

An Analysis of Street Tree Benefits for Columbus, Ohio

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EXECUTIVE SUMMARY

An inventory of public trees planted prior to 2000 is maintained by the Urban Forestry Section of the Columbus Recreation and Parks Department by Jack Low and Mike Gimeson. This information was shared with and then analyzed by The Ohio State University's School of Environment and Natural Resources. A total of 90,696 street trees were in the inventory. A common bid price for this service is \$3.00 per tree and thus the inventory represents a savings of \$272,100 for Columbus' taxpayers over contracting for this service. Most importantly however, is that, Columbus has a tree inventory that can be used to better manage the tree resource of the community. Benefits mentioned above do not include the value of the subsequent analysis and report by OSU Extension.

Analysis of the inventory data was done using iTree, a software suite distributed by the USDA Forest Service. The specific program in the iTree suite used to identify benefits was iStreets and is available at no charge should this be desired. This program allows individuals interested in making informed decisions about the community tree resource and to explore many aspects including biodiversity and the value of environmental services. Only recently has there been a tool to enable urban forestry managers to define environmental benefits of the community's urban forest.

A long standing rule of thumb for biodiversity is the 10–20–30 guideline which suggests that no more than 10 percent of trees should be from the same species, no more than twenty percent should be from the same genera, and no more than thirty percent should be from the same family. In Columbus, large and medium growing maples exceed the limit for genus at 28%. Care should be taken to limit all maples, regardless of size, in future plantings. Native ash plantings which are sensitive to emerald ash borer (EAB) represent 11.7% of the street tree population prior to any recent removals of the 10,634 trees currently on the street. An equally devastating pest of Columbus, 26,047 maples would have nearly 2.5 times the impact of EAB if one were to emerge. Large trees should be used where possible as larger trees produce markedly more environmental benefits than small ones as will be seen later. A resident preference survey by the School of Environment and Natural Resources in Toledo, OH confirms that residents prefer larger trees.

Under ideal conditions tree numbers among smaller size classes should be stable and then decline as tree size increases and older trees die. Looking at the citywide totals (Table 2) suggests that Columbus does have an active tree planting program with trees of a variety of sizes in the inventory. Tree sizes are variable at present with nearly 10.6% of the trees larger than 24-inch diameter.

Importance values as detailed in (Table 4) show that 2,531 larger growing silver maples (2.8% of the trees) have a greater importance value (a measure of canopy cover) than 7,067 smaller growing flowering crabapples (7.8% of the trees). This demonstrates the need for planting larger statured trees whenever possible as the importance value is also a measure of the overall contribution of the species to the total environmental benefits delivered. The importance value of silver maple is nearly twice that of flowering crabapples despite the fact that there are more than 2.5 times as many crabapples.

A major benefit of urban trees is their ability to intercept rainfall and reduce storm water runoff (Table 5). Dealing with storm water runoff is a major cost for many communities. Columbus, OH is about to embark on

a multi-billion dollar sewer and storm water upgrade for the community. Trees on Columbus streets intercept more than 101.6 million gallons of storm water annually at a savings to residents of 2.7 million dollars per year in contrast to running that water into the sewer system.

Carbon sequestration, as reported here, represents the carbon removed from the air and stored in the community's trees (Table 6). Approximately 161,180 tons of carbon has been stored by 90,696 trees over time. Columbus' trees currently sequester and avoid more than 44 million lbs of CO₂ annually (Table 7) and would represent carbon credits worth \$332,473 per year if a carbon trading system were in place and if a system for accounting for them were available for community trees. These are net gain figures and include deductions for tree losses and maintenance. Annual CO₂ benefits vary by species and size. Smaller crabapples sequester and avoid \$10,014, while a smaller number of larger silver maples sequester and avoid \$31,069 or more than 8.6 times as much per tree.

Energy savings by trees are exceptionally important in view of the citizenry's increasing concern over the nation's energy dependency. Planting trees in our communities may well be more cost effective than building power plants as we work toward meeting our energy needs less expensively. Energy is saved by shading structures, evaporating water (evapotranspiration) and reducing wind speed around structures (Table 8). Annually, Columbus street trees save nearly \$883,000 in electricity and \$1.5 million in natural gas for a total savings of nearly 2.5 million dollars or an average of \$27 per tree.

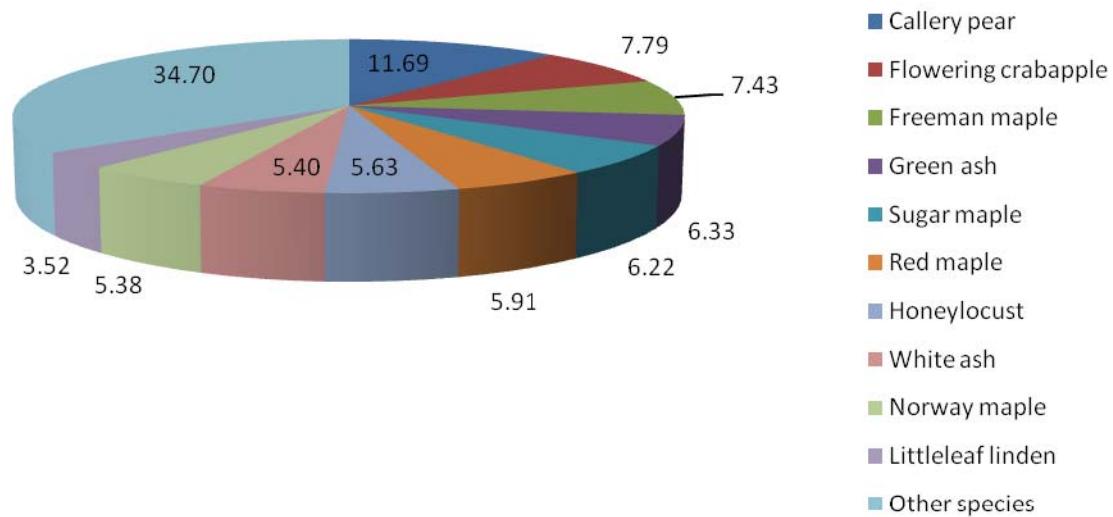
Annual air quality savings (reduced ozone, nitrous and sulfur oxides as well as particulate matter) for Columbus street trees is \$399,735 (Table 9). This includes both direct savings (\$80,505) from the trees and avoided pollution which is much greater at (\$346,288). Avoided pollution is pollution not generated at a power source because energy was not required by Columbus consumers. The total annual air quality benefits are discounted by \$27,058 for the volatile emissions from the trees themselves.

