lots, developed four classes of canopy categories, and compiled twenty property samples that represented each of the four classes of canopy categories. The canopy cover classes are 0-25%, 25-50%, 50-75%, and 75-100% front yard tree canopy coverage. I then decided that the sampling size would be twenty lots or five from each percentage category. By choosing lots with varying levels of canopy, I imagined we could have different levels of strategy for planting trees. Some of these lots would only allow for one T1, canopy, tree to be planted but with other plantings such as T2, mid-story tree or a Shrub layer. The patches of lawn and other plantings could be added to maximize habitat building and species diversity.

Front Yard Vegetation Structure and Tree Species Selection

Four vertical layers were uses to describe the structure of the vegetation: T1 denoted mature canopy trees; T2 denote mature mid story trees; S denote a shrub layer of vegetation up to about 9 feet and the H or herbaceous layer denoted vegetation 3 feet and below including lawns   The goal was to highlight the plantable area for T1 trees, those that would grow to an estimated eight of 20 ft. or greater. However, offering solutions on the shrub (S) or small tree levels (T2) would also prove useful to fill patches not occupied by the larger trees.

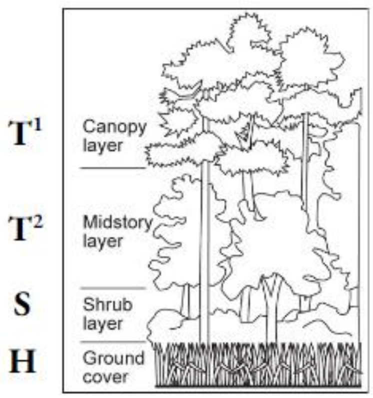


Figure 28: Vegetation structural layers

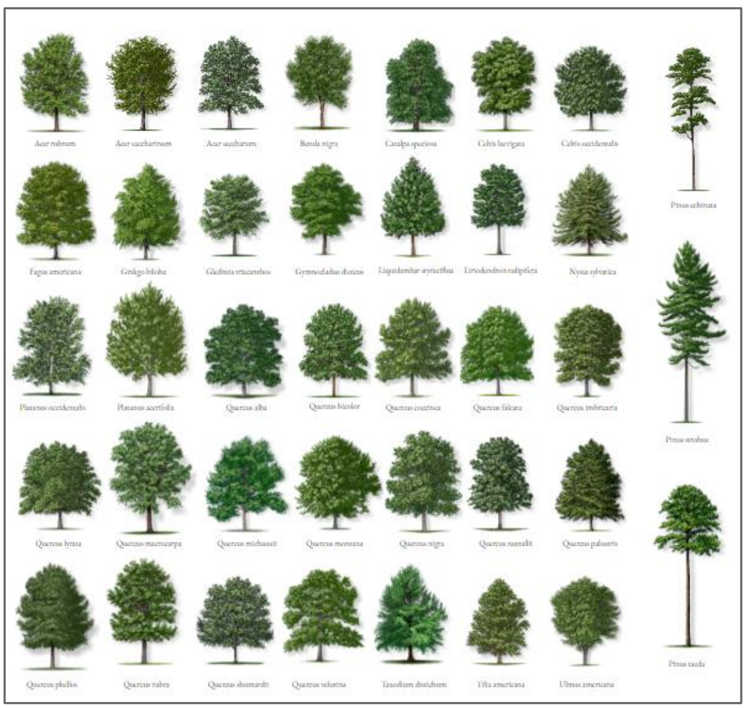
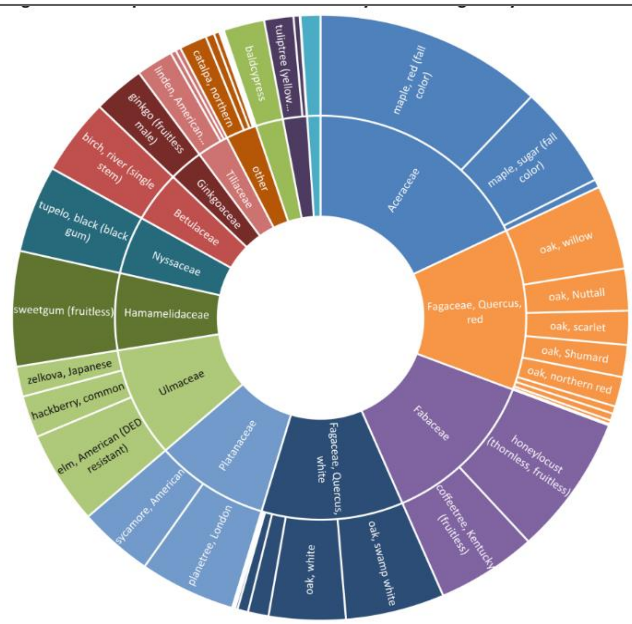


Figure 29: Native T1 and T2 tree species examples suggested for Maryland

landscapes. Keep in mind that this is a partial list of species available and does not represent all of the lower layers of the forest canopy layer model such as shrubs.



To maintain a diverse population of tree species, widely accepted industry guidelines suggest that no more than 30% of new plantings should be in the same taxonomic family, no more than 20% in the same genus, and no more than 10% in any one species. The most commonly planted family was *Fagaceae* (oaks and beech) at 25%, the genus was oaks at 24%, and the species was red maple at 12%.

Figure 30: Tree species planted by Tree Montgomery in fiscal year 2015 - 2021.

Below are the abbreviations used for data collection and presentation. These abbreviations will be broken down and explained in the design interventions section of the paper, including lot metrics, data, and photos.

Chapter 4: Design Interventions and Results

Chapter 4 is organized into three sections. The author selected twenty (20) total samples with five(5) samples per each canopy coverage class. Section 1 provides examples of design intervention for one sample from each of the four classes for typical front yards to provide an in-depth documentation of before and after images and benefit documentation. Section 2 provides a summary documentation of selected measures and the existing plan metrics for the other remaining sixteen (16) front yard samples for four(4) samples in each of the four (4) coverage classes. Section 3 provides an example of an illustrative brochure that utilizes information from the samples to create a document that can be used to persuade homeowners to utilize County tree resources.

Section 1: Design Intervention Examples

Once the neighborhood and individual lots were selected for analysis and intervention it was time to start analyzing data about the lots on an individual basis.

To properly measure canopy growth data, several measurements were needed. Many of them overlapped, but this was necessary to calculate the plantable area over property owned by either the homeowner or the Maryland Department of Transportation. This would allow us to quickly assess plantable areas for large T1 trees in the private lawn area and the right of way. Increasing canopy coverage from large trees is the goal of this thesis and so this number is essential to understand and measure. The breakdown of the metrics in this way was important to determine certain square footage numbers that were needed to determine the maximum plantable area within each lot. Each code in Figure 13 is represented by a four-letter abbreviation and they each pertain to a different area of the single-family front yard lots. Figures 15 - 17 below show how I subtracted or added landscape values to reach the very important value of PLNT(T1). This value represents the area that is not covered by impervious surface, road, or existing T1 tree canopy. This value is the plantable area for large T1 trees within this individual lot project scope. That is the value I wanted to measure from each lot to gain an overall acreage of the neighborhood plantable area and determine the number of trees that could potentially be planted here if we maximized our efforts to cover the open, unplanted lawn area. However, this does not mean that we can't plant permanent T2 trees here beneath the T1 canopy or even shrub layers to maximize the biodiversity of each lot. In fact, these multi-layered and diverse species planting plans should be considered wherever possible, or with homeowners who would like to take a more rewilding approach to their front yards.

Table 1: Abbreviations for sample lot selection.

