An Analysis of Tree Benefits for Ohio Statehouse Grounds

By

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EXECUTIVE SUMMARY

A full inventory of public trees was undertaken by Ohio Division of Forestry's Urban Forester Lisa Bowers and Tamra Farley, Grounds Supervisor at the Statehouse. This information was then analyzed by The Ohio State University's School of Environment and Natural Resources. A total of 170 public trees were inventoried. A common bid price for this service is $3.00 per tree and thus the inventory represents a savings of $510 for Ohio's taxpayers over contracting for this service. Most importantly however, is that the Ohio Statehouse Grounds Committee now has a tree inventory that can be used to better manage the tree resource of the grounds. Benefits mentioned above do not include the value of the subsequent analysis and report.

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 Shade Tree Resource Analysis Tool for Urban forest Managers (STRATUM) 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.

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 20 percent should be from the same genera, and no more than 30 percent should be from the same family. On the statehouse grounds, crabapples (apples) are the only taxa that exceed the limit for specie and genus at 21% and they are smaller trees. Care should be taken to limit crabapples in future plantings. Ash plantings represent only 4 individuals or 2% of the ground's trees. Limited numbers and moderate size limit the impact of EAB at the Ohio Statehouse. One group that is could be used to replace the ash is the elms which would be an alternative choice for a large deciduous tree and is currently available in the nursery trade. Large trees produce markedly more environmental benefits than small ones as will be seen later.

Under ideal conditions tree numbers among smaller size classes should be stable and then decline as tree size increases and older trees die. Few larger trees are found on the Statehouse Ground's recently developed areas. (Tables 2 and 3). Fortunately, the state house is planting trees that will live longer and mature at larger sizes such as preferred by a resident preference survey in Toledo, OH. .

Trees are variable in size at present with less than 3% of the trees larger than 24-inch diameter. Importance values as detailed in (Table 4) show that the 11 larger red oaks have a similar importance value (a measure of canopy cover) as 33 smaller crabapples. This demonstrates the Statehouse's need for planting larger statured trees whenever possible as the importance value is a measure of the overall contribution of the species to the sum of environmental benefits delivered.

A major benefit of urban trees is their ability to intercept rainfall and reduce storm water runoff (Table 5). 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 the statehouse grounds

intercept more than 147,583 gallons of storm water annually at a savings to Columbus, OH of 4,000 dollars per year despite the relatively small size of the property.

Carbon sequestration, as reported here, represents the carbon removed from the air and stored in the ground's trees (Table 6). More than 374,712 pounds or 187 tons of carbon have been stored by the 174 trees over time. The ground's trees currently sequester and avoid nearly 71,922lbs of CO_2 yearly (Table 8) and would represent carbon credits worth $539.42 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 CO_2 benefits vary by species and size. A recent analysis in Xenia, Ohio showed that the community's 641 larger (average 18-24-inch) maples contributed $4.91 per tree vs. $3.19 per tree on the statehouse grounds.

Annual air quality savings (reduced ozone, nitrous and sulfur oxides as well as particulate matter) for statehouse trees is $686 (Table 9). This includes both direct savings ($106) from the trees and avoided pollution which is much greater at ($668). Avoided pollution is pollution not generated at power source because energy was not required (avoided) by the statehouse. The total annual air quality benefits are discounted by $88 for the volatile emissions from the trees themselves.

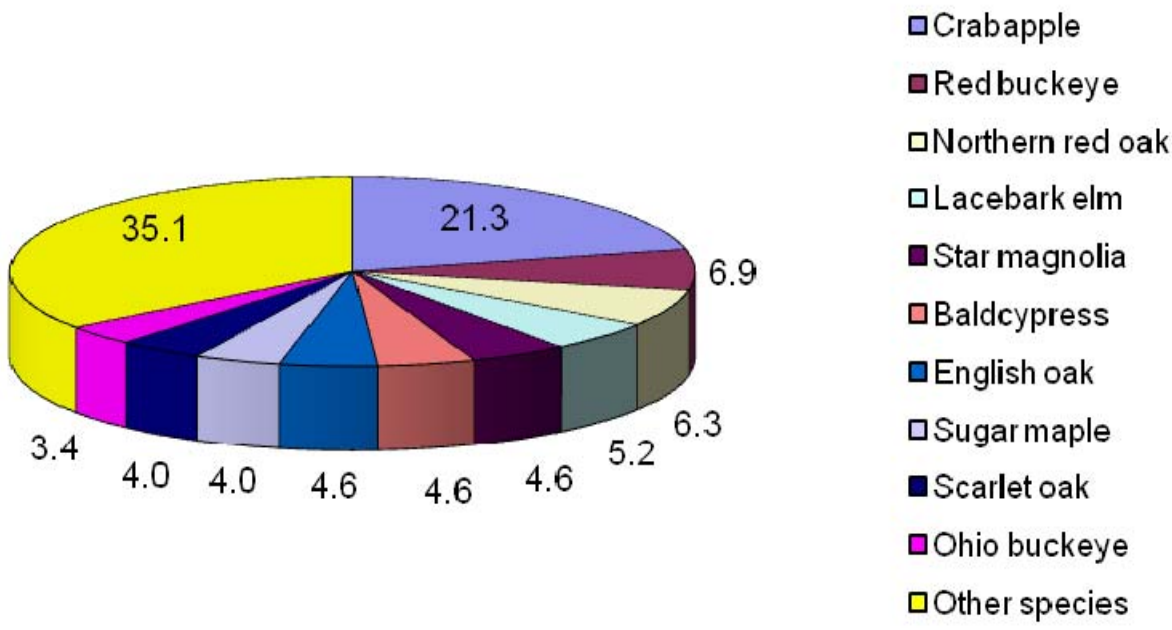
Energy savings by trees are exceptionally important in view of the citizenry's increasing concern over the nation's energy dependency. Planting trees in our communities may well be more cost effective than building power plants to as a conservation alternative to meeting our energy needs. Energy is saved by shading structures, evaporating water (evapotranspiration) and reducing wind speed around structures (Table 7). Ohio's statehouse saves $1,720 in electricity and $2,905 in natural gas for a total savings in excess of $4,625 or an average of $26.58 per tree.

