i-Tree Ecosystem Analysis

Fairfax County

Urban Forest Effects and Values
August 2010

i-Tree

UFORE
Urban Forest Effects Model

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Fairfax County urban forest was conducted during 2009. Data from collected 201 field plots (out of total 300 plots) located throughout Fairfax County were analyzed using the Urban Forest Effects (UFORE) model developed by the U.S. Forest Service, Northern Research Station.

Key findings

- Number of trees: 20,900,000
- Most common species: Red maple, American beech, Tulip tree
- Percentage of trees less than 6" (15.2 cm) diameter: 60.4%
- Pollution removal: 4,670 tons/year ($21.7 million/year)
- Carbon storage: 3,879,000 tons ($80.2 million)
- Carbon sequestration: 218,000 tons/year ($4.51 million/year)
- Building energy savings: $11.9 million / year
- Avoided carbon emissions: $421 thousand / year
- Structural values: $29.2 billion

Ton: short ton (U.S.) (2,000 lbs)
Carbon storage: the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation
Carbon sequestration: the removal of carbon dioxide from the air by plants through photosynthesis
Structural value: value based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree)

For an overview of UFORE methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

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I. Tree Characteristics of the Urban Forest

The urban forest of Fairfax County has an estimated 20,900,000 trees. Trees that have diameters less than 6-inches constitute 60.4 percent of the population. The three most common species are Red maple (13.80 percent), American beech (12.00 percent), and Tulip tree (8.73 percent).

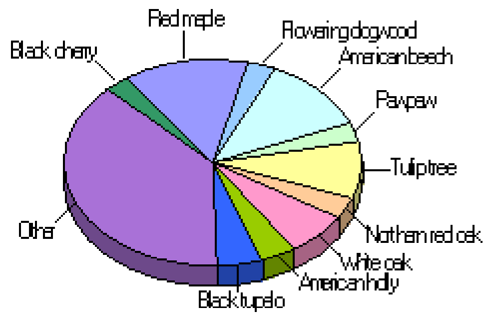

Figure 1. Tree species composition in Fairfax County

Among the land use categories, the highest tree densities occur in Misc Gov Park o followed by Other Gov. Faci and Water and other. The overall tree density in Fairfax County is 92.9 trees / acre (see Appendix III for comparable values from other cities).

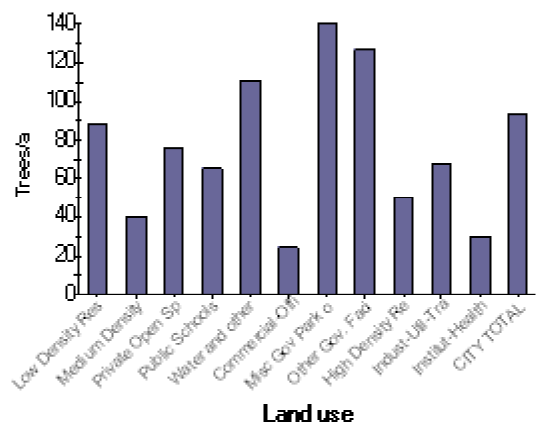

Figure 2. Number of trees in Fairfax County by land use

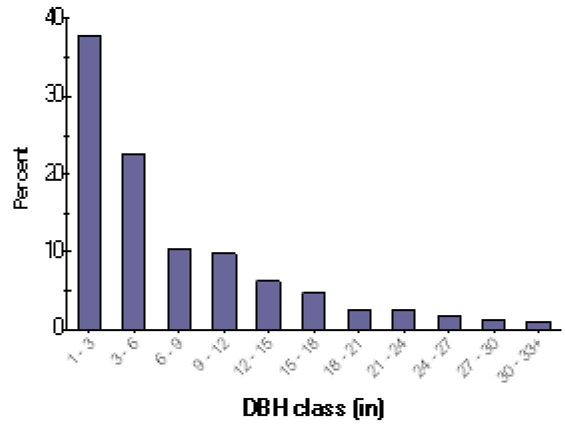

Figure 3. Percent of tree population by diameter class (DBH=stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. An increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Fairfax County, about 91 percent of the trees are from species native to North America, while 89 percent are native to the state or district. Species exotic to Virginia make up 9 percent of the population. Most exotic tree species have an origin from Asia (3.9 percent of the species).