CAN1 – Canopy Over Property
CAN2 – Canopy Over Lawn and ROW Only
CBF – Chesapeake Bay Foundation
H – Herbaceous / Grass
IMPV – Impervious Surfaces
PLNT – Plantable Area
PLNT(T1) – Plantable Area – CAN2

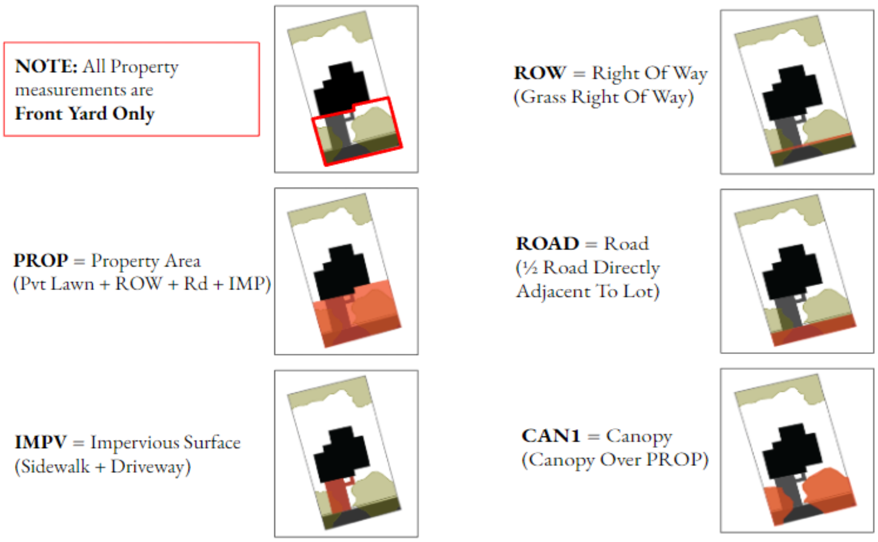
PLOC – Pedestrian Level of Comfort
PROP - Property
ROAD - Road
ROW – Right of Way
S - Shrubs
T1 – Tier 1 Plants – Large Tree
T2 – Tier 2 Plants – Small Tree

Table 2: Abbreviation codes for areas.

Codes	
Note:	All Property Areas are front yard only.
PROP	Property Area (Pvt Lawn + ROW,+ ROAD + IMPV)
IMPV	Sidewalk + Driveway
ROW	Grass Right of Way
ROAD	1/2 Road Directly Adjacent To Property
CAN1	Canopy Over PROP
CAN2	Canopy Over Pvt Lawn And ROW Only
PLNT	Plantable Area (PROP - (ROAD + IMPV))
PLNT(T^1)	Plantable Area - CAN2

Table 3: Tree size codes for data collection.

T^1	Tier 1 Plants (Large Tree)
T^2	Tier 2 Plants (Small Tree)
S	Shrubs
H	Herbaceous / Grass
Each tier is out of 100% coverage	



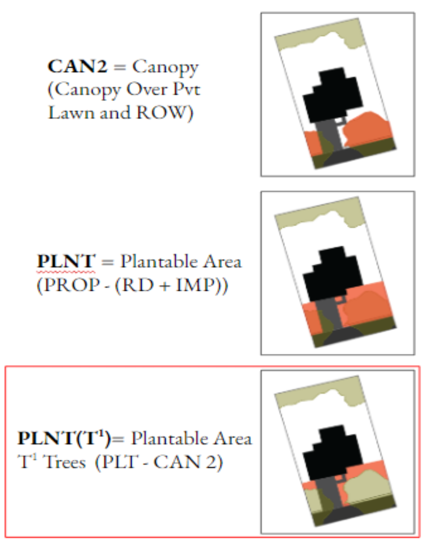


Figure 31: Property data measurement areas.

To properly determine plantable area and canopy coverage over the lawn, several categories had to be measured and subsequently subtracted from the total. The goal was to determine the plantable area for T1 trees over the lawn area, which is PLNT(T1) shown here in red outline.

After determining the values, I was looking for each individual lot I began measuring several lots in the neighborhood. As mentioned, I wanted to find twenty lots that represented the four categories of differing tree canopy levels. This would allow me to offer different suggestions for each of these different categories. Assuming each lot would fall into one of these four categories I would then have a base plan to approach for each of the lots. For example, if the lot was in the 0 to 25" tree canopy category I would suggest planting two to four T2 trees, depending on square footage, that would eventually grow to T1 size. This is an important distinction to make as well. Planting a large canopy tree as a sapling qualifies it at that time as a T2 tree. Many T2 trees become T1 trees, but many do not. Crape Myrtles will always be a T2 tree due to their maximum size and growth pattern. Tulip Poplars are T2 trees at the time of planting but grow to become T1 canopy trees at the upper end of the layer spectrum. It is important to categorize these trees appropriately to allow the data to be collected in an accurate manner. Figure 12 above explains this forest layer relationship.

Now that we understand this, we can propose different interventions for each lot according to the different needs. As mentioned above, lots with large swaths of plantable turf area will be used to maximize space for eventual T1 trees. Lots in the category of 75 to 100% canopy cover could also have space for eventual T1 trees as the older existing canopy dies off in the coming years. However, we can also plant T2 trees here depending on the health of the existing canopy or the desires of the homeowner as far as layout and use of space. Herbaceous ground cover and shrub layers also perform necessary ecosystem services in a layered landscape. Pollinators can use these understory plants as a food source, and they beautify yards in a way that large canopy trees cannot. Remember however that the goal of this thesis is to maximize the planting of T1 canopy trees and ensure that they grow to a healthy height to perform the services that this neighborhood needs them for. Furthermore, the diverse set of tree species available from Montgomery Planning and other plant sources throughout the county will ensure the greatest possible success of this program I am implementing.

Another part of achieving this goal of maximizing tree canopy and the main goal of this thesis is to document the benefits of these trees and persuade homeowners to take advantage of county tree planting programs. I hoped to do this through a series of brochures that could be handed out to residents during a face-to-face consultation in their individual front yards. This thesis is very much a design of a desktop method that can be used by Montgomery Planning to reach these homeowners and provide them with this information. There exists a large gap between the available trees in county nurseries and the desire by homeowners to plant them. Many residents are not even aware that these programs exist or that they have options for free healthy trees at little or no cost to them. I am striving to close this gap and fill these open turf lots with healthy trees for the future of the neighborhoods that perhaps don't even know they have poor existing canopy infrastructure.

Case Study 1: 3204 Cordoba St. (0 - 25 % Canopy Cover)

For each of the four categories I chose one lot to use as an example for the graphic that would be included in the brochures for the homeowners of the Calverton neighborhood. The property representing category one is 3204 Cordoba St. This lot has very little existing plant material in the front yard. I have suggested that in these types of yards, we can plant two or three, or even four trees that will grow to T1 height over time. Filling the gaps with other plantings on the shrub or herbaceous levels is also good but was not the focus of these graphic representations. Below you can see the before and after depictions of the yard and the changes in square feet of coverage for each category.

The plan metrics represent the total area in square feet of each of the categories. These category abbreviations are broken down in Figure 13 above. The measurements were taken in ArcGIS Pro and represent only the front yard. The front corners of the house were used as guides to measure straight out to the existing property sidelines and out to the road. The structural metrics represent the percentage of coverage that each of the layer categories currently provides. These numbers can go as low as 0% and as high as 100%. The 1 Year and 25 Year projections in this case are if no changes are made to the current landscape. An existing street photograph, aerial photograph, GIS lot aerial, and location within the project scope map are provided for each property. We can see that on this lot that the current T1 canopy cover is 0%, the T2 canopy layer is at 5%, the shrub layer (S) is at 5% and the herbaceous layer (H) is at 90%. That last category of herbaceous (H) includes the turf lawn area that we are attempting to decrease over time.

Next, I researched the tree species available through Montgomery Planning's Tree Montgomery Program and chose the trees I felt would best serve this sight moving forward. For this sight, I chose Acer rubrum and Amelanchier alnifolia. I used Photoshop to digitally render the trees into the landscape to allow the homeowner to see the possible spacing and aesthetic of the trees within the scope of the yard. This technique was also applied to the aerial photo and the GIS aerial as well. Plan metrics were adjusted for estimated growth through the ArcGIS Pro platform and the numbers were recorded. Structural metrics were estimated for the 1 Year and 25 Year timelines and included in the Structural Metrics Table within the graphic. As you can see, these two trees alone can increase canopy coverage greatly over time and provide many benefits when they reach maturity. The T1 category of coverage will have increased from 0 to around 55% over the span of 25 years and potentially even more if the trees are properly maintained, pruned, watered, and accompanied by understory plantings to increase biodiversity.

Plan Metrics	
Code	Total Area (Sq Ft)
PROP	5197
IMPV	1084
ROW	791
ROAD	984
CAN1	0
CAN2	0
PLNT	3129
PLNT(T^1)	3129

Table 4: Plan metrics showing before

Plan Metrics	
Code	Total Area (Sq Ft)
PROP	5197
IMPV	1084
ROW	791
ROAD	984
CAN1	1763
CAN2	1763
PLNT	3129
PLNT(T^1)	1366

Table 5: Plan metrics showing after

Plantable area for T1 trees, shown in red, has increased due to new T1/T2 tree plantings.

