MUNICIPAL TREE PLANTING PROGRAMS

A Cost-Benefit Analysis

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Scioto Analysis
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Executive Summary

Cities across the country are adopting plans to expand their urban tree canopies, aiming to improve the aesthetics, safety, and health of their neighborhoods. Ohio is no exception to this trend, with the cities of Columbus, Cincinnati, and Cleveland all adopting plans with quantified canopy commitments. Tree planting programs have been argued to be good for the environment, public health, and aesthetic beauty of communities that justify the cost of planting and pruning trees. In this cost-benefit analysis, we estimate the specific economic benefits and costs a tree-planting campaign will generate for eight Ohio cities: Athens, Cincinnati, Cleveland, Columbus, Dayton, Findlay, Toledo, and Youngstown.

Overall, we estimate that tree planting will cost Ohio communities $10.29 per tree, while economic present benefits from carbon sequestration, stormwater runoff prevented, air pollution reduced, energy saved, and crime reduced range from about $10-21 per tree depending on the city. The total net benefits of policy expanding canopy cover after discounting could be as much as $110 million for one city. Beyond the economic benefits, we also find that expanding canopy cover by just 10% could prevent as many as hundreds of crimes depending on the city, increase home value, and cause a variety of physical and mental health benefits.

Tree Planting Economics

Researchers from a range of disciplines have studied the benefits of tree planting. One of the central benefits these researchers have focused on is health. Often, health and income are linked with a higher income allowing a family to access services and neighborhoods that lead to better health outcomes. Researchers in Toronto used self-reports of health and health perception and individual tree data to find that "having 10 more trees in a city block, on average, improves health perception in ways comparable to an increase in annual personal income of $10,000." They also find that having 11 more trees in a city block decreases cardio-metabolic conditions in ways comparable to an increase in annual personal income of $20,000 and moving to a neighborhood with $20,000 higher median income or being 1.4 years younger.[1]

Researchers have found health benefits of neighborhood trees that are both physical and mental. Trees generate physical health benefits by creating an environment for more physical activity–a more accessible and aesthetically pleasing environment encourages and causes people to be more physically active.[2] Mental health impacts are less obvious but researchers have found that time around trees increases focus and reduces ADHD symptoms and that exercising in areas with trees reduces the prevalence of stress hormones and self-assessed scores for anxiety and depression.[3]

Recently, policymakers interested in tree planting are not just focusing on the benefits mentioned above but are also trying to address problems of equity. The City of Cleveland has announced a recommitment to its tree plan with targeted planting guided by American Forests'

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[1] Kardan, O., Gozdyra, P., Misic, B. *et al.* Neighborhood greenspace and health in a large urban center. *Sci Rep* 5, 11610 (2015). https://doi.org/10.1038/srep11610

[2] Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. Am J Prev Med. 2002 Apr;22(3):188-99. doi: 10.1016/s0749-3797(01)00426-3. PMID: 11897464.

[3] Department of Enviromental Conservation: Lands & Forests. "Immerse Yourself In A Forest For Better Health" New Yourk State.

Tree Equality Score.[4] This new focus on equity is in line with research published in *the Lancet* that found health disparities related to income were lower in populations living in the greenest areas.[5] Trees do not just improve public health at large, they can also impact the health gap in communities.

One way trees both improve health and environmental quality is by improving air quality by removing pollutants from the air. Researchers estimate that urban trees remove $3.8 billion worth of air pollution annually in the United States.[6] According to the USDA Forest Service, one Ohio tree will remove 3,100 pounds of carbon over 20 years. In just one year, the tree will remove 15 pounds of pollutants, and over its lifetime reduce the net emission of power plants by 30 pounds.[7]

Trees also have been found to increase home value. A study using hedonic pricing and available home pricing data in 2007 found that trees contribute to about 13%-19% of property value in a sample city of Austin, Texas.[8] Even just being near a forested area or having a view of trees led to home prices increasing by 10% for inner-city homes.[9]

Trees also save homeowners money by reducing heating, cooling, and energy costs. USDA Forest Service researchers combined field data and cover maps with state and local pollutant costs to estimate that trees in urban or community areas (jurisdictions delineated by the US Census Bureau) reduce national residential energy usage by $4.7 billion annually.[10] Trees do this by naturally cooling with shade; the EPA reports that shaded areas are 20-45°F cooler and reduce peak summer temperatures by 2-9°F.[11]

The final benefit we found in the existing literature was in intercepting stormwater runoff. Stormwater runoff is a problem for municipalities for many reasons: it can cause flooding which threatens public safety and can spark public health crises because of impacts on water quality, contaminating drinking water[12]. One tree in Ohio can ameliorate this problem by intercepting 27,000 gallons of water, preventing 4,800 gallons of runoff[13].

