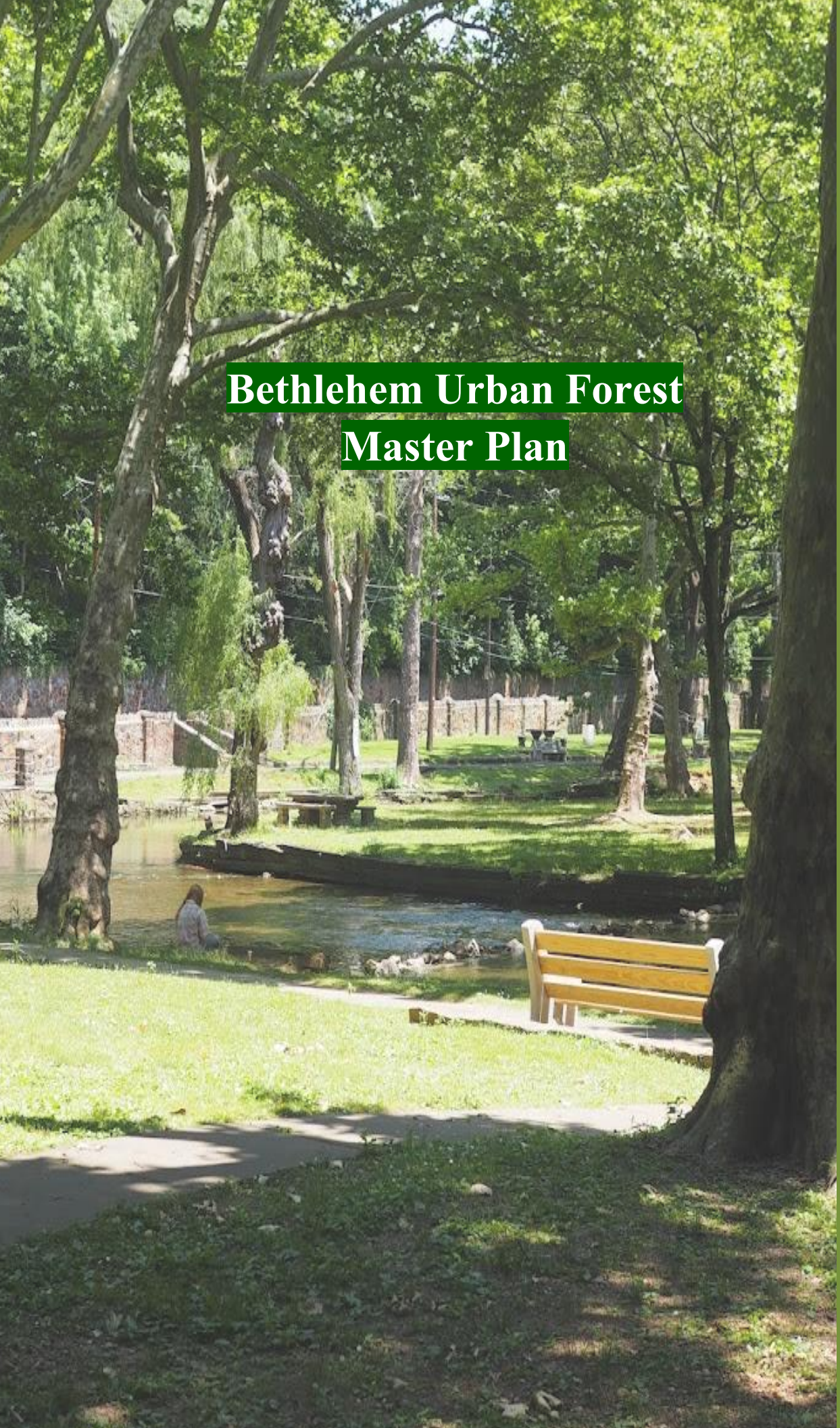

Bethlehem Urban Forest Master Plan

City of Bethlehem Urban Forestry

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Introduction

The objective of the Urban Forest Master Plan is to ensure the long-term health and growth of Bethlehem's urban forest through sustainable development and preservation of the City's trees, and the education of the public regarding the importance of the urban forest. This plan aims to ensure a healthy and thriving urban forest that benefits all residents and visitors, now and in the future. To ensure the vitality of Bethlehem's urban tree canopy, this document outlines strategies for its safeguarding, enhancement, and expansion. It serves as an initial framework, detailing the necessary resources and their optimal application. It identifies essential tools and strategic deployment, acting as a reference for future decisions pertaining to the preservation, conservation, and upkeep of the City's trees, encompassing the necessary staff and funding for optimal results.

The City of Bethlehem recognizes the essential contributions of trees to the well-being of all who live, work, and visit here.

Trees:

- Purify air and water by removing pollutants
- Mitigate climate change by sequestering atmospheric carbon dioxide
- Regulate urban temperatures by providing shade
- Manage stormwater runoff and control erosion
- Support diverse wildlife populations
- Enhance physical and mental health
- Strengthen community bonds
- Offer opportunities for environmental education
- Increase real estate values
- Beautify the cityscape

The positive effects of trees permeate every scale of our community, from individual residences to entire districts and the City overall. Consequently, Bethlehem is dedicated to guaranteeing that all residents have fair and equal access to trees and green areas. The trees along the City's streets, parks and backyards are especially important in meeting the goals laid out in the Climate Action Plan (CAP). This plan addresses section L2. 2 in the CAP-- Develop an Urban Forest Master Plan. Find Bethlehem's CAP here: Bethlehem Climate Action Plan.