Aesthetic and miscellaneous benefits from trees contribute \$2,760,688 annually to the community in the form of increased property values and enhanced community identity among other things (Table 10). This is an average of \$30.44 per tree per year. Research in public housing has shown that areas with trees facilitate interaction among residents and lead to reduced domestic violence and more sociable environments. Customer surveys suggest that customers prefer to spend their money and time in commercial streetscapes with trees and are willing to spend up to 11% more in commercial settings with trees.

When all benefits are included Columbus' street trees contribute nearly 8.7 million dollars annually to the community (Table 11). Species vary in their annual benefits but mature size, longevity, and maintenance costs are but some of the factors determining annual benefits. Thus Columbus' 90,696 trees contribute an average of nearly \$96 per tree. This would be well in excess of their maintenance and planting costs.

The Columbus Urban Forestry Section budget for 2009 is \$2,521,720. The return on Columbus's investment in the urban forest would be \$8.7 million from storm water abatement, CO₂ avoidance and storage, energy savings, air quality, aesthetic benefits, and the like. This is an annual return on investment of 290%. Irrespective of how you consider it, Columbus's street trees are truly a contributing part of the community. Unlike most community infrastructure, tree benefits per tree continue to increase over a tree's lifetime as initial installation and maintenance costs are spread over more time.

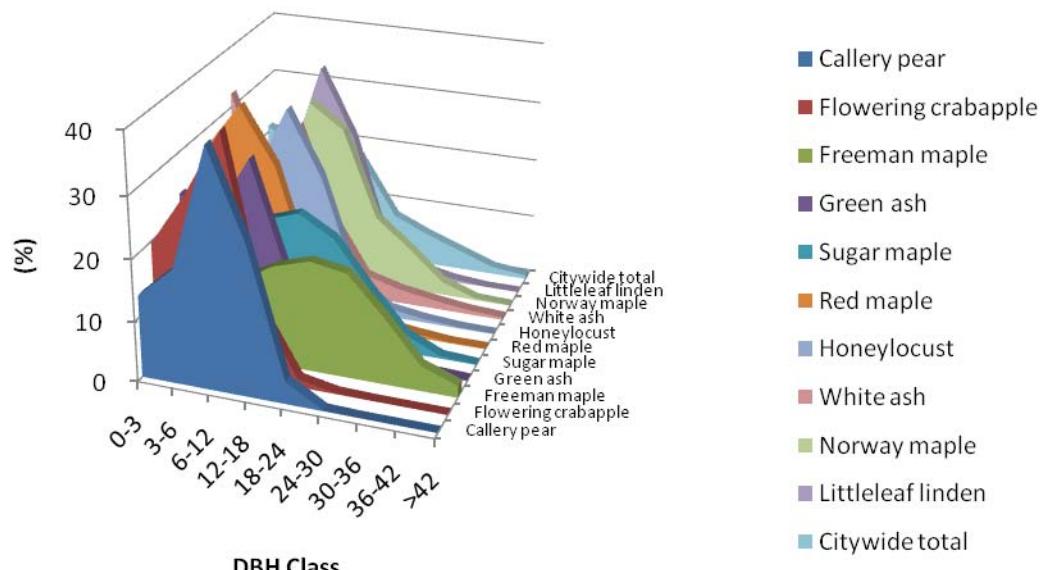
Table 1. Percent Species Distribution of Columbus' Ten Most Common Street Trees



Species	Percent
Callery pear	11.69
Flowering crabapple	7.79
Freeman maple	7.43
Green ash	6.33
Sugar maple	6.22
Red maple	5.91
Honeylocust	5.63
White ash	5.40
Norway maple	5.38
Littleleaf linden	3.52
Other species	34.70
Total	100.00



Table 2. Relative Age Distribution of the Top 10 Most Commonly Planted Columbus Street Tree Taxa (%)



Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42
Callery pear	13.6	18.9	38.9	24.8	3.7	0.2	0.0	0.0	0.0
Flowering crabapple	19.7	28.4	38.9	11.4	1.3	0.2	0.0	0.0	0.0
Freeman maple	10.7	7.1	13.0	16.5	18.2	17.2	11.1	4.2	2.0
Green ash	23.4	20.7	30.7	13.1	6.2	4.0	1.3	0.4	0.2
Sugar maple	17.2	12.8	18.6	20.6	17.3	9.9	3.1	0.4	0.1
Red maple	27.0	34.6	25.5	7.7	2.7	1.4	0.7	0.2	0.2
Honeylocust	16.0	20.9	32.9	22.3	5.5	1.4	0.6	0.2	0.1
White ash	32.3	17.3	28.4	13.1	4.0	2.4	1.5	0.7	0.4
Norway maple	9.9	11.4	30.4	26.4	11.9	7.4	2.3	0.3	0.0
Littleleaf linden	18.3	16.7	34.4	23.2	5.2	1.8	0.5	0.0	0.0
Columbus total	21.1	17.8	25.8	16.8	7.9	5.4	3.3	1.2	0.6



Table 3. Population of Columbus Streets Trees by Scientific Name and Size Class.