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[4] McKnight, Tatyana. "City of Cleveland Announces New Equity Focused Approach for TreePlanting" Cleveland City Hall. 15 September 2021.

[5] Mitchell R, Popham F. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet. 2008 Nov 8;372(9650):1655-60. doi: 10.1016/S0140-6736(08)61689-X. PMID: 18994663.

[6] David J. Nowak, Daniel E. Crane, Jack C. Stevens. "Air pollution removal by urban trees and shrubs in the United States", Urban Forestry & Urban Greening,Volume 4, Issues 3–4,2006, Pages 115-123, ISSN 1618-8667,https://doi.org/10.1016/j.ufug.2006.01.007.

[7] "Tree Benefits," USDA Forest Service and other partners iTree tools https://www.itreetools.org/cta-tree-benefits

[8] Wolf, K.L. August 2007. City Trees and Property Values. Arborist News 16, 4: 34-36.

[9] Wolf, K.L. August 2007. City Trees and Property Values. Arborist News 16, 4: 34-36.

[10] Nowak, David J.; Appleton, Nathaniel; Ellis, Alexis; Greenfield, Eric. 2017. Residential building energy conservation and avoided power plant emissions by urban and community trees in the United States. Urban Forestry & Urban Greening. 21: 158-165. https://doi.org/10.1016/j.ufug.2016.12.004

[11] "Using Trees and Vegitation to Reduce Heat Islands" US Enviromental Protection Agency https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands#4

[12] Department of Energy and Environment District of Columbia "Why is Stormwater a Problem?" https://doee.dc.gov/service/why-stormwater-problem

[13] "Tree Benefits," USDA Forest Service and other partners iTree tools https://www.itreetools.org/cta-tree-benefits

Existing literature has also identified the costs of tree planting. The largest of these is pruning with removal and disposal coming second followed by inspections[14]. Other costs include the cost to grow the tree or purchase it and to plant the tree.

Cities Selected

We chose seven cities in different regions of Ohio to test the impact of tree planting programs to reach urban canopy goals. Each of these cities has a different baseline canopy cover, size, and location within the state, giving us a varied understanding of trees' impact around the state. These canopy covers were found using self-reported city data or estimated with the ITree canopy tool, which estimates tree coverage and impacts using US Forest Service research and data. The seven cities we chose are Athens, Cincinnati, Cleveland, Columbus, Dayton, Findlay, Toledo, and Youngstown.

Table 1. City size and tree cover

City	Current Canopy Cover	City Footprint	Estimated number of trees
Athens	75%	10 sq mi	1.7 million
Cincinnati	38%	80 sq mi	7.4 million
Columbus	22%	213 sq mi	11.5 million
Cleveland	19%	82 sq mi	3.6 million
Dayton	29%	57 sq mi	3.7 million
Findlay	17%	20 sq mi	0.8 million
Toledo	20%	84 sq mi	3.7 million
Youngstown	27%	35 sq mi	2.1 million

City footprint found on Encyclopedia Britannica. Number of trees estimated by dividing the total square feet in a city by 120 feet, the average canopy size of the four most common types of trees in Ohio

Methodology

This study uses standard policy analytic techniques to estimate the impact of tree-planting initiatives in the above cities. We carry out a best-practice cost-benefit analysis following the guidance in Boardman et al's Cost-benefit Analysis: Concepts and Practice to estimate the

[14] McPherson, E.G., J. R. Simpson, P. J. Peper, S. E. Maco, and Q. Xiao. 2005. Municipal forest benefits and costs in five US cities (PDF)(6 pp, 267K). *Journal of Forestry* 103(8):411–416.

economic impact of tree-planting programs.[15] We also drew from studies such as "Municipal Forest Benefits and Costs in Five US Cities" by McPherson et al and published in the Journal of Forestry for methodological guidance.[16]