The city's tree canopy encompasses vegetation across both public and private land, spanning streetscapes, parks, open recreational areas, residential yards, and the grounds of businesses and institutions. This plan emphasizes what the City can and will do within those public areas, streets, and parks, with a commitment to assisting residents and business owners with tree matters on private property when the City can.

Vegetated urban areas, including tree-lined roads, parks, and shared gardens, offer essential ecological functions. These spaces further contribute to residents' physical activity levels, mental wellness, and overall health. The implementation of this initiative aims to cultivate community awareness, knowledge, and active participation regarding the significance of trees, especially in concentrated urban settings.

Access to green space is also increasingly recognized as an environmental justice issue. The City of Bethlehem has made commitments to racial and social equity in all aspects of its governmental operations and practices. All people, regardless of socioeconomic or racial background should be guaranteed access to trees and the green spaces where trees are often found.

The City of Bethlehem recognizes the importance of these trees and their preservation but there are challenges that come with this task. The City has been working with property owners to mitigate issues that come with tree-lined streets and parks. Over the years and throughout history, trees were planted in small wells where they have outgrown that space. This can then lead to structural problems and sidewalk issues, leaving homeowners frustrated with the work that must be done. The Forestry department works toward minimizing frustrations and costs for these property owners from a time long before us when trees were planted. The City also looks to provide guidance for future plantings to be the most beneficial for the area, underground utilities, sidewalks, homeowners and the community, while still trying to grow the urban canopy.

Trees

Urban forests are vital ecosystems encompassing trees and other vegetation within and around our communities. These include street and yard trees, vegetation in parks and along the public right-of-way and waterways. Urban forests provide communities a wealth of environmental, economic and social benefits while also creating habitat for fish and wildlife (“American Forests”, 1997).

Ecological systems, which encompass the interaction of living organisms and their physical surroundings, generate essential benefits that support human existence. These benefits, often referred to as ecosystem services, include: water purification, stormwater management, carbon sequestration, human health enhancement, biodiversity, and wildlife habitat (“Ecosystem Services” 2024). A robust tree canopy, which is the overhead layer of foliage formed by tree crowns, plays a critical role in the provision of these vital services.

Establishing a goal to increase our tree canopy is crucial for Bethlehem as it works toward implementing its CAP goals. While the City is responsible for trees on property it owns

and controls, such as parks and other government facilities, it has limited responsibility for trees growing along streets, alleys and any other public right-of-way. Through its Tree Ordinance—Article 910—the City guides best practices for the strategic planting, ongoing maintenance, and protective measures for street trees. Sections under Article 910 include permit requirements, protection of trees, tree surgeons required to do work, property owner's privileges, public nuisances, planting of trees by the City, and more. Article 910 can be found here: ARTICLE0910

Goals

The urban forest master plan proposes a series of actions aimed at fulfilling the City's defined goals. To ensure effective implementation, the plan's evaluation methods, used to gauge progress and identify shortcomings, will require ongoing refinement throughout the execution process.

Goal 1: Grow a more extensive urban forest throughout the City by increasing the canopy cover by 25% by 2035

Goal 2: Improve and maintain the health of the urban forest by selecting noninvasive, disease-resistant and climate-resilient trees for planting, and by caring for existing trees (e.g., watering and parasite management)

Goal 3: Increase support for and understanding of the urban forest

Goal 4: Use the preceding goals as one of the means to achieve the ambitions laid out in Bethlehem's Climate Action Plan. These ambitions include: the community-wide GHG emission reduction targets, the environmental justice and equity objectives, the Mitigation Strategy objectives and Adaptation Strategy objectives.

Based on annual reviews, additional recommendations from the plan will be evaluated for implementation.

This Urban Forest Master Plan employs a framework that pairs identified challenges in urban forestry with actionable solutions.

*This section is modeled after the following source:

Trees for People October 2020: An Action Plan for Lancaster City's Urban Forest. https://www.allianceforthebay.org/wp-content/uploads/2021/03/Trees-for-People-October-2020-FINAL.pdf.

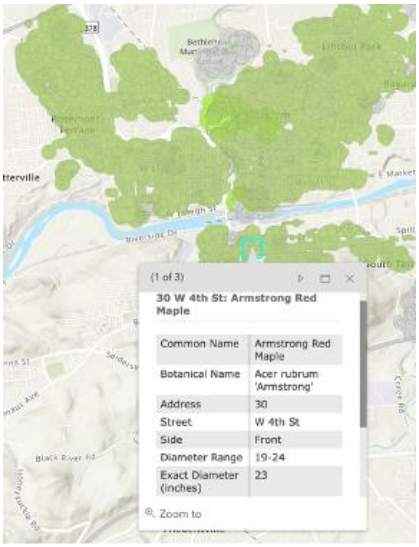
I. Urban Tree Inventory

The first step in effective urban forest management begins with a comprehensive understanding of our existing tree resources. This requires detailed information about both the quantity and quality of our trees. Key questions include: How many trees do we have? Where are they located? What areas lack sufficient trees? What species of trees are present? What is the size and age distribution of our trees? What is the health status of our trees? This chapter addresses these questions and outlines a strategy for maintaining accurate, up-to-date information to guide management decisions.