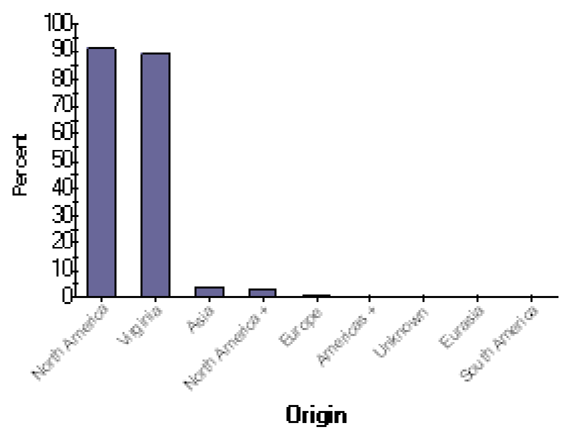

Figure 4. Percent of live trees by species origin

"North America +" = native to North America and at least one other continent except South America
"Americas +" = native to North and South America and at least one other continent

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. In Fairfax County, the three most dominant species in terms of leaf area are Tulip tree, American beech, and Red maple.

The 10 most important species are listed in the table below. Importance values (IV) are calculated as the sum of relative leaf area and relative composition.

Table 1. Most important species in Fairfax County

Common Name	*Percent Population*	*Percent Leaf Area*	*IV*
Tulip tree	8.7	23.8	32.5
Red maple	13.8	11.3	25.0
American beech	12.0	12.3	24.3
White oak	6.7	9.8	16.4
Northern red oak	3.4	5.1	8.5
Black tupelo	4.9	1.9	6.8
American holly	3.8	0.9	4.7
Black cherry	2.6	1.7	4.3
Hickory	2.1	2.1	4.2
Flowering dogwood	3.0	0.8	3.8

The two most dominant ground cover types are Duff/mulch (29.6 percent) and Grass (28 percent).

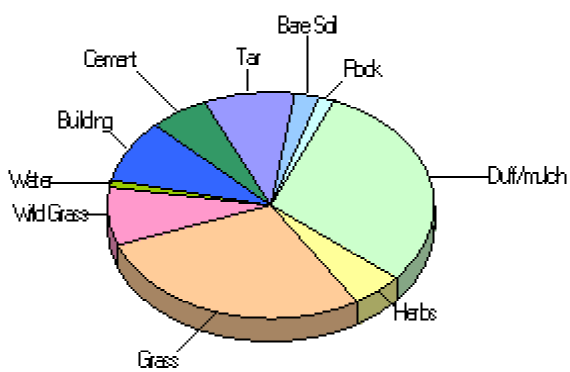

Figure 5. Percent ground cover in Fairfax County

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power plants. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation[1].

Pollution removal by trees and shrubs in Fairfax County was estimated using field data and recent pollution and weather data available. Pollution removal was greatest for ozone. It is estimated that trees and shrubs remove 4,670 tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 10 microns (PM10), and sulfur dioxide (SO2)) per year with an associated value of $21.7 million (based on estimated national median externality costs associated with pollutants[2]).