Species	DBH Class (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Broadleaf Deciduous Large (BDL)										
<i>Acer x freemanii</i>	723	479	878	1,111	1,228	1,161	746	283	133	6,742
<i>Fraxinus pennsylvanica</i>	1,342	1,188	1,760	750	353	230	77	25	12	5,737
<i>Acer saccharum</i>	969	720	1,052	1,163	976	557	177	24	6	5,644
<i>Acer rubrum</i>	1,450	1,855	1,366	414	143	77	37	9	10	5,361
<i>Fraxinus americana</i>	1,580	846	1,389	642	194	117	72	36	21	4,897
<i>Acer saccharinum</i>	24	47	141	339	525	615	513	224	103	2,531
<i>Platanus x acerifolia</i>	182	134	401	658	319	182	172	41	15	2,104
<i>Liquidambar styraciflua</i>	86	162	455	467	141	36	9	2	0	1,358
<i>Celtis sp</i>	20	106	230	183	143	112	121	51	39	1,005
<i>Quercus rubra</i>	135	216	90	62	63	67	70	33	37	773
<i>Quercus palustris</i>	44	119	71	91	97	106	97	25	18	668
<i>Catalpa speciosa</i>	19	14	52	110	137	171	111	30	12	656
<i>Tilia americana</i>	275	51	63	112	56	28	9	3	2	599
<i>Juglans nigra</i>	21	52	90	138	98	74	30	6	3	512
<i>Ulmus americana</i>	8	79	107	77	68	30	27	23	10	429
<i>Ailanthus altissima</i>	25	41	65	66	58	36	27	14	2	334
<i>Populus deltoides</i>	16	10	48	68	48	31	44	25	24	314
<i>Tilia tomentosa</i>	139	65	54	3	0	2	0	0	0	263
<i>Platanus occidentalis</i>	6	3	3	24	37	45	56	45	28	247
<i>Acer grandidentatum</i>	156	43	17	0	0	0	0	0	0	216
<i>Liriodendron tulipifera</i>	19	19	49	45	31	19	6	0	0	188
<i>Quercus acutissima</i>	69	68	19	10	3	0	1	0	1	171
<i>Tilia species</i>	31	15	63	47	4	0	0	0	0	160
<i>Ulmus parvifolia</i>	81	20	39	0	0	0	0	0	0	140
<i>Quercus robur</i>	80	55	2	1	1	0	0	0	0	139
<i>Fraxinus americana var biltmoreana</i>	63	23	26	13	3	2	0	0	0	130
<i>Ulmus procera</i>	1	2	4	12	16	32	27	25	11	130
<i>Quercus alba</i>	2	18	13	18	20	29	12	10	7	129
<i>Quercus sumardii</i>	15	41	33	8	7	6	8	6	2	126
<i>Quercus imbricaria</i>	81	14	13	3	2	1	4	3	2	123
<i>Ulmus rubra</i>	1	3	16	28	15	21	13	8	3	108
<i>Fraxinus excelsior</i>	0	0	31	43	16	4	3	1	0	98
<i>Quercus species</i>	32	24	4	6	4	14	7	4	2	97
<i>Acer nigrum</i>	9	19	26	24	8	6	1	0	0	93
<i>Quercus macrocarpa</i>	10	22	5	7	12	6	16	3	4	85
<i>Quercus coccinea</i>	46	3	4	2	1	4	2	2	2	66
Broadleaf Deciduous Large	26	13	9	4	9	2	1	0	1	65
<i>Gymnocladus dioicus</i>	35	5	4	2	2	3	0	0	0	51
<i>Aesculus hippocastanum</i>	10	1	2	10	12	7	4	2	0	48
<i>Populus species</i>	5	6	9	6	5	5	1	2	0	39
<i>Betula pendula</i>	9	18	10	1	0	0	0	0	0	38
<i>Betula papyrifera</i>	7	7	12	4	1	0	0	0	0	31
<i>Acer species</i>	11	7	2	1	2	4	1	0	1	29
<i>Fagus grandifolia</i>	1	1	2	4	4	5	7	1	1	26
<i>Carya cordiformis</i>	0	5	3	7	3	4	1	2	0	25
<i>Carya glabra</i>	0	0	2	7	4	3	2	4	1	23
<i>Populus nigra</i>	3	7	3	4	1	0	1	0	0	19
<i>Salix babylonica</i>	1	2	1	4	4	1	2	2	2	19
<i>Quercus muehlenbergii</i>	0	0	3	2	2	0	3	5	2	17

Species	DBH Class (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Tilia platyphyllos	0	6	11	0	0	0	0	0	0	17
Fagus sylvatica	7	3	4	1	0	0	0	0	0	15
Carya species	0	0	3	1	9	1	0	0	0	14
Tilia x euchlora	0	0	8	5	0	0	0	0	0	13
Fraxinus quadrangulata	0	0	1	3	3	2	3	0	0	12
Salix nigra	0	0	1	1	1	4	1	1	2	11
Quercus velutina	0	1	1	1	2	0	3	2	0	10
Juglans regia	0	2	4	2	1	0	0	0	0	9
Larix laricina	1	3	3	2	0	0	0	0	0	9
Celtis laevigata	1	0	3	3	0	1	0	0	0	8
Fagus sp	2	1	1	0	1	0	2	1	0	8
Quercus falcata	3	0	0	0	2	1	2	0	0	8
Populus alba	1	0	1	0	0	4	1	0	0	7
Aesculus flava	0	0	0	1	3	1	1	0	0	6
Quercus michauxii	1	1	0	0	0	2	1	1	0	6
Carya ovata	0	0	1	1	2	1	0	0	0	5
Populus balsamifera	0	0	0	1	2	0	0	0	0	3
Quercus prinus	1	0	1	0	0	1	0	0	0	3
Oxydendrum arboreum	0	1	1	0	0	0	0	0	0	2
Paulownia tomentosa	0	1	1	0	0	0	0	0	0	2
Populus grandidentata	0	0	0	1	0	1	0	0	0	2
Populus tremuloides	1	1	0	0	0	0	0	0	0	2
Quercus marilandica	2	0	0	0	0	0	0	0	0	2
Ulmus glabra	2	0	0	0	0	0	0	0	0	2
Castanea dentata	0	0	0	0	0	0	1	0	0	1
Cercidiphyllum japonicum	1	0	0	0	0	0	0	0	0	1
Celtis occidentalis	0	0	0	0	1	0	0	0	0	1
Juglans cinerea	0	1	0	0	0	0	0	0	0	1
Populus x canescens	0	0	0	0	1	0	0	0	0	1
Populus heterophylla	0	0	0	0	0	0	1	0	0	1
Quercus lyrata	0	0	0	0	0	1	0	0	0	1
Tilia heterophylla	0	0	0	0	0	1	0	0	0	1
Ulmus x hollandica	0	0	1	0	0	0	0	0	0	1
Total	7,891	6,669	8,787	6,824	4,904	3,876	2,534	984	519	42,988
Broadleaf Deciduous Medium (BDM)										
Pyrus calleryana	1,440	2,000	4,122	2,629	391	17	1	0	1	10,601
Gleditsia triacanthos	815	1,070	1,683	1,141	281	73	31	9	5	5,108
Acer platanoides	484	554	1,483	1,291	583	359	112	13	2	4,881
Tilia cordata	582	532	1,096	740	165	56	17	1	0	3,189
Acer campestre	296	304	371	62	15	4	1	0	0	1,053
Ulmus pumila	9	56	119	115	117	160	119	55	17	767
Acer negundo	20	86	166	187	92	68	31	14	5	669
Carpinus betulus	421	46	31	3	0	0	0	0	0	501
Prunus serotina	14	43	112	98	49	39	14	4	3	376
Acer truncatum	284	58	3	0	0	0	0	0	0	345
Phellodendron amurense	267	12	0	0	0	0	0	0	0	279
Corylus colurna	147	24	19	6	0	0	0	0	0	196
Robinia pseudoacacia	1	17	49	43	33	21	12	2	0	178
Quercus bicolor	98	9	7	0	7	16	17	7	8	169
Ulmus species	6	74	15	14	9	11	5	1	1	136
Ginkgo biloba	25	22	50	11	9	7	4	1	0	129
Betula nigra	64	19	12	5	4	0	0	0	0	104
Eucommia ulmoides	39	9	17	21	2	0	0	0	0	88