Trees are dynamic living organisms—growing, aging, and susceptible to various environmental impacts—and the inventory must reflect this dynamism. As trees are impacted by extreme weather, accidents, pests, and declining health with age, new trees are planted. To remain useful, inventories must be continuously updated, ideally in real time. Additionally, maintenance records need to be integrated into the inventory, and must periodically be completely redone.

Recognizing trends in these data can help guide short and long-term management planning. Bethlehem's current street and park tree inventory data can be found on the Tree Map at the following link: BETHLEHEM TREE INVENTORY MAP. These data were put together by Bethlehem's former City Forester, David Shaffer. The inventory documents 13,363 street trees and identifies 494 potential vacant planting sites, including 196 in the Southside, a frontline community. Frontline communities bear the worst impacts of climate change but have contributed the least. These communities include low-income, indigenous, and people of color (BIPOC).

The type of data that can be found on the tree inventory map is shown below.



The City should commit to a schedule for periodic re-inventories every 10 years, along with a system for real-time updating of the inventory. Keeping the inventory updated can save money long-term.

With the information from the tree inventory, the next step is to further evaluate a broad range of urban forest characteristics including, but not limited to, which tree species are overplanted, native versus nonnative species, the age distribution of the trees, potential branch/fruit/seed droppings, which trees are susceptible to a new pest and changing climate conditions, and where there are too few trees. To effectively plan and manage its urban forest, the city needs an assessment that determines both the current and attainable tree canopy coverage. This information will provide the foundation for developing specific goals and strategies aimed at promoting environmental sustainability, public health, and community development through a resilient urban forest.

Expanding the urban canopy relates to section L2.1: Expand the inventory of Bethlehem's trees and ecosystem services in the CAP.

Action 1:

- **Finish the inventory of Bethlehem trees and possible planting sites.**
- **Bethlehem will implement a ten-year cycle for tree canopy re-inventory, recognizing that accurate data on tree location and extent is fundamental for informed management decisions. These data-driven strategies will foster the sustainability and growth of the city's urban forest, maximizing the benefits it provides.***This section is modeled after the following source:

Trees for People October 2020: An Action Plan for Lancaster City's Urban Forest.
https://www.allianceforthebay.org/wp-content/uploads/2021/03/Trees-for-People-October-2020-FINAL.pdf.

II. Assessment of Tree Attributes, Site Characteristics, and Tree Species Benefits

Tree Attributes

Species Diversity

The diversity of tree species within an urban forest significantly impacts management strategies, including cost control, planting objectives, canopy integrity, and the ability to respond to invasive threats. A lack of species diversity heightens the risk of substantial losses from species-specific diseases, such as the destructive effects of Dutch elm disease (Ophiostoma novo-ulmi) across the Mid-Atlantic (Castello 1995 & Sinclair 2005). Therefore, promoting species diversity is a key factor in successful urban forestry management. The widespread devastation of American elm trees (Ulmus americana), once a staple of urban landscapes in the United States, is largely attributed to Dutch elm disease. This fungal disease, which began its destructive spread in the 1930s and continues to pose a threat, has resulted in the death of a significant portion of these trees (Copeland 2022). Many communities were stripped of most of their mature shade trees, creating a drastic void in canopy cover.

In recent years, urban landscapes throughout the Midwest and Northeast have experienced additional significant tree mortality due to the invasive Emerald Ash Borer. This pest has led to the estimated destruction of over 30 million ash trees, resulting in the rapid defoliation of streets previously dominated by this single species (“Emerald” 2022).

Maintaining a diverse urban forest yields numerous ecological and community benefits. A common guideline for species diversity is the 10-20-30 rule, which suggests that no more than 10% of the urban forest should be comprised of a single species, 20% of a single genus, or 30% of a single family (Kendal 2014). This principle aims to enhance resilience against pests and diseases that often target specific tree taxa. However, alternative recommendations exist, such as the 5-10-15 rule advocated by the University of Florida, which suggests an even greater level of diversity (Ricketts 2023).

To expand canopy coverage and compensate for tree loss due to natural deaths (estimated at 1%–3% annually) and external stressors (including invasive species and weather-related events like storms, wind, ice, snow, floods, and droughts), strategic tree planting is essential (Nowak 2002). Developing a plan for replacing aging trees and pinpointing optimal locations for new canopy development is crucial for maintaining a healthy urban forest.

Diameter Size Class Distribution

In addition to species variety, a diverse age structure is crucial for a healthy urban forest. Examining the distribution of tree diameters, specifically diameter at breast height (DBH), provides a valuable estimate of the relative age of a tree population and informs necessary planting and maintenance strategies. Richards (1983) proposed an 'ideal' diameter distribution, characterized by a large proportion of young trees and a progressively smaller proportion of larger, mature trees. This distribution suggests a population with abundant young growth and fewer established, older trees. However, it's vital to recognize that larger, mature trees contribute disproportionately to ecological, health, and social benefits, necessitating their careful preservation. DBH data obtained from tree inventories can serve as a reliable proxy for age, aiding in this analysis.