Structural Metrics			
Before	Current %	1 Year	25 Year
T^1	0	0	0
T^2	5	5	10
S	5	7	20
H	90	90	90

Table 6: Structural metrics before.

Structural Metrics			
After	Current %	Year	25 Year
T^1	0	10	55
T^2	5	20	20
S	5	10	25
H	90	90	70

Table 7: Structural metrics after: Estimated 25-year T1 canopy levels are shown in red.

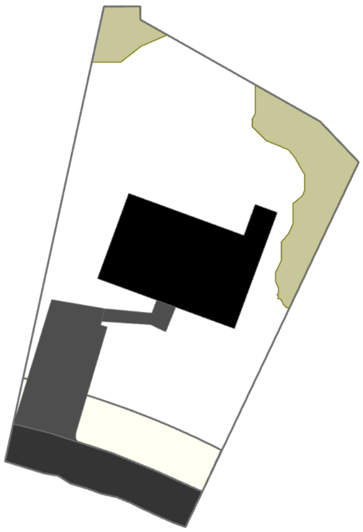


Figure 32: Canopy measurements before design interventions

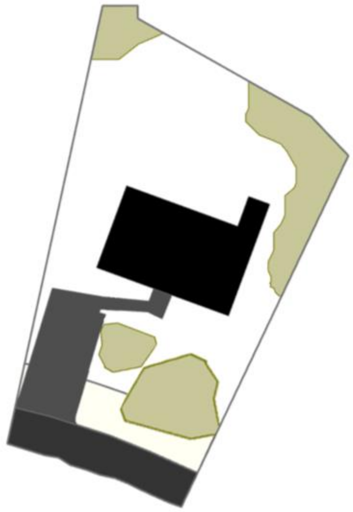


Figure 33: GIS canopy measurements before and after design interventions

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Figure 34: Street view

Figure 35: Photoshop perspective renderings showing proposed tree plantings.

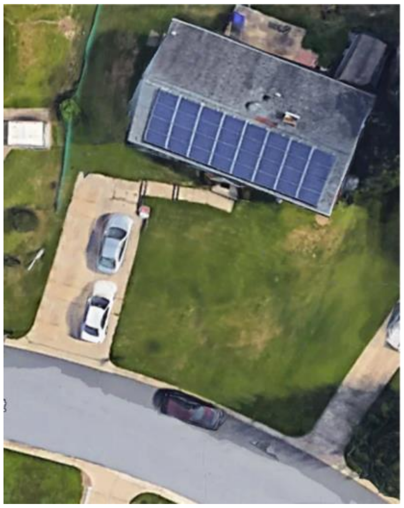


Figure 36: Existing aerial

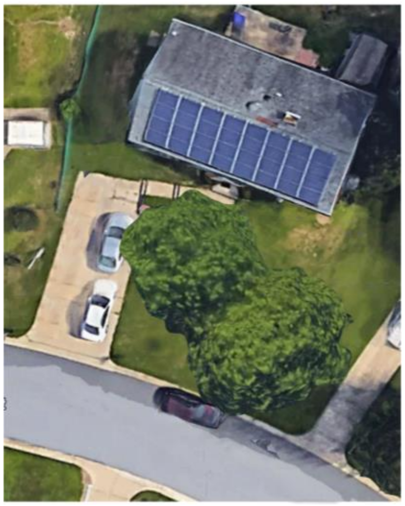


Figure 37: Photoshop aerial renderings showing proposed tree plantings.

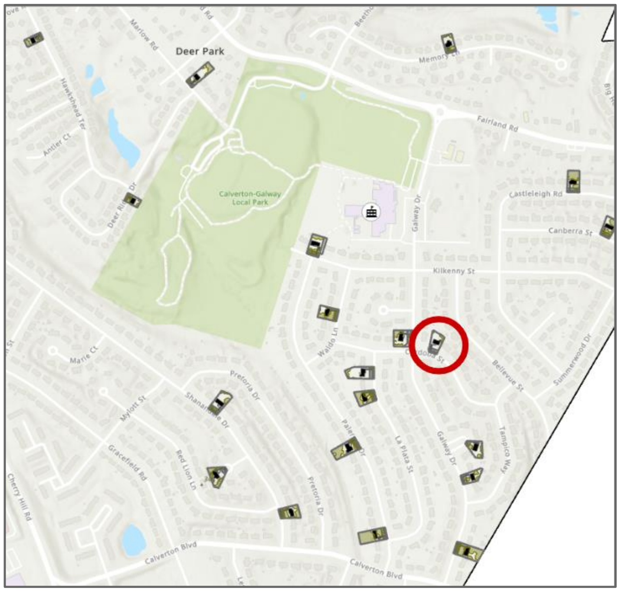
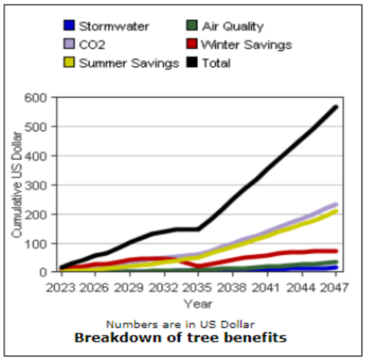


Figure 38: Project scope focused location of 3204 Cordoba St

With these metrics in hand, we can then utilize the I-Tree program to estimate the benefits each tree or trees as a group can provide over this 25-year span. This I-Tree program calculates metrics and ecosystem benefits such as stormwater benefits, air pollution benefits, energy consumption savings, and air quality index improvements. These numbers can translate to real savings over time for homeowners from a home energy consumption standpoint and the ecosystem services cannot be overstated. Below we can see graphics taken from the I-Tree program that shows the aerial location of the trees relative to the existing structure, a breakdown over time of benefits, and an explanation of these benefits in detail.

Figure 39: Aerial location of proposed trees relative to the existing structure.

Overall Benefits



Air Quality Benefits

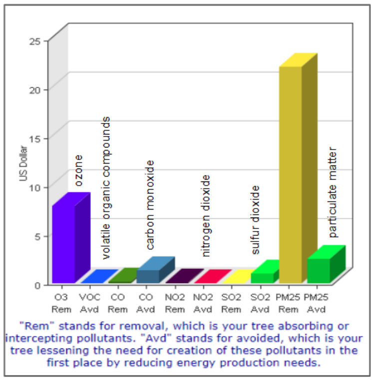


Figure 40: Overall benefits in each category of data measurement from the two proposed tree plantings at 3204 Cordoba St

Figure 41: Air quality benefits of the two trees over the 25-year span.

CO2 Benefits

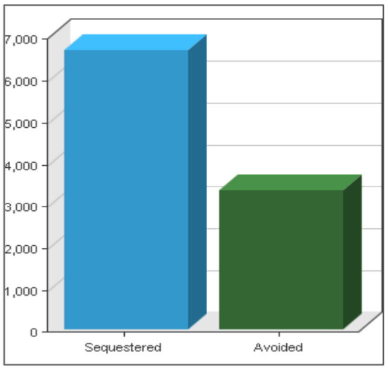


Figure 42: Carbon sequestration over a 25-year span from plantings.

Over the next 25 years, if cared for, these 2 trees will:

- provide a total of $567 worth of overall benefits.
- intercept a total of 15,665 gallons of rainfall and help avoid 1,780 gallons of stormwater runoff.
- conserve a total of 1,652.2 Kilowatt-hours of electricity and reduce consumption of heating fuel by 52.8 therms.
- remove 39 pounds of air pollutants.
- reduce atmospheric carbon dioxide (CO2) by a total amount of 10,033 pounds.

These I-Tree graphics, illustrations, and data sets would be included in the brochure that is provided for each property within the project scope of the Galway Elementary School district. When implemented at each property the overall environmental and social benefits would be profound for the area's school children and the citizens of the entire neighborhood. By personalizing the data and Photoshop illustrations I believe we can truly affect the decision-making process of the citizens and show them the benefits these trees can offer.

Case Study 2: 3054 Memory Ln. (25 - 50 % Canopy Cover)

Case study two involves a lot slightly different from case study one.

Plan Metrics	
Code	**Total Area (Sq Ft)**
PROP	3468
IMPV	622
ROW	100
ROAD	952
CAN1	470
CAN2	401
PLNT	1894
PLNT(T^1)	1493

Table 8: Plan metrics showing before design interventions.