Policy Options

Many Ohio cities have made commitments to increasing their canopy cover. These commitments guided our proposed policy options. Most cities in our sample have a canopy cover in the 20%-40% range with the exception of Findlay at 17% and Athens at 75%. The three largest Ohio cities (Columbus, Cleveland, and Cincinnati) have all committed to canopy cover expansion plans that boost urban tree cover by 10-20 percentage points. Cleveland has set the goal of 30% by 2040,[17] Columbus has a plan to reach 40% by 2050,[18] and based on the most recent available data, Cincinnati has almost met its 40% goal set out in their 2018 green plan.[19]

Based on the current canopy cover and policies already in place, we analyzed urban canopy goals for cities of 30% canopy cover, 40% canopy cover, 50% canopy cover, and 80% canopy cover.

Policy Implications

The categories of cost and benefits we analyzed in the study are listed below. We selected these categories based on data accessibility and a review of the literature on costs and benefits of tree planting. The benefit data came from using the iTree tools[20] and crime estimates from the literature and cost estimates came from McPherson et al[21] in their 2005 comprehensive cost-benefit analysis of municipal tree planting in eight cities nationwide.

Benefits

1) Co2 sequestered
2) Stormwater runoff prevented
3) Air pollution reduction
4) Energy savings
5) Crime prevented

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[15] Boardman, Anthony E. et al 2018. *Cost-benefit analysis: concepts and practice Fith Edition*. Cambridge, United Kingdom ; New York, NY : Cambridge University Press,

[16] McPherson, E.G., J. R. Simpson, P. J. Peper, S. E. Maco, and Q. Xiao. 2005. Municipal forest benefits and costs in five US cities (PDF)(6 pp, 267K). *Journal of Forestry* 103(8):411–416.

[17] McKnight, Tatyana. "City of Cleveland Announces New Equity Focused Approach for TreePlanting" Clevland City Hall. 15 September 2021.

[18] City of Columbus: Recreation and Parks "Columbus Urban Forest Master Plan" Spring 2021

[19] "Urban Canopy Policy: Cincinnati OH" Urban land Institute https://developingresilience.uli.org/case /urban-canopy-policy/

[20] US Forest Service "Itree: My Tree tool" https://mytree.itreetools.org/#/

[21] McPherson, E.G., J. R. Simpson, P. J. Peper, S. E. Maco, and Q. Xiao. 2005. Municipal forest benefits and costs in five US cities (PDF)(6 pp, 267K). *Journal of Forestry* 103(8):411–416.

We took a conservative approach and did not include home value in the calculation of the benefits of trees. We did this because we believed home value benefits may include crime and health benefits for residents. There may be home value benefits not captured by crime and health that we did not include in this analysis.

Costs

1) Cost of tree (Annual municipal forest expenditure)
2) Cost of tree maintenance
3) Tree removal
4) Tree litter removal

Costs

Based on the approach laid out in "Municipal Forest Benefits and Costs in Five US Cities" by McPherson et al, we used a set cost for a tree for each city. The total cost we found for one municipal tree is $44.77 and when adjusted for the marginal excess burden of taxation (MEBT), the true economic cost after factoring out transfers comes out to $10.29 in deadweight economic loss per tree. We used a MEBT of 23% based on a range of 18%-28% suggested by Boardman et. al. in the fifth edition of their book *Cost-Benefit Analysis: Concepts and Practices*[22]. We found the cost detailed here by using data provided in McPherson et. al. study, choosing the midpoint of the range (if a range was given), adjusting for inflation, then totaling the four areas of cost above.

Table 2. Per-Tree Costs in Ohio

	McPherson Costs	Inflation-adjusted cost	MEBT Cost
Cost of Tree	$6.48	$12.19	$2.80
Cost of Tree Maintenance	$4-$21	$18.94	$4.36
Tree Removal	$2.81-$4.22	$4.55	$1.05
Tree Litter Removal	$5.75	$9.09	$2.09
Total	**-**	**$44.77**	**$10.30**

We estimated the costs for tree-planting programs in a given city by multiplying the per tree cost by the estimated number of trees in that city. This number was determined by finding the square feet of canopy cover in the city then dividing that by a sample tree canopy (120 square feet) to estimate the number of trees in that city. Using this method, we were able to determine how many trees it would take to increase the canopy of a specific city to a given percentage of canopy coverage. We used this number to find the cost for policy options of 30%, 40%, and 50% tree cover.