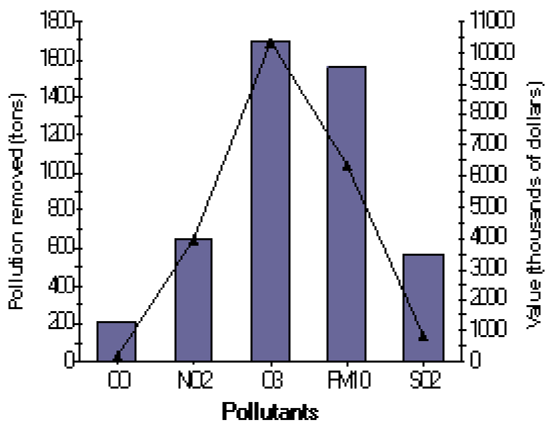

Figure 6. Pollution removal and associated value for trees in Fairfax County (line graph is value)

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power plants[3].

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Fairfax County trees is about 218,000 tons of carbon per year with an associated value of $4.51 million. Net carbon sequestration in the urban forest is about 193,000 tons.

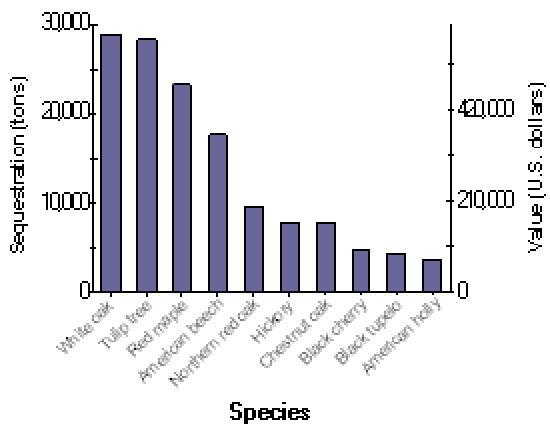

Figure 7. Carbon sequestration and value for species with greatest overall carbon sequestration in Fairfax County

As trees grow they store more carbon as wood. As trees die and decay, they release much of the stored carbon back to the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be lost if trees are allowed to die and decompose. Trees in Fairfax County are estimated to store 3,879,000 tons of carbon ($80.2 million). Of all the species sampled, Tulip tree stores the most carbon (approximately 18.6% of the total carbon stored. White oak sequesters the most carbon (14.9% of all sequestered carbon.)

V. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings[4].

Based on 2002 prices, trees in Fairfax County are estimated to reduce energy-related costs from residential buildings by $11.9 million annually. Trees also provide an additional $420,899 in value[5] by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of 22,900 tons of carbon emissions).

Table 2. Annual energy savings due to trees near residential buildings. Note: negative numbers indicate an increased energy use or carbon emission.

	Heating	*Cooling*	*Total*
MBTU[1]	387,875	n/a	387,875
MWH[2]	6,045	101,162	107,207
Carbon avoided (t)	7,574	15,281	22,855

[1]One million British Thermal Units
[2]Megawatt-hour

Table 3. Annual savings[1] (US $) in residential energy expenditure during heating and cooling seasons. Note: negative numbers indicate a cost due to increased energy use or carbon emission.

	Heating	*Cooling*	*Total*
MBTU[2]	2,321,373	n/a	2,321,373
MWH[3]	539,798	9,033,416	9,573,213
Carbon avoided (t)	139,483	281,415	420,899

[1]Based on state-wide energy costs for Virginia.
[2]One million British Thermal Units
[3]Megawatt-hour

VI. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees [6]. Annual functional values also tend to increase with increased number and size of healthy trees, and are usually on the order of several million dollars per year. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

<u>Structural values:</u>

- Structural value: $29.2 billion
- Carbon storage: $80.2 million

<u>Annual functional values:</u>

- Carbon sequestration: $4.51 million
- Pollution removal: $21.7 million
- Lower energy costs and carbon emission reductions: $12.3 million (Note: negative value indicates increased energy cost and carbon emission value)