Species	DBH Class (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Maclura pomifera	1	18	20	20	13	11	3	0	1	87
Zelkova serrata	6	25	18	23	8	0	0	0	0	80
Aesculus glabra	11	6	16	12	10	9	1	0	0	65
Morus rubra	1	10	18	15	4	0	3	0	1	52
Koelreuteria paniculata	6	9	4	13	6	2	0	0	0	40
Salix species	8	7	4	6	1	0	3	1	1	31
Nyssa sylvatica	22	1	1	1	0	0	0	0	0	25
Sophora japonica	1	12	1	0	3	0	0	0	0	17
Betula species	7	1	4	0	0	1	0	0	0	13
Carya alba	1	2	3	4	1	0	1	1	0	13
Catalpa bignonioides	1	0	1	1	2	4	4	0	0	13
Fraxinus velutina	0	0	0	6	2	3	1	0	0	12
Acer pseudoplatanus	0	1	1	3	3	0	0	0	1	9
Carpinus caroliniana	1	2	4	2	0	0	0	0	0	9
Cladrastis kentukea	0	6	1	2	0	0	0	0	0	9
Fraxinus species	2	1	2	1	1	2	0	0	0	9
Sassafras albidum	2	2	1	0	0	0	1	0	0	6
Betula populifolia	2	0	0	1	2	0	0	0	0	5
Fraxinus nigra	1	0	3	1	0	0	0	0	0	5
Broussonetia papyrifera	0	1	0	2	1	0	0	0	0	4
Acer buergerianum	2	0	0	0	0	0	0	0	0	2
Aesculus x carnea	0	0	0	0	1	1	0	0	0	2
Aesculus pavia	0	0	0	2	0	0	0	0	0	2
Catalpa ovata	0	0	0	0	1	0	0	1	0	2
Diospyros virginiana	0	0	0	2	0	0	0	0	0	2
Carya illinoinensis	0	0	0	0	0	1	0	0	0	1
Castanea mollissima	0	0	1	0	0	0	0	0	0	1
Carya texana	0	0	0	1	0	0	0	0	0	1
Fraxinus ornus	0	0	0	0	1	0	0	0	0	1
Quercus ellipsoidalis	0	0	0	0	0	0	1	0	0	1
Total	5,087	5,039	9,458	6,484	1,817	865	382	110	46	29,288

Broadleaf Deciduous Small (BDS)										
Malus hybrid	1,394	2,006	2,752	807	92	13	2	1	0	7,067
Morus alba	52	137	252	199	111	84	51	24	10	920
Amalanchier species	514	259	78	5	0	0	0	0	0	856
Prunus species	312	206	147	40	15	6	1	0	0	727
Syringa reticulata	601	103	16	0	2	0	1	0	0	723
Amelanchier x grandiflora	553	83	8	1	0	0	0	0	0	645
Cercis canadensis	149	129	202	57	11	5	2	1	0	556
Crataegus species	47	186	180	64	6	0	1	0	0	484
Cornus florida	273	94	24	0	0	0	0	0	0	391
Alnus glutinosa	215	61	25	1	1	0	1	0	0	304
Crataegus crusgalli	190	18	16	4	1	1	0	0	0	230
Prunus campanulata	147	11	21	2	0	0	0	0	0	181
Amelanchier arborea	51	113	14	1	0	0	0	0	0	179
Cornus kousa	163	14	2	0	0	0	0	0	0	179
Acer ginnala	90	51	37	0	0	0	0	0	0	178
Prunus serrulata	53	48	45	9	4	6	4	1	0	170
Malus species	17	20	48	29	20	3	1	0	0	138
Prunus serrulata	114	8	0	0	0	0	0	0	0	122
Sorbus acuparia	34	40	13	3	0	0	2	0	0	92
Crataegus viridis	79	3	0	0	0	0	0	0	0	82
Prunus cerasifera	11	22	29	10	0	0	0	0	0	72