Plan Metrics	
Code	**Total Area (Sq Ft)**
PROP	3468
IMPV	622
ROW	100
ROAD	952
CAN1	1612
CAN2	1483
PLNT	1894
PLNT(T^1)	411

Table 9: Plan metrics showing after design interventions.

Plantable area for T1 trees, shown in red, has decreased due to new T1/T2 tree plantings.

Structural Metrics			
Before	Current %	1 Year	25 Year
T^1	21	23	30
T^2	5	7	10
S	5	5	7
H	84	84	84

Table 10: Structural metrics before and after design interventions.

Structural Metrics			
After	Current %	1 Year	25 Year
T^1	21	24	72
T^2	20	25	7
S	5	5	18
H	81	83	84

Table 11 Structural metrics before and after design interventions. Estimated 25-year T1 canopy levels are shown in red.

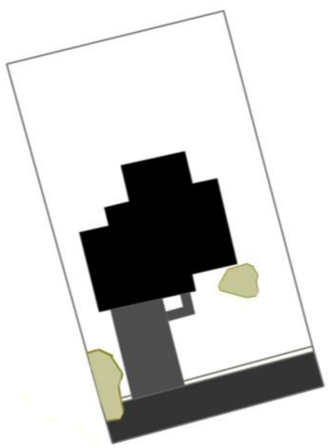


Figure 43: Canopy measurements before design interventions.

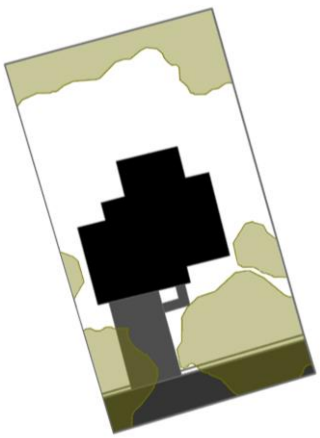


Figure 44: Canopy measurements after design interventions.

Figure 45: Street view

Figure 46: Photoshop perspective renderings showing proposed tree plantings.

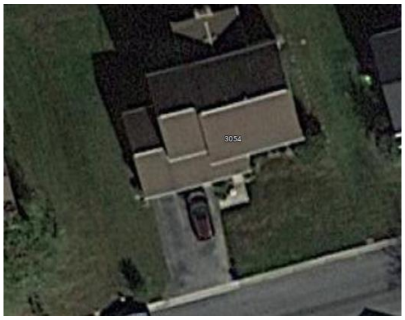


Figure 47: Aerial view

Figure 48: Photoshop aerial renderings showing proposed tree plantings.

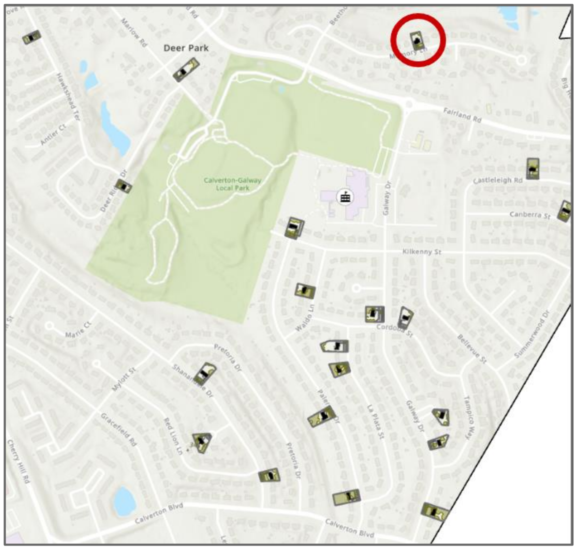


Figure 49: Project scope focused location of 3054 Memory Lane

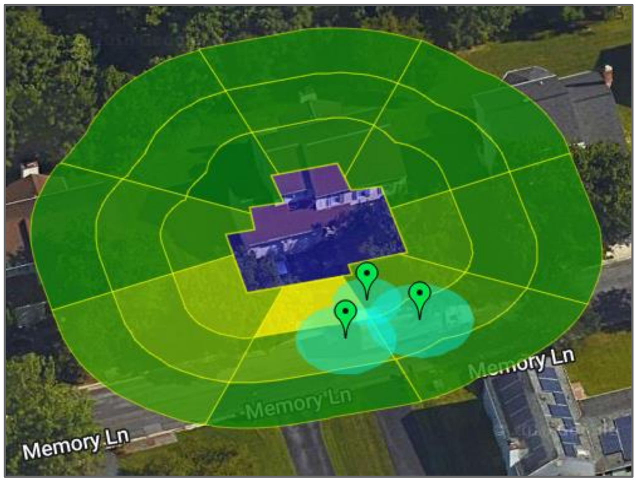


Figure 50: Aerial location of proposed trees relative to the existing structure.

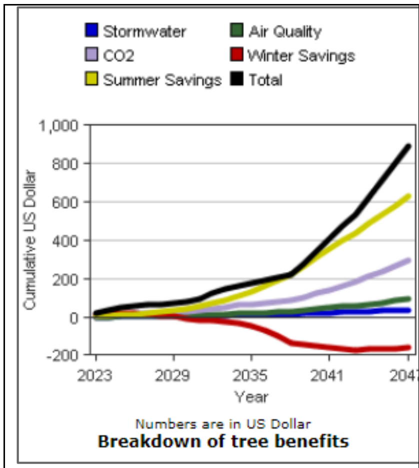


Figure 51: Overall benefits in each category of data measurement from the two proposed tree plantings at 3054 Memory Ln.

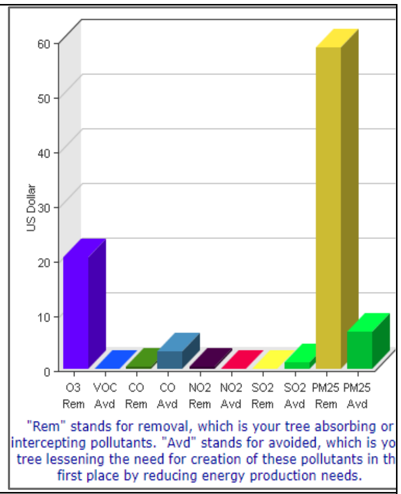


Figure 52: Air quality benefits of the two trees over the 25-year span.

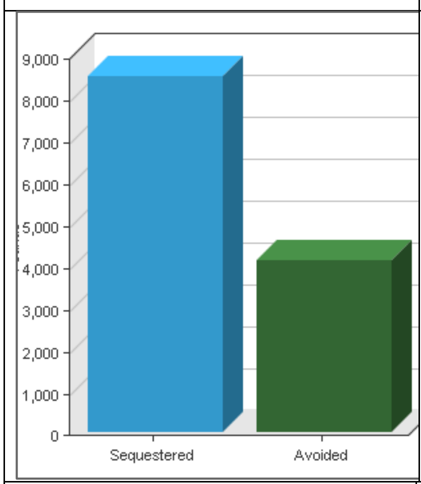


Figure 53: Carbon sequestration over a 25-year span from plantings.

Case Study 3: 12308 Palermo Dr. (50 - 75 % Canopy Cover)

Plan Metrics	
Code	Total Area (Sq Ft)
PROP	6163
IMPV	897
ROW	1254
ROAD	1217
CAN1	2895
CAN2	2458
PLNT	4049
PLNT(T^1)	1591

Table 12: Plan metrics before design interventions.

Plan Metrics	
Code	Total Area (Sq Ft)
PROP	6163
IMPV	897
ROW	1254
ROAD	1217
CAN1	3575
CAN2	3331
PLNT	4049
PLNT(T^1)	718

Table 13: Plan metrics after design interventions. Plantable area for T 1 trees, shown in red, has decreased due to new T1/T2 tree plantings.

Structural Metrics			
Before	Current %	1 Year	25 Year
T^1	40	42	55
T^2	10	17	5
S	2	3	5
H	90	90	90

Table 14: Structural metrics before design interventions

Structural Metrics			
After	Current %	1 Year	25 Year
T^1	40	43	75
T^2	23	26	9
S	2	3	10
H	90	90	80

Table 15: Structural metrics after design interventions. Estimated 25-year tree canopy levels are shown in red.