[22] Boardman, Anthony E. et al 2018. *Cost-benefit analysis: concepts and practice Fifth Edition*. Cambridge, United Kingdom ; New York, NY : Cambridge University Press (pg 70)

Table 3. Marginal excess burden of taxation (economic cost) of tax-funded tree-planting programs

City	30% Canopy Coverage	40% Canopy Coverage	50% Canopy Coverage	80% Canopy Coverage
Athens	$0	$0	$0	$1 million
Cincinnati	$0	$4 million	$23 million	$80 million
Columbus	$43 million	$97 million	$151 million	$314 million
Cleveland	$22 million	$41 million	$61 million	$120 million
Dayton	$1 million	$15 million	$28 million	$68 million
Findlay	$6 million	$10 million	$15 million	$29 million
Toledo	$19 million	$39 million	$58 million	$116 million
Youngstown	$2 million	$10 million	$19 million	$43 million

The highest costs we found are for Columbus, likely because it has the largest square footage and is on the lower end of current canopy cover of the cities we tested. This means that it would take more trees to reach the policy goals set out which would lead to higher costs.

Note this analysis assumes municipal tree planting to achieve a tree canopy goal is done completely by the public sector using tax dollars. Trees planted and maintained by private businesses and residents and initiatives by nonprofits and foundations would not cause deadweight loss costs and would lead to lower overall economic costs. This means these estimates are high-end estimates for the costs of achieving urban canopy goals.

Benefits

We estimated benefits of tree planting using the iTree MyTree tool. This tool allows users to enter data about a specific tree (e.g. species, distance to a building, health, and size) and estimates the environmental and monetary benefits that a specific tree generates annually using USDA Forest Service research. For this study, we created five sample trees for each city placed at randomized locations, varying the direction the tree was in relation to building, the size, and the species (varying the species between the four most common types of trees in Ohio). We then found the sum benefits of these sample trees and divided them by five to find the average benefit one tree in that particular city would give us.

The annual benefits of an Ohio city tree ranged from about $23-$44 in sum current-value dollars. Most of the benefits we found came from energy savings. Within some cities, energy savings account for almost half of total benefits.

Table 4. Pre-Discount Per-Tree Benefits in Ohio

City	CO2 Sequestered	Stormwater Runoff Prevented	Air Pollution Reduced	Energy Saved	Crime Prevented	Sum Benefits
Athens	$3.66	$0.41	$0.10	$23.80	$0.25	**$28.22**
Cincinnati	$6.59	$4.40	$6.84	$26.36	$5.69	**$49.88**
Columbus	$3.77	$4.75	$7.55	$11.25	$3.24	**$30.56**
Cleveland	$3.00	$3.16	$18.73	$10.71	$12.15	**$47.75**
Dayton	$5.44	$3.00	$10.00	$8.26	$4.88	**$31.58**
Findlay	$3.57	$2.79	$8.52	$8.26	$0.79	**$23.93**
Toledo	$5.23	$4.70	$5.29	$8.26	$5.74	**$29.22**
Youngstown	$3.71	3.81	$7.77	$9.02	$1.85	**$26.16**

We estimated the impacts of two additional benefits aside from the benefits estimated by the iTree tool: increase in house prices and reduction in crime. A Baltimore study cited that a 10% increase in the tree canopy led to a 12% reduction in crime.[23] Using local crime data reported in the Neighborhood Scout database and estimates of the economic impact of crime from the Washington Institute of Public Policy, we estimate the economic benefit of reduced crime.[24] We found that if each city increased its canopy by 10%, it would prevent anywhere from 8 to 750 crimes depending on the size of the city and current crime rate.

Table 5. Estimated crimes prevented per city with 10 percentage-point increase in canopy

City	Estimated Crimes Prevented
Athens	3
Cincinnati	330
Columbus	610
Cleveland	750
Dayton	180

[23] Troy, Austin; Grove, J. Morgan; O'Neill-Dunne, Jarlath. 2012. The relationship between tree canopy and crime rates across an urban-rural gradient in the greater Baltimore region. Landscape and Urban Planning. 106: 262-270.