Aesthetic and miscellaneous benefits from trees contribute $4,245 annually to the community in the form of increased property values and enhanced community identity among other things (Table 10). 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 the average statehouse tree contributes $81 per tree annually to the community (Table 12). Species vary in their annual benefits but mature size, longevity, and maintenance costs are but some of the factors determining annual benefits. Thus the statehouse's 174 trees contribute $14,095 per year. This would be well in excess of their maintenance and planting costs.

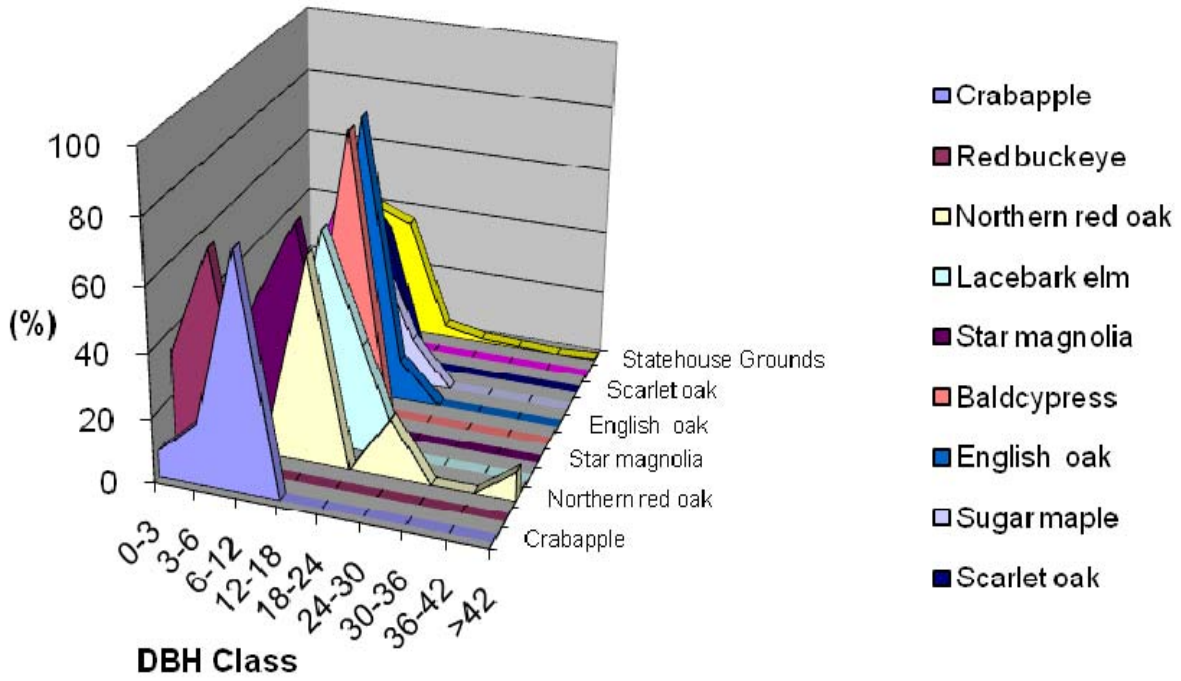
The Statehouse Building and Grounds' budget is $55,000.00 according to the Grounds Supervisor and the return that investment would be $14,095 from storm water abatement, CO2 avoidance and storage, energy savings, air quality, aesthetic benefits, and the like. This is a 25.6% return on investment. Even the moderate sized trees in on a moderate sized property are truly a contributing part of the community. Unlike most community infrastructure, tree benefits per tree continue to increase over a tree's lifetime. A recent study revealed that the larger trees in Xenia, OH contribute $102 annually per tree in benefits. As the trees grow we expect to reach a point where the trees will actually deliver more in benefits than they cost to maintain since costs of maintenance and installation are spread over the tree's lifetime.