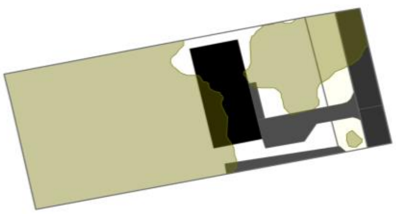
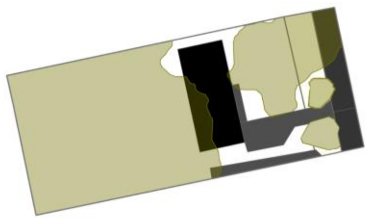
 .	
Figure 54: Canopy measurements before design interventions	Figure 54: Canopy measurements after design interventions.

Figure 55: Street view.

Figure 56: Photoshop perspective renderings showing proposed tree plantings.

Figure 57: Aerial view.

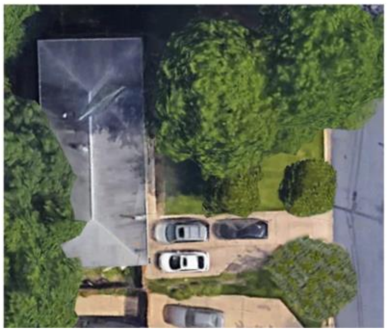


Figure 58: Photoshop aerial renderings showing proposed tree plantings.

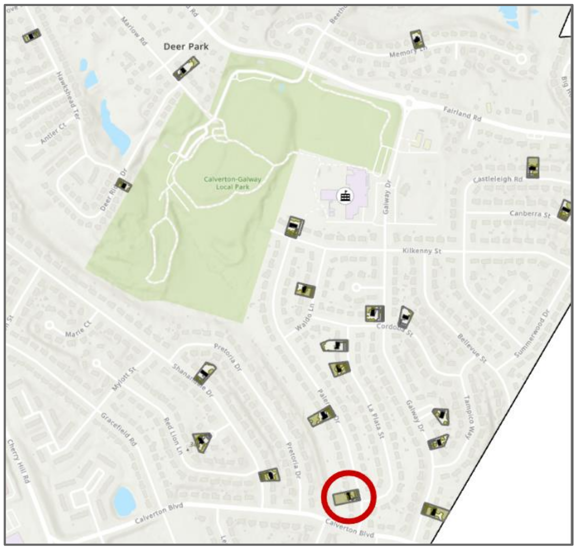


Figure 59: Project scope focused location of 12308 Palermo Drive.

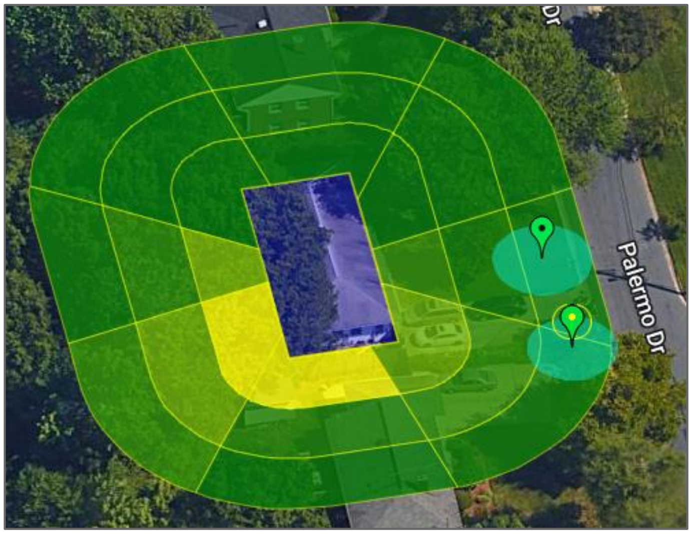


Figure 60: Aerial location of proposed trees relative to the existing structure.

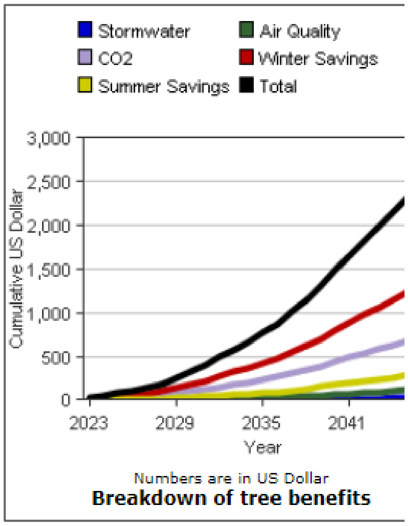


Figure 61: Overall benefits in each category of data measurement from the two proposed tree plantings at 12308 Palermo Drive.

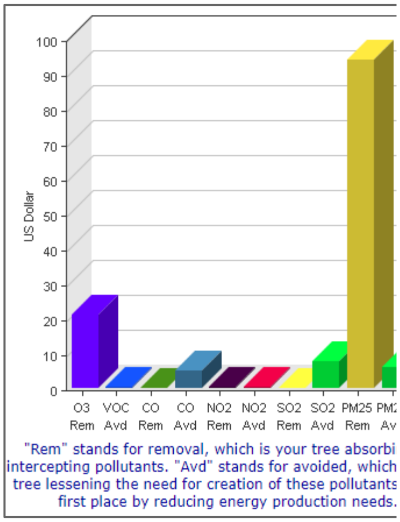


Figure 62: Air quality benefits of the two trees over the 25-year span

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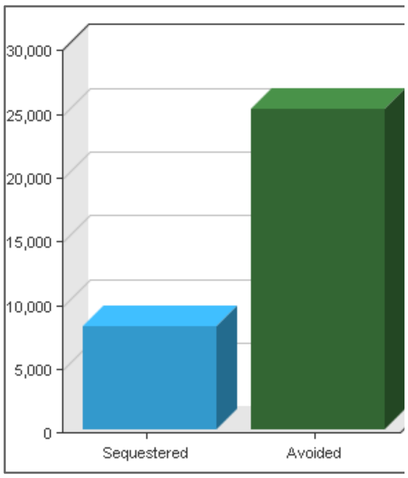

Figure 63: Carbon sequestration over a 25-year span from plantings.

Case Study 4: 12416 La Plata St. (75 - 100 % Canopy Cover)

Plan Metrics	
Code	Total Area (Sq Ft)
PROP	5741
IMPV	829
ROW	1101
ROAD	1134
CAN1	3000
CAN2	2608
PLNT	3778
PLNT(T^1)	1170

Table 16: Plan metrics before design interventions.

Plan Metrics	
Code	Total Area (Sq Ft)
PROP	5741
IMPV	829
ROW	1101
ROAD	1134
CAN1	3285
CAN2	3005
PLNT	3778
PLNT(T^1)	773

Table 17: Plan metrics after design interventions. Plantable area for T 1 trees, shown in red, has decreased due to new T1/T2 tree plantings.

Structural Metrics			
Before	Current %	1 Year	25 Year
T^1	76	77	29
T^2	5	5	10
S	22	22	27
H	63	63	59

Table 18: Structural metrics before and after design interventions.

Structural Metrics			
After	Current %	1 Year	25 Year
T^1	76	77	90
T^2	5	5	20
S	22	22	27
H	60	62	54

Table 19: Structural metrics before and after design interventions. Estimated 25-year T1 canopy levels are shown in red.

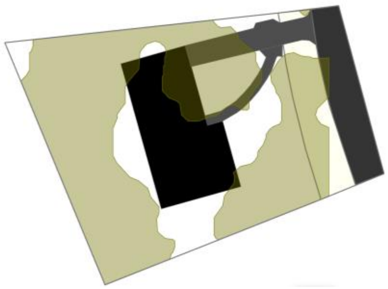

Figure 64: Before canopy measurements before design interventions.

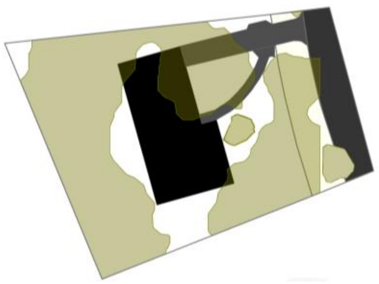

Figure 65: After canopy measurements after design interventions.

Figure 66: Before existing Street view

Figure 67: After Photoshop perspective renderings showing proposed tree plantings.

Figure 68: Aerial view.

Figure 69: Photoshop aerial renderings showing proposed tree plantings.