To ensure the long-term resilience of urban forests, a diverse composition of tree genera and species is crucial, irrespective of specific planting guidelines. When selecting trees for urban environments, it is paramount to match species to site conditions. Emphasizing native species or those with enhanced climate resilience is advisable. Furthermore, considering the existing neighborhood tree population and promoting biodiversity in species selection is essential.

Site Characteristics

When considering tree planting, it's crucial to match the appropriate species to the specific location. Building upon the previous discussion regarding suitable tree attributes, this section will address site selection, examining factors such as site conditions, available growing space, and potential conflicts with infrastructure and utilities. This analysis will offer recommendations for optimal tree planting sites.

Site Condition Considerations

Determining the suitability of a planting site requires careful evaluation of various site characteristics, including the potential for sidewalk impact, available growing space, and conflicts with existing infrastructure.

- Potential Damage to Sidewalks and Hardscape:

Improperly planted or maintained trees can lead to significant damage to hardscape elements like curbs and sidewalks, while also causing harm to the tree's root system and trunk. Tree inventories can document instances of tree-related damage, such as lifted curbs and sidewalks. These data are essential for scheduling necessary pruning and planning repairs to affected infrastructure.

To minimize hardscape damage, trees should only be planted in areas that provide sufficient aboveground and belowground growing space, adhering to local tree ordinances. In Bethlehem,

tree wells must measure a minimum of 2.5 by 2.5 feet to accommodate a small-sized tree. This approach aligns with best practices in urban forestry, which emphasize the importance of matching tree species to site conditions to prevent infrastructure conflicts.

According to the US Forest service, urban tree planting projects should contain proper planning to avoid potential infrastructure damage ("Urban Forest" 2022).

The International Society of Arboriculture (ISA) also provides resources that emphasize the importance of proper tree placement to avoid infrastructure conflicts (https://www.isa-arbor.com).

Growing Space

Adequate growing space, encompassing both horizontal and vertical dimensions, is crucial for urban tree health and safety ("Tree Pruning" 2012). This space includes the clearance between the lowest branches and street/sidewalk surfaces, as well as the distance from structures, signage, and street furniture. Proper clearance ensures that tree canopies do not obstruct vehicular or pedestrian traffic, impinge on buildings, or obscure signs and signals. Pruning practices to address clearance issues and elevate tree crowns must adhere to municipal regulations. In Bethlehem, tree limbs must clear sidewalks by 8 feet and roadways by 14 feet. Additionally, the size of the tree well or lawn area allocated for the tree is a vital aspect of growing space, with a minimum tree well size of 2.5 by 2.5 feet required for small trees.

Urban trees frequently encounter conflicts with infrastructure, including buildings, sidewalks, and underground utilities, which can create public health and safety hazards (Miller R. 1997). The financial implications of managing trees with growth space deficiencies must be evaluated to determine whether removal and replacement present a more sustainable solution.

Overhead utility lines, such as electric and communication wires, represent the most conspicuous form of utility conflict ("Utility Pruning" 2012). It is essential to document the presence of overhead utilities during planting site assessment and to integrate this information into tree pruning and species selection decisions. Less visible underground utilities, including gas, water, and sewer lines, typically do not directly interfere with tree roots. However, surface-level components like vents and valve boxes located in sidewalks and tree lawns often create conflict. Planting sites with identified utility conflicts necessitate thorough investigation to ensure appropriate tree selection and placement.

Minimizing tree-sidewalk conflicts in constrained urban spaces requires a multifaceted approach. Selecting tree species with minimal surface rooting tendencies, employing planting techniques that promote deep root development, and ensuring meticulous site and soil

preparation are crucial. Additionally, adaptable sidewalk designs and the use of alternative paving materials can mitigate conflicts when feasible and permitted (Gilman, 2023).

Older residential areas with limited planting space present unique challenges. Immediate planting efforts should prioritize sites under municipal control or within public rights-of-way (ROWs) that offer ample growing space and minimize potential conflicts. However, retrofitting planting sites in densely developed urban areas with restricted space often exceeds the financial capacity of individual property owners, similar to the existing ROW tree maintenance responsibilities (Roman, 2013). These areas, paradoxically, exhibit the greatest need for tree planting. Moreover, dense residential zones with minimal tree lawns frequently suffer from limited on-street parking, further complicating public space retrofitting. The prevalence of street trees in undersized tree wells necessitates innovative and collaborative solutions to expand urban tree cover in these neighborhoods (Coder 2012). These concerns are addressed in the CAP and in section V; Addressing Environmental Injustice on page 14.

When choosing locations for municipal street tree retrofitting projects, it's essential to incorporate community feedback (Tyrväinen 2020). While established methods like structural soils, tree trenches, and modular subsurface pavement systems offer significant benefits, their high costs often limit their application on private properties (Lindsey 1991). A more economically viable option is the implementation of curb extensions, which protect existing trees and create space for new plantings (Ewing 2009). To ensure community acceptance, these extensions should be placed in areas where parking is already restricted. Additionally, where feasible, expanding sidewalk radius can significantly improve the health and survival of both new and existing trees (Gilman 2012).