Table 1. Species Distribution of Statehouse Ground's Trees



Species	Percent
Crabapple	21.3
Red buckeye	6.9
Northern red oak	6.3
Lacebark elm	5.2
Star magnolia	4.6
Baldcypress	4.6
English oak	4.6
Sugar maple	4.0
Scarlet oak	4.0
Ohio buckeye	3.5
Other species	35.1
Total	**100.00**

Table 2. Relative Age Distribution of the Top 10 Most Commonly Planted Tree Taxa on the Statehouse Grounds (%)



Common Name	DBH class (in)								
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42
Crabapple	8.1	18.9	73.0	0.0	0.0	0.0	0.0	0.0	0.0
Red buckeye	33.3	66.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern red oak	0.0	0.0	9.1	63.6	0.0	18.2	0.0	0.0	9.1
Lacebark elm	0.0	0.0	0.0	66.7	33.3	0.0	0.0	0.0	0.0
Star magnolia	0.0	37.5	62.5	0.0	0.0	0.0	0.0	0.0	0.0
Baldcypress	0.0	0.0	12.5	87.5	0.0	0.0	0.0	0.0	0.0
English oak	0.0	0.0	0.0	87.5	12.5	0.0	0.0	0.0	0.0
Sugar maple	0.0	0.0	42.9	42.9	14.3	0.0	0.0	0.0	0.0
Scarlet oak	0.0	0.0	57.1	42.9	0.0	0.0	0.0	0.0	0.0
Ohio buckeye	0.0	33.3	66.7	0.0	0.0	0.0	0.0	0.0	0.0
Statehouse Grounds	**4.6**	**11.5**	**41.4**	**36.8**	**3.4**	**1.1**	**0.6**	**0.0**	**0.6**

Table 3. Population of Statehouse Ground's 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	>42	Total
Broadleaf Deciduous Large (BDL)									
Quercus rubra	0	0	1	7	0	2	0	1	11
Ulmus parvifolia	0	0	0	6	3	0	0	0	9
Quercus robur	0	0	0	7	1	0	0	0	8
Acer saccharum	0	0	3	3	1	0	0	0	7
Quercus coccinea	0	0	4	3	0	0	0	0	7
Liquidambar styraciflua	0	0	0	6	0	0	0	0	6
Acer rubrum	0	0	4	0	0	0	0	0	4
Fraxinus americana	0	0	0	4	0	0	0	0	4
Zelkova serrata	0	0	0	4	0	0	0	0	4
Fagus sylvatica	0	0	1	1	0	0	0	0	2
Liriodendron tulipifera	0	0	0	2	0	0	0	0	2
Gymnocladus dioicus	0	0	0	0	1	0	0	0	1
Tilia americana	0	0	0	0	0	0	1	0	1
Ulmus americana	0	0	1	0	0	0	0	0	1
Subtotal	**0**	**0**	**14**	**43**	**6**	**2**	**1**	**1**	**67**
Broadleaf Deciduous Medium (BDM)									
Aesculus glabra	0	2	4	0	0	0	0	0	6
Tilia cordata	0	0	4	1	0	0	0	0	5
Betula nigra	0	0	0	3	0	0	0	0	3
Gleditsia triacanthos	0	0	0	3	0	0	0	0	3
Nyssa sylvatica	0	0	2	0	0	0	0	0	2
Subtotal	**0**	**2**	**10**	**7**	**0**	**0**	**0**	**0**	**19**
Broadleaf Deciduous Small (BDS)									
Malus species	3	7	27	0	0	0	0	0	37
Aesculus pavia	4	8	0	0	0	0	0	0	12
Crataegus phaenopyrum	0	0	5	1	0	0	0	0	6
Cornus mas	0	0	2	0	0	0	0	0	2
Prunus serrulata	1	0	1	0	0	0	0	0	2
Subtotal	**8**	**15**	**35**	**1**	**0**	**0**	**0**	**0**	**59**
Broadleaf Evergreen Medium (BEM)									
Magnolia virginiana	0	0	1	5	0	0	0	0	6
Subtotal	**0**	**0**	**1**	**5**	**0**	**0**	**0**	**0**	**6**
Broadleaf Evergreen Small (BES)									
Magnolia stellata	0	3	5	0	0	0	0	0	8
Subtotal	**0**	**3**	**5**	**0**	**0**	**0**	**0**	**0**	**8**

Table 3 cont. Population of Statehouse Ground's 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	>42	Total
Conifer Evergreen Large (CEL)									
Taxodium distichum	0	0	1	7	0	0	0	0	8
Pinus nigra	0	0	4	1	0	0	0	0	5
Total	**0**	**0**	**5**	**8**	**0**	**0**	**0**	**0**	**13**
Conifer Evergreen Medium (CEM)									
Picea pungens	0	0	2	0	0	0	0	0	2
Total	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**2**
Statehouse Ground's Totals	**8**	**20**	**72**	**64**	**6**	**2**	**1**	**1**	**174**

Table 4. Importance Values for the Statehouse Grounds Most Abundant Public Tree Species