[24] Further information on the methodology of finding crime data is found here: https://www.neighborhoodscout.com/about-the-data/crime-rates

Findlay	8
Toledo	330
Youngstown	330

We did not add the benefit of increased home values to total benefit calculations in order to not count health and crime impacts twice since they are likely a portion of the home value increase. The projected increase in home value because of tree planting is in the table below. Good tree cover in a neighborhood (defined as a binary of having mature trees in the yard or no trees) on average increases a home's value by 8 percent.[25] By multiplying the current home value in these different cities by 8 percent, we find an estimate for how much home value would increase if the tree cover in their yard increased. We estimate that home value would increase by about $3,500-$17,900 depending on the city and the total value benefit to the homes throughout city (found by multiplying the benefit for one home by the total number of homes) could range from $170 million to $2.7 billion in increased home values.

Table 6. Estimated increase in home values by city with better tree coverage

City	Home value increase with good tree coverage	Citywide home value increase
Athens	$17,000	$238 million
Cincinnati	$17,000	$1 billion
Columbus	$18,000	$2.7 billion
Cleveland	$8,000	$760 million
Dayton	$7,000	$360 million
Findlay	$15,000	$170 million
Toledo	$8,000	$730 million
Youngstown	$4,000	$110 million

We did not include other benefits of trees such as physical and mental health benefits in the final estimation of the benefit of tree-planting programs. We took this conservative approach to calculate benefits in order to reduce double-counting issues.

Using a similar methodology to the above cost calculations, we calculated the benefits for our proposed policy options by multiplying the total average tree benefit (the benefits of carbon sequestration, stormwater runoff prevented, air pollution reduced, energy saved, and crime) by

[25] Wolf, K.L. August 2007. City Trees and Property Values. Arborist News 16, 4: 34-36.

the number of trees it would take to meet a given canopy coverage goal. The largest benefit would be a 50% canopy cover in Columbus and the smallest benefit would come from 80% canopy cover in Athens.

Table 7. Pre-discount economic benefit of tree-planting programs

City	30% Canopy Coverage	40% Canopy Coverage	50% Canopy Coverage	80% Canopy Coverage
Athens	N/A	N/A	N/A	$3.2 million
Cincinnati	N/A	$18 million	$110 million	$390 million
Columbus	$130 million	$290 million	$450 million	$930 million
Cleveland	$100 million	$190 million	$280 million	$560 million
Dayton	$4 million	$45 million	$86 million	$210 million
Findlay	$14 million	$24 million	$35 million	$67 million
Toledo	$55 million	$110 million	$160 million	$330 million
Youngstown	$6.2 million	$27 million	$47 million	$110 million

"N/A" values correspond to cities that have already reached listed canopy goals.

Discounting

Cities will not see benefits of tree planting immediately since it takes time for a tree to grow and reach maturity. In order to account for this, we estimated a 30-year maturity of these benefits at a discount rate of 3%. We opted for a discount rate of 3% because that is more commonly accepted in environmental economics and for policies that are necessarily future-focused, which tree planting programs are. It is important to note that this discount rate had a large effect on the monetized benefits realized in a given city.

Table 8. Present value economic benefit of tree-planting programs

City	30% Canopy Coverage	40% Canopy Coverage	50% Canopy Coverage	80% Canopy Coverage
Athens	N/A	N/A	N/A	$1.3 million
Cincinnati	N/A	$7.6 million	$46 million	$160 million
Columbus	$53 million	$120 million	$190 million	$380 million
Cleveland	$41 million	$79 million	$120 million	$230 million

Dayton	$1.7 million	$19 million	$35 million	$86 million
Findlay	$5.7 million	$10 million	$14 million	$28 million
Toledo	$23 million	$45 million	$68 million	$140 million
Youngstown	$2.6 million	$11 million	$20 million	$45 million

"N/A" values correspond to cities that have already reached listed canopy goals.

Net Benefits

Based on the above calculations, we were able to find that, with a few exceptions, tree-planting programs have economic benefits that outweigh the costs after discounting for 30 years into the future. The largest net present benefits were found in Cleveland.