Tree Species Benefits

The urban forest is a critical asset for enhancing the quality of life in cities. When managed effectively, trees provide Bethlehem with substantial health, environmental, economic, and social advantages that surpass the costs associated with planting, maintenance, and removal. These benefits are particularly crucial for climate change adaptation and mitigation. Utilizing scientific studies and practical research, many of these advantages can be quantified following a tree inventory analysis. Trees represent a long-term capital investment that yields numerous sustainability benefits, or city services, over extended periods.

Specifically, trees contribute to:

- **Air and water purification:** Trees remove pollutants, improving air and water quality (Nowak 2002).
- **Stormwater management:** Tree canopies and root systems stabilizing soil reduce runoff (Xiao 1998).

- **Urban cooling:** Trees provide shade, reducing temperatures and energy consumption (Akbari 2001).
- **Increased property values:** Trees enhance the aesthetic appeal of neighborhoods, raising property values (Donovan 2010).
- **Wildlife habitat:** Trees provide shelter and food for various species. (McKinney 2002).
- **Social interaction:** Green spaces promote community interaction (Maas 2006).
- **Educational opportunities:** Urban forests provide living laboratories for environmental education.
- **Improved physical and mental well-being:** Exposure to nature reduces stress and improves health. (Ulrich 1984).
- **Aesthetic value:** Trees enhance the visual appeal of urban landscapes.

Health Benefits

The impact of trees on public health has become a significant area of medical research, particularly concerning the mitigation of high temperatures and air pollution. In urban environments like Bethlehem, heat waves pose a substantial risk, especially to vulnerable populations such as young children and the elderly, whose thermoregulatory systems are less efficient (Basu & Samet 2002). Individuals with pre-existing cardiovascular and respiratory conditions are also at heightened risk. This issue is exacerbated by the urban heat island effect, where a lack of vegetation and an abundance of heat-absorbing surfaces like concrete and asphalt contribute to elevated ambient temperatures in urban areas (Oke 1982).

Furthermore, air pollution remains a critical environmental concern. Particulate matter, a key pollutant, can penetrate deep into the respiratory system, increasing the incidence of respiratory diseases, including asthma, and cardiovascular diseases like heart attacks and strokes (McDonald et al. 2016). Additionally, ground-level ozone, which is often intensified during heat waves, further contributes to respiratory ailments (Silva et al. 2016). Areas identified as disproportionately impacted by the heat island effect and air pollution are deemed frontline communities in the CAP.

Urban forests offer significant mitigation for air pollution and temperature regulation. Their extensive leaf canopy acts as a natural filter, trapping airborne particulate matter due to its large surface area (Nowak et al. 2006). Trees also contribute to cooling urban environments through two primary mechanisms: first, by providing shade, they reduce the absorption and retention of solar radiation by surfaces like streets and buildings, thus lessening the urban heat island effect, which is particularly pronounced during warm nights (Oke 1982). Second, through transpiration, trees release substantial amounts of water vapor, resulting in evaporative cooling, similar to human perspiration (Ellison et al. 2017). For example, a mature oak can transpire over

50 gallons of water daily (McDonald 2016). It is important to note, that trees also absorb ozone through their stomata, which can be harmful to the tree's health (Reich 1987).

Studies indicate that urban trees can have a substantial impact on human health. Research conducted by The Nature Conservancy suggests that increased urban tree cover can reduce mortality during heat waves. For instance, during the 2003 European heat wave, cooler, greener urban areas experienced a 21% decrease in mortality for every 1.8°F reduction in temperature (McDonald 2015). Furthermore, within approximately 300 feet of trees, particulate matter concentrations can reduce by 7 to 24%, and air temperatures can decrease by 2 to 4°F ("Urban Trees" 2017). In Syracuse, NY, the existing urban tree canopy is estimated to reduce annual health impacts from particulate matter by approximately $1.1 million ("Urban Trees" 2017).

In terms of cost-effectiveness, urban tree planting can be a competitive strategy for temperature reduction when measured in dollars per degree of cooling. However, when compared to reducing industrial pollution at the source, tree planting may be a more expensive method for particulate matter removal. Nevertheless, its cost-effectiveness is comparable to other gray infrastructure strategies (McDonald, 2015).

The Climate Action Plan describes ways in which trees can contribute to mitigating the negative effects of climate change by sequestering carbon, filtering the air, and cooling the City down.

As detailed in the following sections, urban trees offer a multitude of benefits, often proving more cost-effective than traditional gray infrastructure solutions.

Triple Bottom Line Benefits

The urban forest, particularly street trees, represents a valuable community asset. Trees contribute significantly to pollution control, energy efficiency, stormwater management, increased property values, wildlife habitat, and aesthetic enhancement. These services and benefits can be quantified as a functional value, reflecting the combined environmental, economic, and social contributions of the urban forest. Here are some of the specific benefits:

Social Equity Benefits

- Tree-lined streets enhance traffic safety by reducing driver stress and speed, potentially mitigating aggressive driving (Wolf 1998a; Kuo & Sullivan 2001a).
- Employees with views of trees from their workspaces report reduced sick leave and increased job satisfaction (Wolf, 1998a).
- Hospital patients with views of trees experience faster recovery, requiring less pain medication and experiencing fewer complications (Ulrich 1984, 1986).

- Urban residents living in areas with greater tree canopy report lower psychological distress and improved general health (University of Washington, 2019).