Species	Number of Trees	% of Total Trees	Leaf Area (ft2)	% Total Leaf Area	Canopy Cover (ft2)	% Total Canopy Cover	Importance Value
Crabapple	37	21.3	6139	3.1	9229	10.6	11.7
Red buckeye	12	6.9	401	0.2	760	0.9	2.7
Northern red oak	11	6.3	27063	13.7	9072	10.4	10.2
Lacebark elm	9	5.2	20813	10.6	8830	10.2	8.6
Star magnolia	8	4.6	821	0.4	1425	1.6	2.2
Baldcypress	8	4.6	16521	8.4	3275	3.8	5.6
English oak	8	4.6	13951	7.1	5905	6.8	6.2
Sugar maple	7	4.0	12016	6.1	5025	5.8	5.3
Scarlet oak	7	4.0	7968	4.0	4471	5.1	4.4
Ohio buckeye	6	3.4	2133	1.1	1379	1.6	2.0
Washington hawthorn	6	3.4	1852	0.9	2255	2.6	2.3
Sweetgum	6	3.4	11036	5.6	5355	6.2	5.1
Sweetbay magnolia	6	3.4	10322	5.2	4043	4.6	4.4
Austrian pine	5	2.9	6018	3.1	1525	1.8	2.6
Littleleaf linden	5	2.9	3824	1.9	1830	2.1	2.3
Red maple	4	2.3	2737	1.4	1867	2.1	1.9
White ash	4	2.3	9671	4.9	3576	4.1	3.8
Zelkova	4	2.3	8143	4.1	3261	3.7	3.4
River birch	3	1.7	5371	2.7	1899	2.2	2.2
Honeylocust	3	1.7	6687	3.4	3297	3.8	3.0
Cornelian-cherry dogwood	2	1.1	436	0.2	632	0.7	0.7
European beech	2	1.1	2067	1.0	1099	1.3	1.2
Tulip tree	2	1.1	3679	1.9	1785	2.1	1.7
Blackgum	2	1.1	507	0.3	537	0.6	0.7
Blue spruce	2	1.1	1895	1.0	539	0.6	0.9
Kwanzan cherry	2	1.1	219	0.1	328	0.4	0.5
Other trees	3	1.7	14728	7.5	3774	4.3	4.5
Total	174	100.0	197019	100.0	86969	100.0	100.0

Table 5. Annual Storm Water Benefits of Statehouse Ground's Trees by Species

Species	Total Rainfall Interception (Gal)	Total ($)	% of Total Tree Numbers	% of Total $	Avg. $/tree
Crabapple	7644	$207	21.26	5.18	$5.60
Red buckeye	777	$21	6.90	0.53	$1.75
Northern red oak	17971	$487	6.32	12.18	$44.28
Lacebark elm	15093	$409	5.17	10.23	$45.45
Star magnolia	1678	$45	4.60	1.14	$5.68
Baldcypress	11365	$308	4.60	7.70	$38.50
English oak	10391	$282	4.60	7.04	$35.20
Sugar maple	8207	$222	4.02	5.56	$31.77
Scarlet oak	6450	$175	4.02	4.37	$24.97
Ohio buckeye	2030	$55	3.45	1.38	$9.17
Washington hawthorn	1989	$54	3.45	1.35	$8.98
Sweetgum	8268	$224	3.45	5.60	$37.35
Sweetbay magnolia	9553	$259	3.45	6.47	$43.15
Austrian pine	4566	$124	2.87	3.09	$24.75
Littleleaf linden	3102	$84	2.87	2.10	$16.81
Red maple	2501	$68	2.30	1.69	$16.95
White ash	6650	$180	2.30	4.51	$45.05
Zelkova	5563	$151	2.30	3.77	$37.69
River birch	3779	$102	1.72	2.56	$34.14
Honeylocust	4670	$127	1.72	3.16	$42.19
Cornelian-cherry dogwood	529	$14	1.15	0.36	$7.17
European beech	1722	$47	1.15	1.17	$23.33
Tulip tree	2756	$75	1.15	1.87	$37.35
Blackgum	603	$16	1.15	0.41	$8.17
Blue spruce	1511	$41	1.15	1.02	$20.47
Kwanzan cherry	272	$7	1.15	0.18	$3.68
Other street trees	7946	$215	1.72	5.38	$71.78
Statehouse Grounds Total	**147,583**	**$4,000**	**100.00**	**100.00**	**$22.99**

Table 6. Stored CO2 Benefits of Statehouse Ground's Trees by Species

Species	Total stored CO2 (lbs)	Total ($)	% of Total Tree Numbers	% of Total $	Avg. $/tree
Crabapple	25799	$194	21.26	6.89	$5.23
Red buckeye	1543	$12	6.90	0.41	$0.96
Northern red oak	71907	$539	6.32	19.19	$49.03
Lacebark elm	38451	$288	5.17	10.26	$32.04
Star magnolia	5073	$38	4.60	1.35	$4.76
Baldcypress	8448	$63	4.60	2.25	$7.92
English oak	33383	$250	4.60	8.91	$31.30
Sugar maple	22120	$166	4.02	5.90	$23.70
Scarlet oak	14884	$112	4.02	3.97	$15.95
Ohio buckeye	4472	$34	3.45	1.19	$5.59
Washington hawthorn	7577	$57	3.45	2.02	$9.47
Sweetgum	21570	$162	3.45	5.76	$26.96
Sweetbay magnolia	9736	$73	3.45	2.60	$12.17
Austrian pine	2255	$17	2.87	0.60	$3.38
Littleleaf linden	7694	$58	2.87	2.05	$11.54
Red maple	4403	$33	2.30	1.17	$8.26
White ash	14687	$110	2.30	3.92	$27.54
Zelkova	12149	$91	2.30	3.24	$22.78
River birch	10785	$81	1.72	2.88	$26.96
Honeylocust	9111	$68	1.72	2.43	$22.78
Cornelian-cherry dogwood	1816	$14	1.15	0.48	$6.81
European beech	4620	$35	1.15	1.23	$17.32
Tulip tree	7190	$54	1.15	1.92	$26.96
Blackgum	948	$7	1.15	0.25	$3.56
Blue spruce	568	$4	1.15	0.15	$2.13
Kwanzan cherry	922	$7	1.15	0.25	$3.46
Other street trees	14788	$245	1.72	8.70	$81.51
Statehouse Grounds Total	**374,712**	**$2,810**	**100.00**	**100.00**	**$16.15**