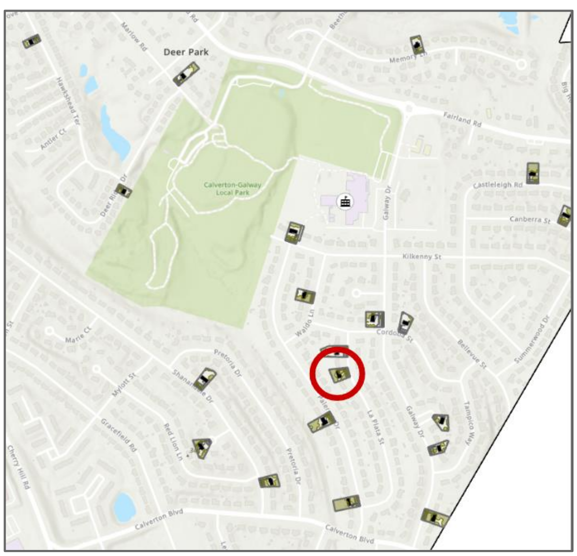

Figure 70: Project scope focused location of 12416 La Plata Street.

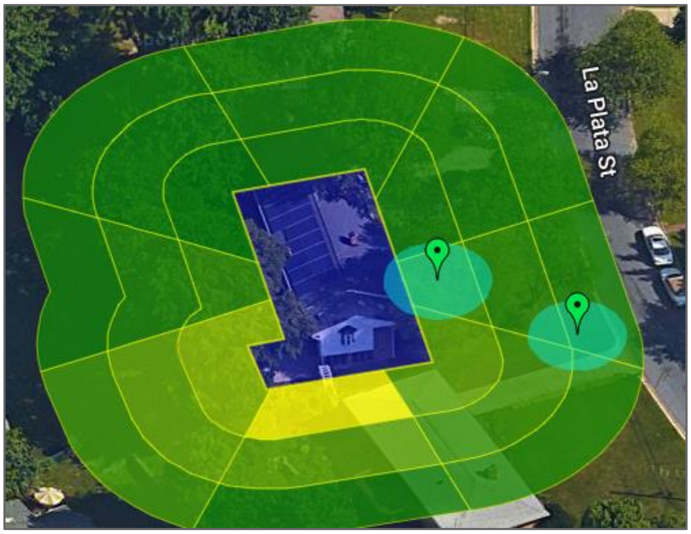

Figure 71: Aerial location of proposed trees relative to the existing structure.

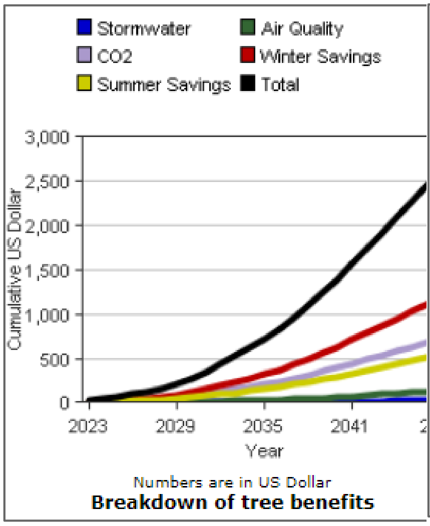

Figure 73: Overall benefits in each category of data measurement from the two proposed tree plantings at 12416 La Plata St.

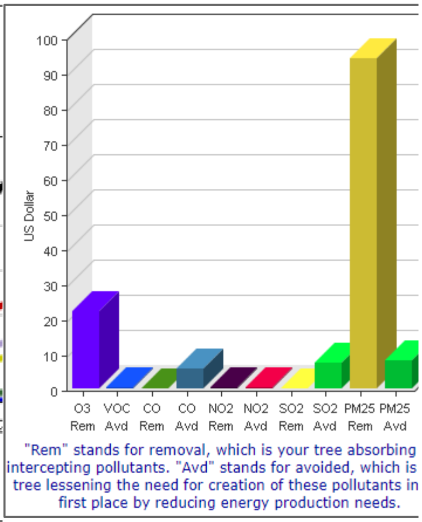

Figure 74: Air quality benefits of the two trees over the 25-year span.

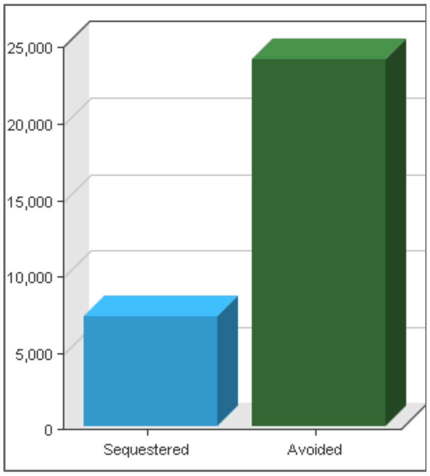

Figure 75: Carbon sequestration over a 25-year span from plantings.

Section 2: Design Intervention Examples - 16 Remaining Properties

Section 2 provides a summary documentation of selected measures and the existing plan metrics for the other remaining sixteen (16) front yard samples for four (4) samples in each of the four (4) coverage classes. These are documented in Figures 76-79.

Figure 76: Single-family front yards containing 0-25% existing tree canopy cover.

Figure 77: Single-family front yards with 25-50% existing tree canopy cover.

Figure 78: Single-family front yards with 50-75% existing tree canopy cover.

Figure 79: Single-family front yards with 75-100% existing tree canopy cover.

Chapter 5: Discussion and Conclusions

Designing tree canopy program and procedure that support tree cover solutions for underserved urban communities within Montgomery County Public School landscapes and surrounding neighborhoods will lead to long term benefits for students and healthier environments for those communities overall. Most importantly, developing a methodology that includes showing homeowners both the data and images of proposed plantings will potentially influence them to plant more trees and to improve their home landscapes as well as the broader ecosystem. Montgomery County has effective programming to provide community members access to free and healthy shade trees for planting on their private properties. They make the process of applying, consulting, and following up easy to navigate. What is missing is a methodology and process that relatively quickly communicates both how trees will benefit the homeowner and what they will look like post planting. This thesis achieves that goal by developing a method to provide the homeowner with both information on benefits and a visual of proposed plantings. The county needs to make community members aware of the benefits of these canopy trees and that they are available from these programs, free of charge.

Summary Implications for Benefits

What would be the results if this method was employed in the case study? The following demonstrates possible benefits from such a project. Tree Montgomery only plants trees from October 15th to May 1st, which means that there is approximately 6 months of actual planting time for tree crews. Accounting for weather and other factors, that's about 150 days. Two 2-man crews working 8-hour days could hypothetically plant 20 trees a day accounting for equipment, unloading, travel etc. There are 1500 single family homes within the project scope. That means that in that time span you could plant 3000 trees, which means planting 2 trees per home.

Thus, over 25 years, the benefits of planting 2 trees per home within our project scope equals…

- **$2,437,500** in total financial savings for the community
- **210,375** pounds of air pollutants removed.
- **32,712,000** pounds of atmospheric CO2 reduced.
- **4,318,500** gallons of stormwater runoff avoided.
- **5,759,250** kilowatt hours of electricity saved.
- **7,599,150** gallons of rainfall intercepted.

32,712,000 pounds of atmospheric CO2 is equivalent to 16,356 tons. That is equivalent to 16,356 gasoline powered cars driving half a year.

7,599,150 gallons of rainfall is equal to 16 Olympic sized swimming pools of water saved over that 25-year span.

Commented [DM1]: https://www.climateneutralgroup.com/en/news/what-exactly-is-1-tonne-of-co2-v2/

5,759,250 kilowatt hours of electricity is enough energy on average to power 575 homes for a full year.

The effects of a program like this would be felt in many ways community wide. The best part is the benefits would only increase and grow with the strengthening of all these neighborhood trees and thus also the ecology of these front yards.

Limitations

Time and detailed field work are limitations of this study and the author notes this may change the actual inventory of vision on the sample sites. In addition ,the timeline of the Fairland Briggs Chaney Master plan could influence effectiveness of tree planting projects. The plan is a massive undertaking for the county and to convince them to change planning goals or divert funds could prove difficult at this juncture. The availability of trees and the waiting period for programs such as Tree Montgomery could slow progress, and Montgomery County Planning's time and workforce limitations could influence the acceptance of these interventions.

Further Research

This project is intended to contribute supporting tree planting in one of the most common land use types: single family detached housing. The case study presented in the research should be applied in similar communities in order to help address problem facing many communities. Further research is warranted. As mentioned previously, a circulation study is highly recommended and would go a long way towards solving other issues such as limited plantable area in right of ways. Hopefully these design interventions can persuade homeowners to plant more trees which in turn can help achieve long-term canopy growth and project success within these communities. A solar study could also go a long way towards maximizing efficiency of these plantings should help homeowners balance solar panels installs and tree planting. The choice of trees would change many aspects of these benefits and so a detailed study of specific benefits of varying species withing this project would help to clarify benefits and maximize overall success of this and all future planting projects.