Table 9. Net present value of tree-planting programs

City	30% Canopy Coverage	40% Canopy Coverage	50% Canopy Coverage	80% Canopy Coverage
Athens	N/A	N/A	N/A	$83,000
Cincinnati	N/A	$3.8 million	$23 million	$80 million
Columbus	$9.6 million	$22 million	$34 million	$70 million
Cleveland	$20 million	$38 million	$56 million	$110 million
Dayton	$350,000	$3.9 million	$7.4 million	$18 million
Toledo	$3.3 million	$6.5 million	$9.8 million	$20 million
Youngstown	$110,000	$490,000	$870,000	$2 million

"N/A" values correspond to cities that have already reached listed canopy goals.

The only city that we estimated to have a negative net present value for tree planting is Findlay. This may be because the characteristics of Findlay do not resemble the other cities calculated. Findlay has the lowest current canopy cover at 17% and is one of the smallest cities we studied by square foot. They also had the lowest calculated environmental and crime benefits. This means that their costs were relatively high because they would have a long way to go compared to other cities to reach the policy threshold that was not made up by the benefits that we measured here. It is important to note that trees had a large economic impact on home value in Findlay in comparison to similar cities and that home value effect is not calculated into the benefits discussed here, so factoring in home value, physical, and mental health benefits could tip the scale into positive net benefits for Findlay tree planting programs.

Sensitivity Analysis

In order to determine how accurate our estimates are, we performed Monte Carlo simulations on multiple inputs and assumptions used in our calculations. These simulations find a range of outcomes to account for the possibility of variations in inputs and outcomes in the real world. We conducted 10,000 simulations and were able to determine the range of likely costs and benefits for each category.

We ran Monte Carlo simulations varying ranges of possible inputs for canopy cover, MEBT rate, discount rate, cost of the tree, and environmental benefit of the tree. The range of potential inputs that we chose for this model was based on a hypothetical best city and worst city based on data we found on the eight cities we conducted analyses on, finding a range of benefits from $35 to $91 per tree before discounting. We found canopy cover percentages from city reports for all cities besides Athens and Findlay. For those we had data on, we used a 5% range of possible canopy coverage. For Athens and Findlay, we used a 10% range from the estimated coverage value using iTree data.

These factors were chosen because they seemed the most likely to fluctuate. Monte Carlo results for inputs and net present value can be found in Appendix A.

Based on these results we can be confident in our estimates for canopy cover as the ranges of possible canopy cover levels in our simulations are quite small, usually within a few percentage points of the point estimate we used. These analyses also showed that our results are very sensitive to discounting. We opted for a discount rate of 3%. We chose a 3% rate because that is more commonly accepted in environmental economics and for policies that are necessarily future-focused, which tree planting programs are. A higher discount rate (representing greater present orientation) could tip many planting programs into negative net present value.

The other factor that we found had a large impact on our results was the marginal excess burden of taxation. We used a 23% MEBT with a range on the Monte Carlo of 18%-28% as suggested by Boardman et al.[26] Lower MEBT rates make planting programs much more economically beneficial, while higher MEBT rates make them more expensive.

Acknowledgments

This analysis was conducted by Madeleine Murphy and Rob Moore.

Appendix A. Monte Carlo Results

Table 10. Monte Carlo results for canopy cover

City	5th Percentile	Median	95th Percentile
Athens	67%	75%	83%
Cincinnati	38%	40%	42%

[26] Boardman, Anthony E. et al 2018. *Cost-benefit analysis: concepts and practice Fifth Edition*. Cambridge, United Kingdom ; New York, NY : Cambridge University Press,(pg 70)

Columbus	22%	22%	23%
Cleveland	18%	19%	20%
Dayton	27%	29%	31%
Findlay	16%	17%	18%
Toledo	19%	20%	21%
Youngstown	24%	27%	30%

Table 11. Per-Tree costs and Benefits

	5th Percentile	Median	95th Percentile
Costs (MEBT)	$8.29	$10.30	$12.32
Benefits	$37	$63	$89

Appendix B. Per Tree Discounted Benefit

City	Per-Tree Benefit
Athens	$11.63
Cincinnati	$20.55
Columbus	$12.59
Cleveland	$19.67
Dayton	$13.01
Findlay	$9.86
Toledo	$12.04
Youngstown	$10.78