Table 7. Annual Energy Benefits of Statehouse Grounds Trees by Species ($/tree)

Species	Total Electricity (MWh)	Electricity ($)	Total Nat. Gas (Therms)	Natural Gas ($)	Total ($)	% of Total Tree Numbers	% of Total $	Avg. $/tree
Crabapple	2.16	$164.22	374.90	$367.41	$531.63	21.26	11.49	$14.37
Red buckeye	0.22	$16.40	33.06	$32.40	$48.79	6.90	1.05	$4.07
Northern red oak	2.24	$169.94	286.62	$280.89	$450.83	6.32	9.75	$40.98
Lacebark elm	2.22	$168.61	274.85	$269.35	$437.96	5.17	9.47	$48.66
Star magnolia	0.36	$27.23	57.76	$56.61	$83.84	4.60	1.81	$10.48
Baldcypress	0.96	$72.85	111.92	$109.68	$182.53	4.60	3.95	$22.82
English oak	1.59	$120.35	193.85	$189.98	$310.33	4.60	6.71	$38.79
Sugar maple	1.26	$95.95	161.94	$158.71	$254.65	4.02	5.51	$36.38
Scarlet oak	1.16	$88.40	148.43	$145.46	$233.87	4.02	5.06	$33.41
Ohio buckeye	0.37	$28.12	57.68	$56.53	$84.64	3.45	1.83	$14.11
Washington hawthorn	0.55	$42.05	88.83	$87.05	$129.10	3.45	2.79	$21.52
Sweetgum	1.47	$111.61	170.38	$166.97	$278.59	3.45	6.02	$46.43
Sweetbay magnolia	1.24	$94.19	133.77	$131.09	$225.28	3.45	4.87	$37.55
Austrian pine	0.38	$28.85	55.97	$54.85	$83.71	2.87	1.81	$16.74
Littleleaf linden	0.52	$39.43	73.77	$72.29	$111.72	2.87	2.42	$22.34
Red maple	0.44	$33.59	66.04	$64.72	$98.30	2.30	2.13	$24.58
White ash	1.07	$81.23	113.50	$111.23	$192.46	2.30	4.16	$48.12
Zelkova	1.00	$75.62	110.07	$107.87	$183.49	2.30	3.97	$45.87
River birch	0.60	$45.73	71.82	$70.38	$116.11	1.72	2.51	$38.70
Honeylocust	0.83	$63.23	100.08	$98.08	$161.31	1.72	3.49	$53.77
Cornelian-cherry dogwood	0.15	$11.24	25.66	$25.15	$36.39	1.15	0.79	$18.19
European beech	0.29	$22.09	37.49	$36.74	$58.83	1.15	1.27	$29.42
Tulip tree	0.49	$37.20	56.79	$55.66	$92.86	1.15	2.01	$46.43
Blackgum	0.13	$10.08	19.76	$19.37	$29.44	1.15	0.64	$14.72
Blue spruce	0.13	$9.61	20.39	$19.99	$29.60	1.15	0.64	$14.80
Kwanzan cherry	0.08	$5.87	13.46	$13.19	$19.06	1.15	0.41	$9.53
Other street trees	0.74	$56.41	105.42	$103.31	$159.72	1.72	3.45	$53.24
Statehouse Grounds Total	22.66	$1,720.10	2,964.23	$2,904.95	$4,625.05	100.00	100.00	$26.58