Bibliography:

Aminpour, F., Bishop, K., & Corkery, L. (2020). The hidden value of in-between spaces for children's self-directed play within outdoor school environments. *Landscape and Urban Planning*, *194*, 103683. https://doi.org/10.1016/j.landurbplan.2019.103683

Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., Alvarez-Pedrerol, M., Nieuwenhuijsen, M. J., & Sunyer, J. (2014). Green and blue spaces and behavioral development in Barcelona schoolchildren: The BREATHE project. *Environmental Health Perspectives*, *122*(12), Article 12. https://doi.org/10.1289/ehp.1408215

Bagot, K. L., Allen, F. C. L., & Toukhsati, S. (2015). Perceived restorativeness of children's school playground environments: Nature, playground features and play period experiences. *Journal of Environmental Psychology*, *41*, 1–9. https://doi.org/10.1016/j.jenvp.2014.11.005

Baró, F., Camacho, D. A., Pérez Del Pulgar, C., Triguero-Mas, M., & Anguelovski, I. (2021). School greening: Right or privilege? Examining urban nature within and around primary schools through an equity lens. *Landscape and Urban Planning*, *208*, 104019. https://doi.org/10.1016/j.landurbplan.2020.104019

Belaire, J. A., Westphal, L. M., & Minor, E. S. (2016). Different social drivers, including perceptions of urban wildlife, explain the ecological resources in residential landscapes. *Landscape Ecology*, *31*(2), 401–413. https://doi.org/10.1007/s10980-015-0256-7

Berland, A., Shiflett, S. A., Shuster, W. D., Garmestani, A. S., Goddard, H. C., Herrmann, D. L., & Hopton, M. E. (2017). The role of trees in urban stormwater management. *Landscape and Urban Planning*, *162*, 167–177. https://doi.org/10.1016/j.landurbplan.2017.02.017

Bikomeye, J. C., Balza, J., & Beyer, K. M. (2021). The Impact of Schoolyard Greening on Children's Physical Activity and Socioemotional Health: A Systematic Review of Experimental Studies. *International Journal of Environmental Research and Public Health*, *18*(2), Article 2. https://doi.org/10.3390/ijerph18020535

Browning, M. H. E. M., & Locke, D. H. (2020). The greenspace-academic performance link varies by remote sensing measure and urbanicity around Maryland public schools. *Landscape and Urban Planning*, *195*, 103706. https://doi.org/10.1016/j.landurbplan.2019.103706

Burr, A., Hall, D. M., & Schaeg, N. (2018). The perfect lawn: Exploring neighborhood socio-cultural drivers for insect pollinator habitat. *Urban Ecosystems*, *21*(6), 1123–1137. https://doi.org/10.1007/s11252-018-0798-y

Carmichael, C. E., & McDonough, M. H. (2018). The trouble with trees? Social and political dynamics of street tree-planting efforts in Detroit, Michigan, USA. *Urban Forestry & Urban Greening*, *31*, 221–229. https://doi.org/10.1016/j.ufug.2018.03.009

Chawla, L., Keena, K., Pevec, I., & Stanley, E. (2014). Green schoolyards as havens from stress and resources for resilience in childhood and adolescence. *Health & Place*, *28*, 1–13. https://doi.org/10.1016/j.healthplace.2014.03.001

Danford, R., Cheng, C., Strohbach, M., Ryan, R., Nicolson, C., & Warren, P. (2014). What Does It Take to Achieve Equitable Urban Tree Canopy Distribution? A Boston Case Study. *Cities and the Environment (CATE)*, *7*(1), Article 1. https://digitalcommons.lmu.edu/cate/vol7/iss1/2

FBCMP, M. (2023). *Fairland and Briggs Chaney Master Plan Public Hearing Draft*.

Flax, L., Korthals Altes, R., Kupers, R., & Mons, B. (2020). Greening schoolyards—An urban resilience perspective. *Cities*, *106*, 102890. https://doi.org/10.1016/j.cities.2020.102890

Francis Norwood, M., Lakhani, A., & Kendall, E. (2021). Teaching traditional indoor school lessons in nature: The effects on student learning and behaviour. *Landscape and Urban Planning*, *206*, 103963. https://doi.org/10.1016/j.landurbplan.2020.103963

Gerstein, D. E., Bates, C. R., & Bohnert, A. M. (2021). Evaluating a Green Schoolyard Transformation: A Protocol Utilizing the RE-AIM Framework. *Children, Youth and Environments*, *31*(1), Article 1.

Giezen, M., & Pellerey, V. (2021). Renaturing the city: Factors contributing to upscaling green schoolyards in Amsterdam and The Hague. *Urban Forestry & Urban Greening*, *63*, 127190. https://doi.org/10.1016/j.ufug.2021.127190

Grove, J. M., Cadenasso, M. L., Pickett, S. T., Machlis, G. E., & Burch, W. R. (2015). *The Baltimore School of Urban Ecology: Space, scale, and time for the study of cities* (Vol. 1–1 online resource (256 pages) : illustrations, maps). Yale University Press. https://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1074246

Hodson, C. B., & Sander, H. A. (2017). Green urban landscapes and school-level academic performance. *Landscape and Urban Planning*, *160*, 16–27. https://doi.org/10.1016/j.landurbplan.2016.11.011

Hodson, C. B., & Sander, H. A. (2021). Relationships between urban vegetation and academic achievement vary with social and environmental context. *Landscape and Urban Planning*, *214*, 104161. https://doi.org/10.1016/j.landurbplan.2021.104161

Iojă, C. I., Grădinaru, S. R., Onose, D. A., Vânău, G. O., & Tudor, A. C. (2014). The potential of school green areas to improve urban green connectivity and multifunctionality. *Urban Forestry & Urban Greening*, *13*(4), 704–713. https://doi.org/10.1016/j.ufug.2014.07.002

Jansson, M., Gunnarsson, A., Mårtensson, F., & Andersson, S. (2014). Children's perspectives on vegetation establishment: Implications for school ground greening. *Urban Forestry & Urban Greening*, *13*(1), 166–174. https://doi.org/10.1016/j.ufug.2013.09.003

Jenerette, G. D., Harlan, S. L., Buyantuev, A., Stefanov, W. L., Declet-Barreto, J., Ruddell, B. L., Myint, S. W., Kaplan, S., & Li, X. (2016). Micro-scale urban surface temperatures are related to land-cover features and residential heat related health impacts in Phoenix, AZ USA. *Landscape Ecology*, *31*(4), 745–760. https://doi.org/10.1007/s10980-015-0284-3

Jennings, V., & Gaither, C. J. (2015). Approaching Environmental Health Disparities and Green Spaces: An Ecosystem Services Perspective. *International Journal of Environmental Research and Public Health*, *12*(2), Article 2. https://doi.org/10.3390/ijerph120201952

Jung, S., Qin, X., & Oh, C. (2016). Improving strategic policies for pedestrian safety enhancement using classification tree modeling. *Transportation Research Part A: Policy and Practice*, *85*, 53–64. https://doi.org/10.1016/j.tra.2016.01.002

Kingsley, C. (1874). *Health and education* (Vol. 1–1 online resource (2 preliminary leaves, 411, [1] pages)). W. Isbister & Co. http://catalog.hathitrust.org/api/volumes/oclc/1878490.html

Konijnendijk, C. C. (Cecil C.). (2005). *Urban forests and trees: A reference book* (Vol. 1–1 online resource (xx, 520 pages) : illustrations, maps). Springer. http://site.ebrary.com/id/10133778

Kuo, M., Browning, M. H. E. M., Sachdeva, S., Lee, K., & Westphal, L. (2018). Might School Performance Grow on Trees? Examining the Link Between “Greenness” and Academic Achievement in Urban, High-Poverty Schools. *Frontiers in Psychology*, *9*. https://www.frontiersin.org/article/10.3389/fpsyg.2018.01669

Kuo, M., Klein, S. E., HEM Browning, M., & Zaplatosch, J. (2021). Greening for academic achievement: Prioritizing what to plant and where. *Landscape and Urban Planning*, *206*, 103962. https://doi.org/10.1016/j.landurbplan.2020.103962

Kweon, B., Ellis, C., Lee, J., & Jacobs, K. G. (2017). *The link between school environments and student academic performance*. https://doi.org/10.1016/J.UFUG.2017.02.002

Kweon, B.-S., Mohai, P., Lee, S., & Sametshaw, A. M. (2018). Proximity of public schools to major highways and industrial facilities, and studentsâ€™ school performance and health hazards. *Environment and Planning B*, *45*(2), Article 2.