Economic Benefits

- Trees increase property values, with higher rental rates for commercial properties with trees (Wolf, 2007).
- Trees regulate temperatures, reducing heating and cooling costs ("The Environmental" 2012; Heisler 1986).
- Consumers are willing to pay more for goods in landscaped areas (Wolf, 1998b, 1999, 2003).
- Consumers perceive higher product quality in business districts with trees (Wolf, 1998b).

Environmental Benefits

- Trees reduce energy consumption and moderate local climates through shading, cooling, and windbreaks.
- Trees mitigate stormwater runoff, reducing the volume reaching drains, rivers, and lakes ("Urban Stormwater" 2003).
- Trees reduce noise, purify air, produce oxygen, and absorb carbon dioxide, with potential reductions in street-level air pollution (Coder, 1996). Studies indicate that children living on tree-lined streets may have lower asthma rates (Lovasi, 2008).
- Trees stabilize soil and provide wildlife habitat.

Overall, examining the benefits of tree species helps further objective L2.1: Expand the inventory of Bethlehem's trees and ecosystem services in the CAP. Having a better understanding of the urban canopy and planting plots will help the City reach the four main goals outlined on page four.

Action 2:

- **Analyze tree data for species distribution, age distribution (using DBH as a proxy), and species benefits. Species benefits can be quantified using the modeling software i-Tree.**
- **Correlate the tree species benefits and characteristics listed with appropriate plot data on site quantity and characteristics.**

Below is an example i-Tree data:

Source: https://www.allianceforthebay.org/wp-content/uploads/2021/03/Trees-for-People-October-2020-FINAL.pdf

Table 2-5. Value of Benefits

Common Trees	Benefits Provided in Dollars				
Common Name	Aesthetic	Stormwater	Carbon	Energy	Air Quality
Red maple	5,406.23	352,540.19	10,508.98	58,921.13	10,089.26
Norway maple	20,186.37	255,426.52	18,790.35	43,827.34	8,246.08
Prunus species	3,189.91	49,041.26	4,205.47	13,519.02	2,137.46
Littleleaf linden	6,728.30	139,854.22	6,188.66	28,883.14	4,798.03
Callery pear	23,237.66	180,400.59	5,691.11	25,743.68	5,653.03
Northern Red oak	11,941.28	307,166.68	20,427.74	45,607.59	8,382.37
Sugar maple	8,578.59	149,920.70	8,914.85	22,024.10	3,772.98
American sycamore	11,865.52	305,766.96	17,826.26	38,500.13	7,081.80
Japanese zelkova	9,287.35	68,652.07	1,692.97	15,223.39	2,442.92
Silver maple	4,917.18	147,256.82	10,013.03	20,402.91	3,856.58

*This section is modeled after the following source:

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III. TREE MANAGEMENT PROGRAM

Management

Effective urban forest stewardship necessitates a multifaceted approach. This includes a thorough resource evaluation, which involves conducting regular tree inventories to understand the existing canopy, and strategic planning, which entails developing comprehensive management plans based on inventory data. Crucial to this process is community engagement, fostering public participation in urban forestry initiatives. Furthermore, targeted tree planting, strategically placing new trees in optimal locations, and systematic maintenance, implementing routine inspections and care, are essential. Finally, supporting research to enhance understanding of urban ecosystems is vital. This proactive approach to urban forest management yields numerous benefits. As highlighted by the U.S. Forest Service, these benefits include reduced program expenditures, enhanced public safety, minimized utility disruptions from storm-related tree damage, and improved aesthetic quality of the urban landscape ("Urban Forests" n.d.). Additionally, the importance of community involvement is stressed by the Arbor Day Foundation, particularly in their Tree City USA program ("Tree City" n.d.). The International Society of Arboriculture (ISA) also provides resources and best practices that support these urban forest management principles ("International" n.d.).

Risk

Mature trees offer substantial benefits to urban communities. However, with increased size comes heightened risk of structural failure, including whole-tree collapse or limb breakage. Therefore, urban forest managers face the critical challenge of accurately assessing and mitigating these risks to ensure public safety. Organizations such as the International Society of Arboriculture offer resources like a tree risk assessment to assist with this process. Effective risk management is also paramount in reducing municipal liability associated with tree failures. Furthermore, urban forestry initiatives and public education programs frequently encounter funding competition with core community services like law enforcement, fire protection, and infrastructure maintenance. Consequently, insufficient financial resources represent a significant impediment to the health and sustainability of urban forests nationwide.

Funding

The long-term viability and sustainability of Bethlehem's urban forestry program are intrinsically linked to the level of financial support it receives, particularly when considered within the context of the city's broader responsibilities. Consistent and adequate funding is essential for the program to effectively achieve its mission, adapt to evolving challenges, and serve the community. While a definitive formula for determining optimal funding levels remains elusive, it is clear that resources must be sufficient to support preventive tree maintenance,

emergency tree care, a robust tree planting initiative, and the necessary staff, equipment, and contractual services for city-owned properties. As noted by the U.S. Forest Service, sustainable urban forestry programs require consistent investment (“Urban Forests” n.d.).