Species	DBH Class (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Acer palmatum	40	16	9	1	0	0	0	0	0	66
Hibiscus syriacus	36	25	4	0	0	0	0	0	0	65
Cornus mas	63	0	0	0	0	0	0	0	0	63
Crataegus phaenopyrum	47	4	3	5	0	0	0	0	0	59
Prunus subhirtella	32	25	0	0	0	0	0	0	0	57
Pyrus species	2	10	17	14	5	1	0	0	0	49
Evodia danielii	38	0	0	0	1	0	0	0	0	39
Cornus racemosa	28	4	0	0	0	0	0	0	0	32
Cornus alternifolia	29	0	0	0	0	0	0	0	0	29
Elaeagnus angustifolia	5	3	10	6	0	1	0	0	0	25
Halesia carolina	24	0	0	0	0	0	0	0	0	24
Prunus sargentii	20	0	3	1	0	0	0	0	0	24
Prunus avium	4	1	6	8	1	2	0	0	0	22
Cotinus coggygria	7	9	4	1	0	0	0	0	0	21
Cornus species	9	6	3	0	0	0	0	0	0	18
Sorbus americana	3	10	4	1	0	0	0	0	0	18
Corylus sp	16	0	0	0	0	0	0	0	0	16
Ligustrum sp	1	1	7	3	0	1	0	0	0	13
Salix matsudana	0	2	4	1	1	1	1	0	0	10
Caragana arborescens	1	8	0	0	0	0	0	0	0	9
Prunus x yedoensis	7	2	0	0	0	0	0	0	0	9
Rhus typhina	3	3	3	0	0	0	0	0	0	9
Prunus americana	0	2	4	1	0	0	0	0	0	7
Elaeagnus umbellata	2	0	3	1	0	0	0	0	0	6
Viburnum sp	4	2	0	0	0	0	0	0	0	6
Ostrya virginiana	2	0	2	1	0	0	0	0	0	5
Salix discolor	0	1	3	1	0	0	0	0	0	5
Albizia julibrissin	1	1	2	0	0	0	0	0	0	4
Crataegus x laballei	0	0	1	3	0	0	0	0	0	4
Lonicera maackii	2	0	2	0	0	0	0	0	0	4
Castanea pumila	0	0	0	0	0	1	1	0	0	2
Magnolia stellata	1	1	0	0	0	0	0	0	0	2
Asimina triloba	0	0	1	0	0	0	0	0	0	1
Prunus pennsylvanica	0	0	0	0	0	0	1	0	0	1
Rhus glabra	0	0	1	0	0	0	0	0	0	1
Styrax japonicum	0	1	0	0	0	0	0	0	0	1
Syringa species	0	0	1	0	0	0	0	0	0	1
Total	5,486	3,749	4,006	1,280	271	125	69	27	10	15,023
Broadleaf Evergreen Large (BEL)										
Grevillea robusta	0	0	0	1	0	1	2	0	0	4
Calocedrus decurrens	0	0	0	0	0	0	1	0	0	1
Quercus nigra	0	0	0	0	0	1	0	0	0	1
Total	0	0	0	1	0	2	3	0	0	6
Broadleaf Evergreen Medium (BEM)										
Magnolia grandiflora	1	1	0	0	0	0	0	0	0	2
Total	1	1	0	0	0	0	0	0	0	2
Broadleaf Evergreen Small (BES)										
Magnolia species	30	39	18	10	5	0	1	0	0	103
Magnolia x soulangiana	8	25	28	14	3	3	0	0	0	81
Magnolia virginiana	57	2	0	1	0	0	0	0	0	60

Species	DBH Class (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Magnolia x loebneri	29	0	0	0	0	0	0	0	0	29
Ilex opaca	0	1	2	0	0	0	0	0	0	3
Ilex species	2	0	0	0	0	0	0	0	0	2
Total	126	67	48	25	8	3	1	0	0	278
Conifer Evergreen Large (CEL)										
Picea abies	57	53	240	193	91	17	0	1	0	652
Pinus strobus	133	194	200	54	14	4	1	0	0	600
Pinus nigra	16	36	89	34	12	2	0	0	0	189
Pinus sylvestris	11	17	60	45	15	3	0	0	0	151
Thuja occidentalis	16	53	47	17	3	0	0	0	0	136
Picea species	48	8	24	24	14	4	0	0	0	122
Tsuga canadensis	17	29	21	2	3	0	0	0	0	72
Taxodium distichum	18	13	3	3	2	1	0	0	0	40
Pinus resinosa	6	7	11	6	3	0	0	0	0	33
Pseudotsuga menziesii	1	6	6	4	0	0	0	0	0	17
Pinus monticola	0	0	2	6	1	0	0	0	0	9
Pinus strobiformis	0	2	1	5	1	0	0	0	0	9
Abies species	1	7	0	0	0	0	0	0	0	8
Cedrus atlantica	0	0	2	2	0	0	0	0	0	4
Pinus echinata	0	1	1	0	0	1	0	0	0	3
Pinus serotina	0	0	1	2	0	0	0	0	0	3
Abies balsamea	1	0	1	0	0	0	0	0	0	2
Abies concolor	0	1	0	0	1	0	0	0	0	2
Cedrus libani	0	0	1	1	0	0	0	0	0	2
Metasequoia glyptostroboides	0	0	1	0	1	0	0	0	0	2
Pinus taeda	0	1	0	0	0	0	0	0	0	1
Total	325	428	711	398	161	32	1	1	0	2,057
Conifer Evergreen Medium (CEM)										
Picea pungens	161	124	258	170	14	0	1	0	0	728
Picea glauca	23	36	56	23	9	2	0	0	0	149
Picea mariana	0	2	5	2	0	0	0	0	0	9
Pinus Species	0	0	6	1	0	0	0	0	0	7
Pinus banksiana	1	0	1	2	0	0	0	0	0	4
Pinus thunbergii	0	0	1	0	0	0	0	0	0	1
Platycladus orientalis	1	0	0	0	0	0	0	0	0	1
Total	186	162	327	198	23	2	1	0	0	899
Conifer Evergreen Small (CES)										
Juniperus species	8	19	26	11	1	0	0	0	0	65
Juniperus virginiana	2	6	21	27	2	2	0	0	0	60
Taxus sp	4	7	8	6	0	0	1	0	0	26
Juniperus chinensis	0	0	2	1	1	0	0	0	0	4
Total	14	32	57	45	4	2	1	0	0	155
Columbus Total	19,116	16,147	23,394	15,255	7,188	4,907	2,992	1,122	575	90,696



Table 4. Columbus' Most Abundant Street Trees by Common Name and Listed by Decreasing Importance Values