Table 8. Annual Carbon Dioxide Benefits of Statehouse Ground's Trees by Species

Species	Sequestered (lb)	Sequestered ($)	Decomp. Release (lb)	Maintenance Release (lb)	Total Release ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total ($)	% Total Tree Numbers	% of Total Dollars	Avg. $/tree
Crabapple	3366	$25.25	-124	-7.2	- 0.98	3629	$27.22	6864	$51.48	21.26	9.5	$1.39
Red buckeye	549	$4.12	-7	-2.3	- 0.07	362	$2.72	902	$6.77	6.90	1.3	$0.56
Northern red oak	2856	$21.42	-345	-2.1	- 2.60	3756	$28.17	6265	$46.99	6.32	8.7	$4.27
Lacebark elm	3340	$25.05	-185	-1.8	- 1.40	3726	$27.95	6880	$51.60	5.17	9.6	$5.73
Star magnolia	489	$3.67	-24	-1.6	- 0.19	602	$4.51	1065	$7.99	4.60	1.5	$1.00
Baldcypress	861	$6.46	-41	-1.6	- 0.32	1610	$12.07	2429	$18.22	4.60	3.4	$2.28
English oak	2351	$17.63	-160	-1.6	- 1.21	2660	$19.95	4849	$36.37	4.60	6.7	$4.55
Sugar maple	1928	$14.46	-106	-1.4	- 0.81	2120	$15.90	3940	$29.55	4.02	5.5	$4.22
Scarlet oak	2073	$15.54	-71	-1.4	- 0.55	1954	$14.65	3953	$29.65	4.02	5.5	$4.24
Ohio buckeye	1012	$7.59	-21	-1.2	- 0.17	621	$4.66	1611	$12.08	3.45	2.2	$2.01
Washington hawthorn	837	$6.28	-36	-1.2	- 0.28	929	$6.97	1729	$12.97	3.45	2.4	$2.16
Sweetgum	2838	$21.29	-104	-1.2	- 0.79	2467	$18.50	5200	$39.00	3.45	7.2	$6.50
Sweetbay magnolia	770	$5.78	-47	-1.2	- 0.36	2082	$15.61	2804	$21.03	3.45	3.9	$3.50
Austrian pine	245	$1.84	-11	-1.0	- 0.09	638	$4.78	871	$6.53	2.87	1.2	$1.31
Littleleaf linden	1407	$10.56	-37	-1.0	- 0.28	871	$6.53	2241	$16.81	2.87	3.1	$3.36
Red maple	661	$4.96	-21	-0.8	- 0.16	742	$5.57	1381	$10.36	2.30	1.9	$2.59
White ash	1975	$14.81	-70	-0.8	- 0.53	1795	$13.46	3698	$27.74	2.30	5.1	$6.93
Zelkova	886	$6.65	-58	-0.8	- 0.44	1671	$12.53	2498	$18.74	2.30	3.5	$4.68
River birch	1543	$11.57	-52	-0.6	- 0.39	1011	$7.58	2501	$18.76	1.72	3.5	$6.25
Honeylocust	1423	$10.67	-44	-0.6	- 0.33	1397	$10.48	2776	$20.82	1.72	3.9	$6.94
Cornelian-cherry dogwood	228	$1.71	-9	-0.4	- 0.07	248	$1.86	467	$3.50	1.15	0.6	$1.75
European beech	429	$3.22	-22	-0.4	- 0.17	488	$3.66	894	$6.71	1.15	1.2	$3.35
Tulip tree	946	$7.10	-35	-0.4	- 0.26	822	$6.17	1733	$13.00	1.15	2.4	$6.50
Blackgum	115	$0.86	-5	-0.4	- 0.04	223	$1.67	333	$2.50	1.15	0.5	$1.25
Blue spruce	77	$0.58	-3	-0.4	- 0.02	212	$1.59	287	$2.15	1.15	0.4	$1.07
Kwanzan cherry	123	$0.92	-4	-0.4	- 0.04	130	$0.97	248	$1.86	1.15	0.3	$0.93
Other street trees	2412	$18.09	-156	-0.6	- 1.18	1247	$9.35	3502	$26.26	1.72	4.9	$8.75
Statehouse Ground's Total	**35741**	**$268.06**	**-1799**	**-33.9**	**- 13.74**	**38014**	**$285.10**	**71922**	**$539.42**	**100**	**100**	**$3.10**