Funding for these programs typically originates from a blend of municipal budget allocations, grant opportunities, and collaborative partnerships with environmental organizations. The Arbor Day Foundation, through programs like Tree City USA, emphasizes the importance of sustained financial commitment for effective urban forestry management (“Tree City” n.d.).

Discussion

The effective stewardship of Bethlehem's urban forest demands sufficient resources. Presently, the city's reliance on a single City Forester to manage all facets of tree care presents an unsustainable model, hindering proactive urban forest management. A comprehensive approach is necessary, encompassing not only routine maintenance but also proactive planning, risk assessment, and community engagement. As recommended by the International Society of Arboriculture (ISA), proper management and expansion of Bethlehem’s urban forest necessitates increased staffing and dedicated funding. This investment will ensure the long-term health and growth of the forest in a sustainable and equitable manner, guaranteeing that the benefits of the urban forest are shared by all residents and that the forest itself is resilient to future challenges. The U.S. Forest Service emphasizes the importance of consistent funding for urban forestry programs to achieve long-term sustainability and maximize community benefits. (“Urban Forests” n.d).

Additionally, the Arbor Day Foundation highlights the significance of proactive urban forest management and community engagement in ensuring the long-term health of urban trees (“Tree City” n.d). The necessity for adequate staffing and funding to effectively manage urban forests is also addressed by the ISA, which provides resources on best practices for urban forestry management. (“International” n.d.).

Action 3

- **Launch an Urban Forest Commission to create a team behind the research and actions laid out in this plan.**
- **Seek new ways to grow the urban forestry budget and grow the canopy.**
- **Create a tree maintenance and inventory cycle.**

These three goals can be forged through policy changes to Article 910, the Tree Ordinance.

Policy Recommendations, Amend Art. 910 to:

1. **Include the creation of a volunteer-based Urban Forest Commission. The commission should include citizens as well as City officials. Create a position for a Tree Commission Head who would act as subordinate to the City Forester. The commission should apply for state and federal grants.**
2. **Explicitly state that new developments should not only be required to replace existing trees, but to add more trees, or some trees if previously none, depending on age and size of the trees being removed and the site conditions. These decisions would come from the City Forester with input from the head of the Tree Commission.**
3. **Attach a fee to land developers for the removal and replacement of trees if the tree removed has more value (e.g., larger in size) than the replacement tree.**
4. **Evaluate the opportunity to incorporate additional trees or save valuable trees from removal in all future city developments. This evaluation should include all the benefits aforementioned in a cost benefit analysis.**
5. **Include trees as an essential part of city infrastructure. This would increase the budget by allowing urban forestry to access the infrastructure budget.**
6. **Create a routine inventory update system every 10 years.**
7. **Create a routine management system, such as a multi-year pruning cycle and assessment of tree risk.**

*This section is modeled on the following source:

Tree Pittsburgh. "Pittsburgh Urban Forest Master Plan." *Tree Pittsburgh*, Tree Pittsburgh, 24 Mar. 2022, https://www.treepittsburgh.org/resource/pittsburgh-urban-forest-master-plan/.

IV. Addressing Climate Change Impact

Climate change poses a significant threat to Bethlehem's community and natural resources, with projected increases in average temperatures, precipitation, extreme heat events, and heavy rainfall. These events will likely result in increased flooding, property damage and urban heat-island effect. That said, the community's health, natural resources, equity and economy are threatened. For this reason, addressing climate change is an essential action in future aspects of Bethlehem's plans, and trees are no exception. Therefore, addressing climate change is crucial in all future city planning, including urban forestry. This Urban Forest Master Plan considers climate change in two primary ways: by increasing urban canopy cover to adapt to climate impacts and by promoting a climate-resilient urban forest, which refers to the tree species' ability to thrive in the impending conditions such as increased drought, precipitation, and temperature

Climate change is an ecosystem-wide impact that will alter the mortality rate, growth rate, and prevalence of tree diseases and pests in the urban forest. That is why it is important to prioritize the planting of climate resilient trees in future tree planting projects. Trees play a vital role in mitigating and adapting to climate change. The ecosystem services they provide are detailed in the benefits portion of section I. Shading, evaporative cooling, water uptake, storage and CO_2 uptake are essential services in the face of rising temperatures and altered precipitation patterns.

In addition to climate resilient species, the CAP also prioritized using more native species. Species native to the northeastern United States are evolutionarily suited for the ecosystems here in Bethlehem, meaning they support biodiversity. Biodiversity refers to the diversity in species types, as well as the number of individuals in the present species. Non-native species can often be invasive, which decreases biodiversity for two main reasons. First, they often can out compete native species because they lack the feedback system: outcompeting for food, growing rapidly, or lacking natural predators, that supports healthy competition between species types (Tobin 2018). Second, a non-native species will not provide the same benefits to other ecosystem constituents. For example, while an ornamental tree species from Asia hosts 6 species of caterpillar, native oak species can support over 500 caterpillar species ("Why Native" 2017). Bethlehem faced an invasive species problem with the Spotted Lanternflies, which resulted in the death of the native tree species—Tree of Heaven—and many other sapling trees. Overall, native species are vital for healthy ecosystems.

Growing the urban forest successfully relates to the following actions in the CAP: L3.1 Update Tree Ordinances and other applicable regulations to prioritize and preserve native species of plants and trees, as well as climate-resistant species, L3.4 Species diversification/removal of

invasives, L6.1 develop a green infrastructure plan to manage stormwater, filter pollutants, and improve public health.