Species	Number of Trees	% of Total Trees	Leaf Area (ft ²)	% of Total Leaf Area	Canopy Cover (ft ²)	% Total Canopy Cover	Importance Value
Freeman maple	6742	7.4	28490144	18.6	8239909	15.7	13.9
Callery pear	10601	11.7	9081611	5.9	4625074	8.8	8.8
Sugar maple	5644	6.2	13439828	8.8	4139106	7.9	7.6
Silver maple	2531	2.8	16139701	10.6	4375364	8.3	7.2
Norway maple	4881	5.4	8437990	5.5	3227819	6.2	5.7
Green ash	5737	6.3	7478364	4.9	2530822	4.8	5.3
Honeylocust	5108	5.6	6423489	4.2	3165683	6.0	5.3
White ash	4897	5.4	6328701	4.1	2369433	4.5	4.7
Flowering crabapple	7067	7.8	1476840	1.0	1724984	3.3	4.0
Red maple	5361	5.9	3301794	2.2	1731547	3.3	3.8
London planetree	2104	2.3	5625519	3.7	1657990	3.2	3.1
Littleleaf linden	3189	3.5	3053983	2.0	1112075	2.1	2.5
Hackberry	1005	1.1	3928786	2.6	1322628	2.5	2.1
Sweetgum	1358	1.5	2292504	1.5	832758	1.6	1.5
White mulberry	920	1.0	699545	0.5	500617	1.0	0.8
Hedge maple	1053	1.2	509605	0.3	311257	0.6	0.7
Other trees	22498	24.8	36065857	23.6	10605454	20.2	22.9
Columbus Total	90696	100.0	152774259	100.0	52472518	100.0	100.0



Table 5. Annual Storm Water Benefits for Columbus' Street Trees by Species Listed by Decreasing Average Dollars/Tree

Species	Total Rainfall Interception (Gal)	Total (\$)	% of Total Tree Numbers	% of Total \$	Avg. \$/tree
Silver maple	10,580,594	\$286,754	2.8	10.4	\$113.30
Freeman maple	19,208,568	\$520,588	7.4	18.9	\$77.22
Hackberry	2,363,042	\$64,043	1.1	2.3	\$63.72
London planetree	3,414,225	\$92,532	2.3	3.4	\$43.98
Sugar maple	7,953,195	\$215,547	6.2	7.8	\$38.19
Norway maple	6,058,642	\$164,201	5.4	6.0	\$33.64
Sweetgum	1,561,347	\$42,315	1.5	1.5	\$31.16
White ash	4,366,715	\$118,346	5.4	4.3	\$24.17
Honeylocust	4,410,103	\$119,522	5.6	4.3	\$23.40
Green ash	4,908,559	\$133,031	6.3	4.8	\$23.19
Callery pear	7,503,224	\$203,352	11.7	7.4	\$19.18
Littleleaf linden	2,158,084	\$58,488	3.5	2.1	\$18.34
White mulberry	537,777	\$14,575	1.0	0.5	\$15.84
Red maple	2,580,819	\$69,945	5.9	2.5	\$13.05
Hedge maple	433,919	\$11,760	1.2	0.4	\$11.17
Flowering crabapple	1,540,569	\$41,752	7.8	1.5	\$5.91
Other street trees	22,004,959	\$596,376	24.8	21.7	\$26.51
Columbus total	101,584,342	\$2,753,127	100.0	100.0	\$30.36



Table 6. Stored CO₂ Benefits of Columbus' Street Trees by Species Ordered by Decreasing Benefits/Tree

Species	Total stored CO ₂ (lbs)	Total (\$)	% of Total Tree Numbers	% of Total \$	Avg. \$/tree
Silver maple	37,769,117	\$283,268	2.8	11.7	\$111.92
Freeman maple	63,384,431	\$475,383	7.4	19.7	\$70.51
London planetree	14,719,731	\$110,398	2.3	4.6	\$52.47
Hackberry	5,556,440	\$41,673	1.1	1.7	\$41.47
Sugar maple	26,343,283	\$197,575	6.2	8.2	\$35.01
Norway maple	18,012,516	\$135,094	5.4	5.6	\$27.68
Sweetgum	4,288,905	\$32,167	1.5	1.3	\$23.69
White mulberry	2,746,221	\$20,597	1.0	0.9	\$22.39
Green ash	14,978,466	\$112,338	6.3	4.7	\$19.58
White ash	10,803,265	\$81,024	5.4	3.4	\$16.55
Littleleaf linden	6,373,526	\$47,801	3.5	2.0	\$14.99
Callery pear	17,903,983	\$134,280	11.7	5.6	\$12.67
Honeylocust	8,534,468	\$64,009	5.6	2.7	\$12.53
Red maple	5,626,485	\$42,199	5.9	1.8	\$7.87
Flowering crabapple	6,053,623	\$45,402	7.8	1.9	\$6.42
Hedge maple	863,350	\$6,475	1.2	0.3	\$6.15
Other street trees	35,563,097	\$588,023	24.8	24.3	\$26.14
Columbus total	322,360,925	\$2,417,707	100.0	100.0	\$26.66



Table 7. Annual Carbon Dioxide Benefits of Columbus' Street Trees by Species Listed by Decreasing Benefits per Tree