Table 9. Annual Air Quality Benefits of Statehouse Trees by Species

Species	Deposit. O3 (lb)	Deposit NO2 (lb)	Deposit PM10 (lb)	Deposit SO2 (lb)	Total Deposit ($)	Avoid NO2 (lb)	Avoid PM10 (lb)	Avoid VOC (lb)	Avoid SO2 (lb)	Total Avoid ($)	BVOC Emission (lb)	BVOC Emission ($)	Total (lb)	Total ($)	% Total Tree Num.	Avg. $/tree
Crabapple	1.3	0.2	0.7	0.1	$7.12	11.0	1.6	1.5	9.8	$66.94	0.0	-$0.03	26.1	$74.03	21.3	$2.00
Red buckeye	0.0	0.0	0.0	0.0	$0.22	1.1	0.2	0.1	1.0	$6.56	0.0	-$0.07	2.4	$6.70	6.9	$0.56
Northern red oak	3.6	0.6	1.8	0.2	$19.31	10.5	1.5	1.5	10.1	$65.88	-5.0	-$18.86	24.7	$66.34	6.3	$6.03
Lacebark elm	1.5	0.2	0.9	0.1	$8.31	10.3	1.5	1.5	10.1	$65.08	0.0	$0.00	26.0	$73.39	5.2	$8.15
Star magnolia	0.2	0.0	0.3	0.0	$1.68	1.8	0.3	0.2	1.6	$10.88	0.0	$0.00	4.4	$12.56	4.6	$1.57
Baldcypress	1.2	0.2	1.1	0.2	$8.31	4.4	0.7	0.6	4.3	$27.85	-4.0	-$14.95	8.7	$21.21	4.6	$2.65
English oak	1.9	0.3	1.0	0.1	$10.36	7.4	1.1	1.0	7.2	$46.36	-2.6	-$9.72	17.4	$47.00	4.6	$5.88
Sugar maple	0.8	0.1	0.5	0.0	$4.35	5.9	0.9	0.8	5.7	$37.20	-0.7	-$2.51	14.1	$39.04	4.0	$5.58
Scarlet oak	0.6	0.1	0.4	0.0	$3.59	5.5	0.8	0.8	5.3	$34.25	-1.4	-$5.39	12.0	$32.45	4.0	$4.64
Ohio buckeye	0.1	0.0	0.1	0.0	$0.91	1.8	0.3	0.2	1.7	$11.27	-0.1	-$0.39	4.2	$11.79	3.4	$1.97
Washington hawthorn	0.4	0.1	0.2	0.0	$2.38	2.8	0.4	0.4	2.5	$16.91	0.0	-$0.01	6.8	$19.28	3.4	$3.21
Sweetgum	0.9	0.2	0.6	0.0	$5.24	6.7	1.0	1.0	6.7	$42.70	-2.0	-$7.46	15.1	$40.48	3.4	$6.75
Sweetbay magnolia	0.5	0.1	0.7	0.1	$4.20	5.6	0.8	0.8	5.6	$35.52	-2.7	-$10.15	11.5	$29.57	3.4	$4.93
Austrian pine	0.5	0.1	0.4	0.1	$3.23	1.8	0.3	0.3	1.7	$11.41	-1.5	-$5.61	3.6	$9.03	2.9	$1.81
Littleleaf linden	0.3	0.1	0.2	0.0	$1.75	2.5	0.4	0.3	2.4	$15.57	-0.2	-$0.70	5.9	$16.61	2.9	$3.32
Red maple	0.3	0.1	0.2	0.0	$1.77	2.2	0.3	0.3	2.0	$13.32	-0.1	-$0.53	5.2	$14.56	2.3	$3.64
White ash	0.4	0.1	0.3	0.0	$2.54	4.8	0.7	0.7	4.9	$30.73	0.0	$0.00	11.9	$33.27	2.3	$8.32
Zelkova	0.3	0.1	0.2	0.0	$1.97	4.5	0.7	0.6	4.5	$28.77	0.0	$0.00	11.0	$30.74	2.3	$7.68
River birch	0.5	0.1	0.3	0.0	$2.66	2.8	0.4	0.4	2.7	$17.60	-0.3	-$0.99	6.9	$19.27	1.7	$6.42
Honeylocust	0.8	0.1	0.4	0.0	$4.12	3.9	0.6	0.5	3.8	$24.30	-0.5	-$1.72	9.6	$26.70	1.7	$8.90
Corneliancherry dogwood	0.1	0.0	0.1	0.0	$0.51	0.8	0.1	0.1	0.7	$4.58	0.0	$0.00	1.8	$5.09	1.1	$2.55
European beech	0.3	0.0	0.2	0.0	$1.55	1.4	0.2	0.2	1.3	$8.57	-0.4	-$1.44	3.2	$8.68	1.1	$4.34
Tulip tree	0.3	0.1	0.2	0.0	$1.75	2.2	0.3	0.3	2.2	$14.23	-0.7	-$2.49	5.0	$13.49	1.1	$6.75
Blackgum	0.1	0.0	0.0	0.0	$0.37	0.6	0.1	0.1	0.6	$3.99	0.0	-$0.11	1.5	$4.25	1.1	$2.12
Blue spruce	0.1	0.0	0.1	0.0	$0.98	0.6	0.1	0.1	0.6	$3.86	-0.5	-$1.77	1.2	$3.07	1.1	$1.53
Kwanzan cherry	0.0	0.0	0.0	0.0	$0.26	0.4	0.1	0.1	0.4	$2.40	0.0	$0.00	0.9	$2.65	1.1	$1.33
Other street trees	1.2	0.2	0.6	0.1	$6.63	3.6	0.5	0.5	3.4	$22.22	-0.9	-$3.53	9.1	$25.33	1.7	$8.44
Statehouse Grounds total	**18.3**	**3.2**	**11.4**	**1.0**	**$106.06**	**106.9**	**15.7**	**14.9**	**102.7**	**$668.95**	**-23.6**	**-$88.42**	**250.4**	**$686.60**	**100.0**	**$3.95**

Table 10. Annual Aesthetic or Other Benefits of Statehouse Trees by Species

Species	Total ($)	% Total Tree Numbers	% of Total $	Average $/tree
Crabapple	$187.37	21.3	4.4	$5.06
Red buckeye	$95.14	6.9	2.2	$7.93
Northern red oak	$232.52	6.3	5.5	$21.14
Lacebark elm	$311.84	5.2	7.3	$34.65
Star magnolia	$24.89	4.6	0.6	$3.11
Baldcypress	$241.64	4.6	5.7	$30.21
English oak	$196.06	4.6	4.6	$24.51
Sugar maple	$241.15	4.0	5.7	$34.45
Scarlet oak	$235.21	4.0	5.5	$33.60
Ohio buckeye	$145.84	3.5	3.4	$24.31
Washington hawthorn	$47.49	3.5	1.1	$7.92
Sweetgum	$285.32	3.5	6.7	$47.55
Sweetbay magnolia	$196.82	3.5	4.6	$32.80
Austrian pine	$109.56	2.9	2.6	$21.91
Littleleaf linden	$179.89	2.9	4.2	$35.98
Red maple	$119.35	2.3	2.8	$29.84
White ash	$254.97	2.3	6.0	$63.74
Zelkova	$147.16	2.3	3.5	$36.79
River birch	$165.28	1.7	3.9	$55.09
Honeylocust	$308.11	1.7	7.3	$102.70
Cornelian-cherry dogwood	$12.80	1.1	0.3	$6.40
European beech	$40.33	1.1	0.9	$20.16
Tulip tree	$95.11	1.1	2.2	$47.55
Blackgum	$13.55	1.1	0.3	$6.77
Blue spruce	$42.17	1.1	1.0	$21.08
Kwanzan cherry	$6.44	1.1	0.2	$3.22
Other street trees	$308.62	1.7	7.3	$102.87
Citywide total	**$4,244.63**	**100.0**	**100.0**	**$24.39**