Action 4

- **Update the approved street tree list to include categories with climate resilient species and native species.**
- **Implement clauses in Art. 910 that prioritize the planting of native, climate-resilient species in all future city projects and private, corporate developments.**
- **Support residents planting trees by implementing a Tree Planting Program. The goal of the program should be to aid residents with the planting process and maintenance. The program should also include education on native, climate-resilient species, and encourage the use of those species.**
- **Review the available research on tree pest and disease trend predictions and consider in the species choices. The narrowing of suggested species by these parameters should not obscure the importance of biodiversity.**
- **Strike a balance between implementing native, climate resilient species, and increasing biodiversity.**

*This section was modeled on the following source:

"Bethlehem Climate Action Plan" 2021 https://www.bethlehem-pa.gov/getattachment/Public-Works/Climate-Action-Plan/Climate-Action-Plan_City-of-Bethlehem_04-07-21-FINAL-FINAL.pdf.aspx?lang=en-US

V. Addressing Environmental Justice

Environmental Justice (EJ) issues arise when certain groups bear a disproportionate share of the environmental degradation burdens. Historically, these burdens have fallen most heavily on minority and low-income communities in the U.S (Lieberman-Cribbin et al. 2024). In Bethlehem, tools such as the EPA EJScreen reveal how environmental hazards—such as poor air quality—are concentrated in specific areas, often coinciding with low-income and majority-minority neighborhoods. For example, factories releasing air pollution near these communities are proven to have adverse health effects such as coughing, eye irritation, chest pain, and even lung cancer (Mehraj et al. 2013). In the face of climate change, there is a new set of EJ challenges, such as the urban heat island effect which is particularly noticeable in parts of South Bethlehem. The CAP has laid out some of the EJ concerns to which this master plan aims to address.

The CAP has emphasized these disproportionately impacted areas as frontline communities. These areas are often low-income areas that are densely populated and heavily paved with few or small tree wells and unhealthy soils. This means that willingness and creativity to increase the urban forest in these heavily paved areas where planting is beyond the capacity of the land owner is essential to addressing the goals laid out in the CAP. Specifically, the following sections: L2.3 Prioritize Green Space in Underserved areas, EJ2.1 Evaluate Strategies in this CAP for their Benefits to Frontline Communities, and EJ2.4 Measuring Local Environmental Burden to inform Neighborhood Level Investments.

These environmental justice objectives laid out in the CAP are based on findings that areas with the least trees in many cases correlate to the areas that score highest on the social vulnerability index. The social vulnerability levels are determined by four features: socioeconomic status, household composition and disability, minority status and language, and housing and transportation. In Bethlehem, the south side has the highest social vulnerability index score and thus will need the most assistance in the event of a disaster. Particularly, in the southeastern sector of Bethlehem, the limited tree cover and lack of green space contributes to the urban heat island effect and is correlated to an increased vulnerability to environmental hazards, such as heat exhaustion and poor air quality. Bethlehem strives to promote equity in its CAP, and the Urban Forest Master Plan will also support that mission by addressing EJ issues.

One pressing EJ issue in Bethlehem is the city's asthma rate, which is twice the state and national average, despite smoking rates being slightly lower than the national average (“City of Bethlehem” 2016). This disparity is linked to both the air quality in the greater Lehigh Valley and the localized impact of vehicle traffic. Furthermore, these asthma rates disproportionately affect low income and minority communities due to lower air quality in these areas. In order to

protect the public health and equity of our community, asthma impact should be considered in this master plan.

Tree pollen is often allergenic, and can exacerbate asthma symptoms. The degree to which a species pollen is allergenic varies. Trees that are not allergenic, or allergenic to a low degree, are considered asthma-friendly trees. Prioritizing the planting of asthma-friendly trees, especially in communities with high asthma rates, is essential to ensure that this master plan does not worsen existing EJ issues. This includes updating the approved street-tree list to consist mostly of asthma-friendly trees.

Effective community engagement is essential in supporting frontline communities. This necessitates that the Urban Forestry Commission's actions and plans prioritize partnerships with local organizations and actively seek input from residents of these communities. While the commission is volunteer-based, it is crucial to strive for equitable representation by actively recruiting members from frontline communities.

The following actions will aid the City in supporting frontline communities.

Action 5:

- **Task the Urban Forestry Commission with community outreach, and engagement with local organizations. Ensure that a proportional number of commission members are from the frontline communities.**
- **Provide the Tree Planting Program a budget to assist in the financial aspects of tree planting for those who cannot afford the costs of planting or maintenance.**
- **Prioritize the planting of trees that are asthma-friendly, particularly in areas with high asthma rates. This should be based on the asthma-friendly species identified tree lists that will cross check for climate resilience and native status.**
- **Designate a portion of the tree fund to frontline communities, and prioritize these communities in the implementation of the Urban Tree Master plan.**

*This section was modeled on the following source:

"Bethlehem Climate Action Plan" 2021 https://www.bethlehem-pa.gov/getattachment/Public-Works/Climate-Action-Plan/Climate-Action-Plan_City-of-Bethlehem_04-07-21-FINAL-FINAL.pdf.aspx?lang=en-US

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