Species	Sequestered (lb)	Sequestered (\$)	Decomposition Release(lb)	Maintenance Release (lb)	Total Release (\$)	Avoided (lb)	Avoided (\$)	Net Total (lb)	Total (\$)	% of Total Tree Numbers	% of Total \$	Avg. \$/tree
Silver maple	3,017,141	\$22,629	-181,326	-8,350	-\$1,422.57	1,315,131	\$9,863	4,142,596	\$31,069	2.79	9.34	\$12.28
Freeman maple	5,529,597	\$41,472	-304,619	-16,406	-\$2,407.69	2,633,990	\$19,755	7,842,563	\$58,819	7.43	17.69	\$8.72
London planetree	968,292	\$7,262	-70,662	-4,404	-\$562.99	665,485	\$4,991	1,558,711	\$11,690	2.32	3.52	\$5.56
Hackberry	302,982	\$2,272	-26,695	-2,466	-\$218.71	439,711	\$3,298	713,532	\$5,351	1.11	1.61	\$5.32
Sweetgum	449,539	\$3,372	-20,590	-2,115	-\$170.29	353,395	\$2,650	780,229	\$5,852	1.50	1.76	\$4.31
Sugar maple	1,734,250	\$13,007	-127,003	-9,642	-\$1,024.84	1,536,691	\$11,525	3,134,296	\$23,507	6.22	7.07	\$4.16
Norway maple	1,292,774	\$9,696	-86,873	-8,068	-\$712.06	1,328,262	\$9,962	2,526,095	\$18,946	5.38	5.70	\$3.88
Honeylocust	1,308,260	\$9,812	-41,610	-6,068	-\$357.59	1,224,064	\$9,180	2,484,646	\$18,635	5.63	5.60	\$3.65
Littleleaf linden	860,374	\$6,453	-30,934	-3,874	-\$261.06	519,011	\$3,893	1,344,577	\$10,084	3.52	3.03	\$3.16
Callery pear	2,326,831	\$17,451	-87,415	-12,536	-\$749.63	2,085,035	\$15,638	4,311,915	\$32,339	11.69	9.73	\$3.05
Green ash	1,327,992	\$9,960	-71,949	-6,772	-\$590.41	998,275	\$7,487	2,247,546	\$16,857	6.33	5.07	\$2.94
White ash	1,090,532	\$8,179	-52,419	-5,218	-\$432.28	874,816	\$6,561	1,907,710	\$14,308	5.40	4.30	\$2.92
White mulberry	140,714	\$1,055	-13,184	-1,669	-\$111.40	191,800	\$1,439	317,661	\$2,382	1.01	0.72	\$2.59
Red maple	633,766	\$4,753	-27,085	-4,527	-\$237.09	685,353	\$5,140	1,287,507	\$9,656	5.91	2.90	\$1.80
Hedge maple	117,730	\$883	-4,160	-845	-\$37.54	125,463	\$941	238,188	\$1,786	1.16	0.54	\$1.70
Flowering crabapple	661,594	\$4,962	-29,119	-6,546	-\$267.49	709,206	\$5,319	1,335,135	\$10,014	7.79	3.01	\$1.42
Other street trees	4,719,088	\$35,393	-377,125	-28,569	-\$3,042.71	3,843,427	\$28,826	8,156,820	\$61,176	24.81	18.40	\$2.72
Columbus total	26,481,457	\$198,611	-1,552,769	-128,077	-\$12,606.34	19,529,116	\$146,468	44,329,727	\$332,473	100.00	100.00	\$3.67



Table 8. Annual Energy Benefits for Columbus' Street Trees by Species Listed by Decreasing Benefits per Tree (\$/tree)

Species	Total Electricity (MWh)	Electricity (\$)	Total Natural Gas (Therms)	Natural Gas (\$)	Total (\$)	% Total Trees	% of Total \$	Avg. \$/tree
Silver maple	784	\$59,509	102830	\$100,774	\$160,283	2.8	6.5	\$63.33
Hackberry	262	\$19,897	37087	\$36,345	\$56,242	1.1	2.3	\$55.96
Freeman maple	1570	\$119,187	205863	\$201,746	\$320,933	7.4	13.1	\$47.60
London planetree	397	\$30,113	55204	\$54,099	\$84,212	2.3	3.4	\$40.02
Norway maple	792	\$60,103	112991	\$110,731	\$170,834	5.4	7.0	\$35.00
Sugar maple	916	\$69,534	121835	\$119,398	\$188,932	6.2	7.7	\$33.47
Sweetgum	211	\$15,991	27151	\$26,608	\$42,598	1.5	1.7	\$31.37
Honeylocust	730	\$55,388	98765	\$96,790	\$152,178	5.6	6.2	\$29.79
White mulberry	114	\$8,679	17549	\$17,198	\$25,877	1.0	1.1	\$28.13
Callery pear	1243	\$94,347	176892	\$173,354	\$267,701	11.7	10.9	\$25.25
Green ash	595	\$45,171	79986	\$78,386	\$123,557	6.3	5.0	\$21.54
White ash	522	\$39,585	65931	\$64,613	\$104,197	5.4	4.3	\$21.28
Littleleaf linden	309	\$23,485	42379	\$41,531	\$65,016	3.5	2.7	\$20.39
Red maple	409	\$31,012	56767	\$55,631	\$86,643	5.9	3.5	\$16.16
Hedge maple	75	\$5,677	10593	\$10,381	\$16,058	1.2	0.7	\$15.25
Flowering crabapple	423	\$32,091	67120	\$65,777	\$97,868	7.8	4.0	\$13.85
Other street trees	2291	\$173,913	318497	\$312,127	\$486,040	24.8	19.9	\$21.60
Columbus total	11643	\$883,681	1597438	\$1,565,489	\$2,449,170	100.0	100.0	\$27.00



Table 9. Annual Air Quality Benefits of Columbus' Street Trees by Species Listed by Decreasing Benefits per Tree Species

Species	Deposit O3 (lb)	Deposit NO2 (lb)	Deposit PM10 (lb)	Deposit SO2 (lb)	Total Deposition (\$)	Avoided NO2 (lb)	Avoided PM10 (lb)	Avoided VOC (lb)	Avoided SO2 (lb)	Total Avoided (\$)	BVOC Emission (lb)	BVOC Emission (\$)	Total (lb)	Total (\$)	% Total Trees	Avg. \$/tree
Silver maple	1,725	292	858	76	\$9,334	3,693	541	516	3,547	\$23,115	-904	-\$3,390	10,346	\$29,059	2.8	\$11.48
Hackberry	363	63	188	16	\$1,989	1,264	183	174	1,189	\$7,847	0	\$0	3,441	\$9,836	1.1	\$9.79
Freeman maple	2,894	491	1,473	128	\$15,751	7,398	1,084	1,035	7,107	\$46,305	-1,596	-\$5,985	20,012	\$56,071	7.4	\$8.32
London planetree	399	68	210	18	\$2,193	1,906	277	264	1,801	\$11,851	-362	-\$1,359	4,580	\$12,685	2.3	\$6.03
Norway maple	1,075	186	553	48	\$5,879	3,829	554	528	3,594	\$23,746	-267	-\$1,001	10,099	\$28,624	5.4	\$5.86
Sugar maple	918	156	492	41	\$5,069	4,336	634	605	4,150	\$27,102	-749	-\$2,807	10,584	\$29,364	6.2	\$5.20
Sweetgum	127	20	73	6	\$713	990	145	139	955	\$6,209	0	\$0	2,456	\$6,921	1.5	\$5.10
White mulberry	175	29	81	8	\$927	562	81	77	518	\$3,462	-1	-\$4	1,530	\$4,386	1.0	\$4.77
Honeylocust	682	112	349	31	\$3,708	3,470	506	483	3,306	\$21,648	-440	-\$1,650	8,499	\$23,705	5.6	\$4.64
Callery pear	1,028	177	581	46	\$5,769	6,008	870	828	5,643	\$37,267	-287	-\$1,078	14,893	\$41,959	11.7	\$3.96
White ash	528	84	270	24	\$2,862	2,437	359	343	2,362	\$15,311	0	\$0	6,408	\$18,173	5.4	\$3.71
Green ash	442	71	242	20	\$2,440	2,826	413	394	2,697	\$17,641	0	\$0	7,103	\$20,081	6.3	\$3.50
Littleleaf linden	276	48	152	12	\$1,540	1,480	216	205	1,405	\$9,221	-150	-\$562	3,645	\$10,199	3.5	\$3.20
Red maple	462	79	238	20	\$2,523	1,954	284	271	1,851	\$12,161	-170	-\$638	4,988	\$14,046	5.9	\$2.62
Hedge maple	66	11	36	3	\$368	359	52	50	339	\$2,233	-26	-\$98	891	\$2,503	1.2	\$2.38
Flowering crabapple	348	57	181	16	\$1,900	2,100	300	284	1,916	\$12,879	-2	-\$8	5,200	\$14,771	7.8	\$2.09
Other street trees	3,167	538	1,698	165	\$17,539	10,978	1,596	1,521	10,383	\$68,289	-2,261	-\$8,478	27,785	\$77,349	24.8	\$3.44
Columbus total	14,675	2,483	7,677	677	\$80,505	55,592	8,094	7,716	52,762	\$346,288	-7,215	-\$27,058	142,460	\$399,735	100.0	\$4.41