Łaszkiewicz, E., & Sikorska, D. (2020). Children’s green walk to school: An evaluation of welfare-related disparities in the visibility of greenery among children. *Environmental Science & Policy*, *110*, 1–13. https://doi.org/10.1016/j.envsci.2020.05.009

Leets, L., Sprenger, A., Hartman, R. O., Howard Jackson, J., Britt, M., Gulley, A., Simon Thomas, J., & Wijesinghe, S. (2022). Promoting tree equity in Washington, D.C. *Trees, Forests and People*, *7*, 100209. https://doi.org/10.1016/j.tfp.2022.100209

Leff, M. (2016). *The Sustainable Urban Forest: A Step by Step Approach*. https://www.itreetools.org/documents/175/Sustainable_Urban_Forest_Guide_14Nov2016.pdf

Li, D., Chiang, Y.-C., Sang, H., & Sullivan, W. C. (2019). Beyond the school grounds: Links between density of tree cover in school surroundings and high school academic performance. *Urban Forestry & Urban Greening*, *38*, 42–53. https://doi.org/10.1016/j.ufug.2018.11.001

Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning*, *148*, 149–158. https://doi.org/10.1016/j.landurbplan.2015.12.015

Lim, T. C., Wilson, B., Grohs, J. R., & Pingel, T. J. (2022). Community-engaged heat resilience planning: Lessons from a youth smart city STEM program. *Landscape and Urban Planning*, *226*, 104497. https://doi.org/10.1016/j.landurbplan.2022.104497

Lindemann-Matthies, P., Benkowitz, D., & Hellinger, F. (2021). Associations between the naturalness of window and interior classroom views, subjective well-being of primary school children and their performance in an attention and concentration test. *Landscape and Urban Planning*, *214*, 104146. https://doi.org/10.1016/j.landurbplan.2021.104146

Matsuoka, R. H. (2010). Student performance and high school landscapes: Examining the links. *Landscape and Urban Planning*, *97*(4), 273–282. https://doi.org/10.1016/j.landurbplan.2010.06.011

MCDOT - Trees. (2023). https://www.montgomerycountymd.gov/DOT-Highway/tree/index.html#TreeHome

Mincey, S. K., Schmitt-Harsh, M., & Thurau, R. (2013). Zoning, land use, and urban tree canopy cover: The importance of scale. *Urban Forestry & Urban Greening*, *12*(2), Article 2. https://doi.org/10.1016/j.ufug.2012.12.005

Moreno, A., Tangenberg, J., Hilton, B., & Hilton, J. (2015). An Environmental Assessment of School Shade Tree Canopy and Implications for Sun Safety Policies: The Los Angeles Unified School District. *ISPRS International Journal of Geo-Information*, *4*(2), Article 2. https://doi.org/10.3390/ijgi4020607

Muvengwi, J., Kwenda, A., Mbiba, M., & Mpindu, T. (2019). The role of urban schools in biodiversity conservation across an urban landscape. *Urban*

Forestry & Urban Greening, *43*, 126370. https://doi.org/10.1016/j.ufug.2019.126370

Nilsson, K., Sangster, M., & Konijnendijk, C. C. (2011). Forests, Trees and Human Health and Well-being: Introduction. In K. Nilsson, M. Sangster, C. Gallis, T. Hartig, S. de Vries, K. Seeland, & J. Schipperijn (Eds.), *Forests, Trees and Human Health* (pp. 1–19). Springer Netherlands. https://doi.org/10.1007/978-90-481-9806-1_1

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, *116*(3), 381–389. https://doi.org/10.1016/S0269-7491(01)00214-7

Nowak, D. J., Crane, D. E., & Stevens, J. C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry & Urban Greening*, *4*(3), 115–123. https://doi.org/10.1016/j.ufug.2006.01.007

Ossola, A., Locke, D., Lin, B., & Minor, E. (2019). Greening in style: Urban form, architecture and the structure of front and backyard vegetation. *Landscape and Urban Planning*, *185*, 141–157. https://doi.org/10.1016/j.landurbplan.2019.02.014

Paddle, E., & Gilliland, J. (2018). Equal Opportunity Streets: Assessing the Equity of Publicly Provisioned Street Trees in Walk Zones Surrounding Elementary Schools. *Environmental Justice*, *11*(4), 154–164. https://doi.org/10.1089/env.2017.0002

Petrash, J. (2002). *Understanding Waldorf education: Teaching from the inside out*. Gryphon House. http://catdir.loc.gov/catdir/description/cons041/2002023720.html

Rae, R. A., Simon, G., & Braden, J. (2016). Public Reactions to New Street Tree Planting. In *Urban Forests*. Apple Academic Press.

Reducing Urban Heat Islands: Compendium of Strategies: Trees and Vegetation. (n.d.).

Reforest Montgomery. (2023). Montgomery Planning. https://montgomeryplanning.org/planning/environment/forest-conservation-and-trees/reforest-montgomery/

Riley, C. B., & Gardiner, M. M. (2020). Examining the distributional equity of urban tree canopy cover and ecosystem services across United States cities. *PLOS ONE*, *15*(2), Article 2. https://doi.org/10.1371/journal.pone.0228499

Rodriguez, S. L., Peterson, M. N., & Moorman, C. J. (2017). Does education influence wildlife friendly landscaping preferences? *Urban Ecosystems*, *20*(2), 489–496. https://doi.org/10.1007/s11252-016-0609-2

Schulman, A., & Peters, C. A. (2008). GIS analysis of urban schoolyard landcover in three U.S. cities. *Urban Ecosystems*, *11*(1), 65–80. https://doi.org/10.1007/s11252-007-0037-4

Seattle 2020 Urban Forest Managemant Plan. (2020).

Sivarajah, S., Smith, S. M., & Thomas, S. C. (2018). Tree cover and species composition effects on academic performance of primary school students. *PLOS ONE*, *13*(2), Article 2. https://doi.org/10.1371/journal.pone.0193254

Stevenson, K. T., Moore, R., Cosco, N., Floyd, M. F., Sullivan, W., Brink, L., Gerstein, D., Jordan, C., & Zaplatosch, J. (2020). A national research agenda supporting green schoolyard development and equitable access to nature. *Elementa: Science of the Anthropocene*, *8*(1), 406. https://doi.org/10.1525/elementa.406

Tallis, H., Bratman, G. N., Samhouri, J. F., & Fargione, J. (2018). Are California Elementary School Test Scores More Strongly Associated With Urban Trees Than Poverty? *Frontiers in Psychology*, *9*. https://www.frontiersin.org/article/10.3389/fpsyg.2018.02074

Turner-Skoff, J. B., & Cavender, N. (2019). The benefits of trees for livable and sustainable communities. *PLANTS, PEOPLE, PLANET*, *1*(4), 323–335. https://doi.org/10.1002/ppp3.39

Walters, M., & Sinnett, D. (2021). Achieving tree canopy cover targets: A case study of Bristol, UK. *Urban Forestry & Urban Greening*, *65*, 127296. https://doi.org/10.1016/j.ufug.2021.127296

Wolf, K. (2008). City Trees and Property Values. . . . .

Wolf, K. L., Lam, S. T., McKeen, J. K., Richardson, G. R. A., van den Bosch, M., & Bardekjian, A. C. (2020). Urban Trees and Human Health: A Scoping Review. *International Journal of Environmental Research and Public Health*, *17*(12), Article 12. https://doi.org/10.3390/ijerph17124371

Zhang, Z., Martin, K. L., Stevenson, K. T., & Yao, Y. (2022). Equally green? Understanding the distribution of urban green infrastructure across student demographics in four public school districts in North Carolina, USA. *Urban Forestry & Urban Greening*, *67*, 127434. https://doi.org/10.1016/j.ufug.2021.127434

Zhang, Z., Stevenson, K. T., & Martin, K. L. (2021). Exploring geographical, curricular, and demographic factors of nature use by children in urban schoolyards in Raleigh, NC, USA. *Urban Forestry & Urban Greening*, *65*, 127323. https://doi.org/10.1016/j.ufug.2021.127323