Table 11. Average Annual Benefits of a Single Tree on the Statehouse Grounds by Species in Dollars per Tree

Species	Energy	CO2	Air Quality	Stormwater	Aesthetic/ Other	Total
Crabapple	$14.37	$1.39	$2.00	$5.60	$5.06	$28.42
Red buckeye	$4.07	$0.56	$0.56	$1.75	$7.93	$14.87
Northern red oak	$40.98	$4.27	$6.03	$44.28	$21.14	$116.70
Lacebark elm	$48.66	$5.73	$8.15	$45.45	$34.65	$142.65
Star magnolia	$10.48	$1.00	$1.57	$5.68	$3.11	$21.84
Baldcypress	$22.82	$2.28	$2.65	$38.50	$30.21	$96.45
English oak	$38.79	$4.55	$5.88	$35.20	$24.51	$108.92
Sugar maple	$36.38	$4.22	$5.58	$31.77	$34.45	$112.40
Scarlet oak	$33.41	$4.24	$4.64	$24.97	$33.60	$100.85
Ohio buckeye	$14.11	$2.01	$1.97	$9.17	$24.31	$51.56
Washington hawthorn	$21.52	$2.16	$3.21	$8.98	$7.92	$43.79
Sweetgum	$46.43	$6.50	$6.75	$37.35	$47.55	$144.58
Sweetbay magnolia	$37.55	$3.50	$4.93	$43.15	$32.80	$121.94
Austrian pine	$16.74	$1.31	$1.81	$24.75	$21.91	$66.51
Littleleaf linden	$22.34	$3.36	$3.32	$16.81	$35.98	$81.82
Red maple	$24.58	$2.59	$3.64	$16.95	$29.84	$77.59
White ash	$48.12	$6.93	$8.32	$45.05	$63.74	$172.17
Zelkova	$45.87	$4.68	$7.68	$37.69	$36.79	$132.72
River birch	$38.70	$6.25	$6.42	$34.14	$55.09	$140.61
Honeylocust	$53.77	$6.94	$8.90	$42.19	$102.70	$214.51
Cornelian-cherry dogwood	$18.19	$1.75	$2.55	$7.17	$6.40	$36.06
European beech	$29.42	$3.35	$4.34	$23.33	$20.16	$80.61
Tulip-tree	$46.43	$6.50	$6.75	$37.35	$47.55	$144.58
Blackgum	$14.72	$1.25	$2.12	$8.17	$6.77	$33.03
Blue spruce	$14.80	$1.07	$1.53	$20.47	$21.08	$58.96
Kwanzan cherry	$9.53	$0.93	$1.33	$3.68	$3.22	$18.69
Other street trees	$53.24	$8.75	$8.44	$71.78	$102.87	$245.09

Table 12. Average Annual Benefits of Trees on the Statehouse Grounds by Species in Dollars per Tree

Species	Energy	CO2	Air Quality	Stormwater	Aesthetic /Other	Total ($)	% of Total $
Crabapple	$532	$51	$74	$207	$187	$1,052	7.5
Red buckeye	$49	$7	$7	$21	$95	$178	1.3
Northern red oak	$451	$47	$66	$487	$233	$1,284	9.1
Lacebark elm	$438	$52	$73	$409	$312	$1,284	9.1
Star magnolia	$84	$8	$13	$45	$25	$175	1.2
Baldcypress	$183	$18	$21	$308	$242	$772	5.5
English oak	$310	$36	$47	$282	$196	$871	6.2
Sugar maple	$255	$30	$39	$222	$241	$787	5.6
Scarlet oak	$234	$30	$32	$175	$235	$706	5.0
Ohio buckeye	$85	$12	$12	$55	$146	$309	2.2
Washington hawthorn	$129	$13	$19	$54	$47	$263	1.9
Sweetgum	$279	$39	$40	$224	$285	$867	6.2
Sweetbay magnolia	$225	$21	$30	$259	$197	$732	5.2
Austrian pine	$84	$7	$9	$124	$110	$333	2.4
Littleleaf linden	$112	$17	$17	$84	$180	$409	2.9
Red maple	$98	$10	$15	$68	$119	$310	2.2
White ash	$192	$28	$33	$180	$255	$689	4.9
Zelkova	$183	$19	$31	$151	$147	$531	3.8
River birch	$116	$19	$19	$102	$165	$422	3.0
Honeylocust	$161	$21	$27	$127	$308	$644	4.6
Cornelian-cherry dogwood	$36	$4	$5	$14	$13	$72	0.5
European beech	$59	$7	$9	$47	$40	$161	1.1
Tulip tree	$93	$13	$13	$75	$95	$289	2.1
Blackgum	$29	$2	$4	$16	$14	$66	0.5
Blue spruce	$30	$2	$3	$41	$42	$118	0.8
Kwanzan cherry	$19	$2	$3	$7	$6	$37	0.3
Other street trees	$160	$26	$25	$215	$309	$735	5.2
Statehouse Ground's Total	**$4,625**	**$539**	**$687**	**$4,000**	**$4,245**	**$14,095**	**100.0**