Table 10. Annual Aesthetic or Other Benefits of Columbus' Street Trees by Species Listed by Decreasing Benefit per Tree

Species	Total (\$)	% of Total Tree Numbers	% of Total \$	Avg. \$/tree
Silver maple	\$244,009	2.8	8.8	\$96.41
Freeman maple	\$484,740	7.4	17.6	\$71.90
Honeylocust	\$261,718	5.6	9.5	\$51.24
Hackberry	\$44,552	1.1	1.6	\$44.33
London planetree	\$76,024	2.3	2.8	\$36.13
Sweetgum	\$48,458	1.5	1.8	\$35.68
Sugar maple	\$194,611	6.2	7.1	\$34.48
Littleleaf linden	\$101,536	3.5	3.7	\$31.84
White ash	\$148,276	5.4	5.4	\$30.28
Norway maple	\$134,298	5.4	4.9	\$27.51
Green ash	\$151,768	6.3	5.5	\$26.45
Callery pear	\$258,116	11.7	9.4	\$24.35
Red maple	\$97,195	5.9	3.5	\$18.13
Hedge maple	\$19,015	1.2	0.7	\$18.06
White mulberry	\$8,175	1.0	0.3	\$8.89
Flowering crabapple	\$36,938	7.8	1.3	\$5.23
Other street trees	\$451,257	24.8	16.4	\$20.06
Columbus total	\$2,760,688	100.0	100.0	\$30.44

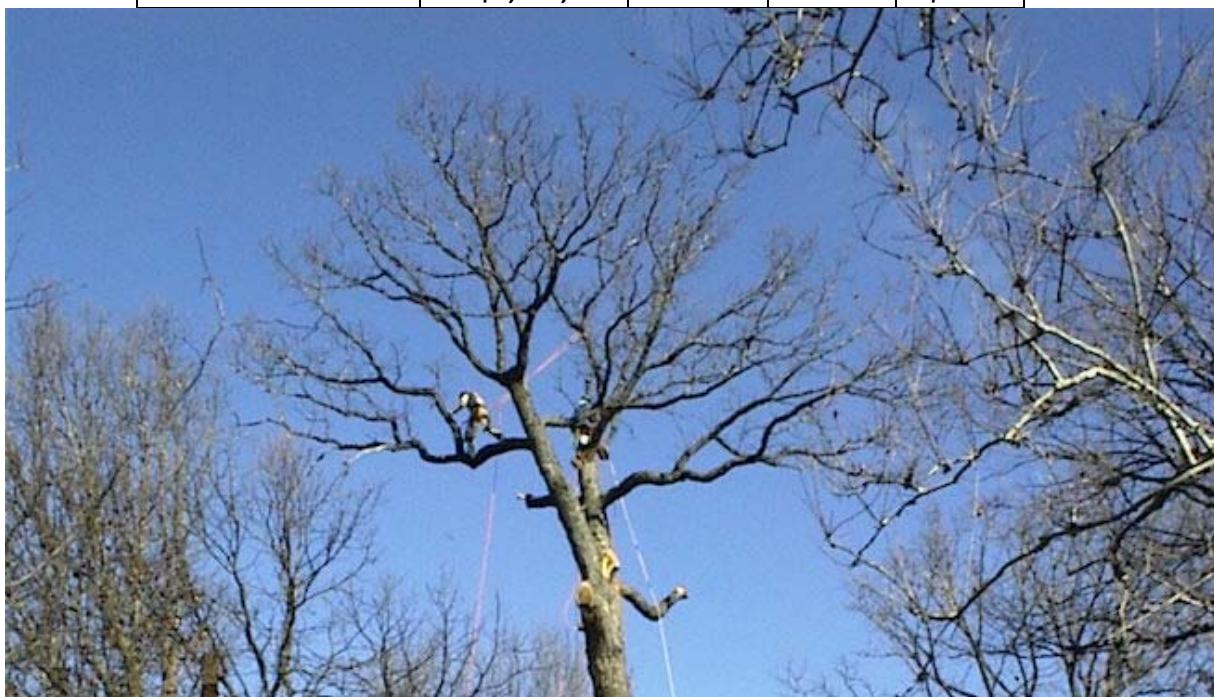


Table 11. Average Annual Benefits of Columbus Street Trees

Benefits	Total (\$)	\$/tree
Energy	\$2,449,170	\$27.00
CO ₂	\$332,473	\$3.67
Air Quality	\$399,735	\$4.41
Stormwater	\$2,753,127	\$30.36
Aesthetic/Other	\$2,760,688	\$30.44
Total Benefits	\$8,695,193	\$95.87