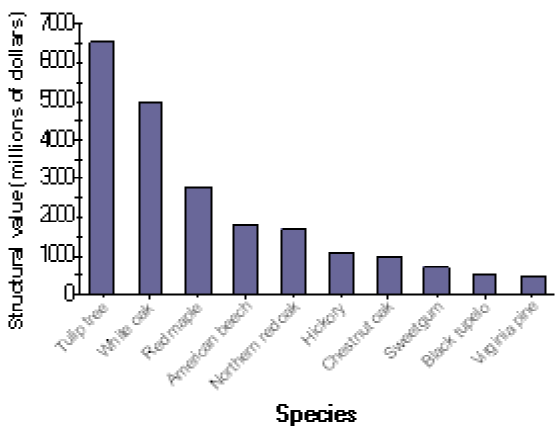

Figure 8. Structural value of the 10 most valuable tree species in Fairfax County

VII. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ. Four exotic pests were analyzed for their potential impact: Asian longhorned beetle (ALB), gypsy moth (GM), emerald ash borer (EAB), and Dutch elm disease (DED).

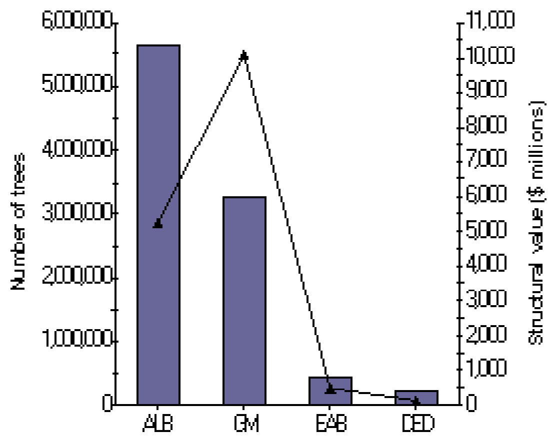

Figure 9. Number of susceptible Fairfax County trees and structural value by pest (line graph is structural value)

The Asian longhorned beetle (ALB) [7] is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 27 percent of the Fairfax County urban forest, which represents a loss of $5.25 billion in damage to the structure.

The gypsy moth (GM)[8] is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. This pest threatens 15.6 percent of the population, which represents a loss of $10.1 billion in structural value.

Emerald ash borer (EAB)[9] has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 2.1 percent of the population ($478 million in structural damage).

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED)[10]. Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Fairfax County could possibly lose 1.1 percent of its trees to this pest ($114 million in structural value).

Appendix I. UFORE Model and Field Measurements

UFORE is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects [5], including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by Asian longhorned beetles, emerald ash borers, gypsy moth, and Dutch elm disease.

In the field 0.10 acre plots were randomly distributed. Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Within each plot, typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings[11].

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations[12]. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models[13,14]. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature[15,16] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[17].

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described the literature[4] using distance and direction of trees from residential structures, tree height and tree condition data.

Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers[8], which uses tree species, diameter, condition and location information[18].

Appendix II. Relative Tree Effects

The urban forest in Fairfax County provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions[19], average passenger automobile emissions[20], and average household emissions[21].

Carbon storage is equivalent to:
- Amount of carbon emitted in Fairfax County in 225 days
- Annual carbon (C) emissions from 2,328,000 automobiles
- Annual C emissions from 1,169,000 single-family houses

Carbon monoxide removal is equivalent to:
- Annual carbon monoxide emissions from 821 automobiles
- Annual carbon monoxide emissions from 3,410 single-family houses

Nitrogen dioxide removal is equivalent to:
- Annual nitrogen dioxide emissions from 40,800 automobiles
- Annual nitrogen dioxide emissions from 27,200 single-family houses

Sulfur dioxide removal is equivalent to:
- Annual sulfur dioxide emissions from 828,000 automobiles
- Annual sulfur dioxide emissions from 13,900 single-family houses

Particulate matter less than 10 micron (PM10) removal is equivalent to:
- Annual PM10 emissions from 4,148,000 automobiles
- Annual PM10 emissions from 400,000 single-family houses

Annual carbon sequestration is equivalent to:
- Amount of carbon emitted in Fairfax County in 13 days
- Annual C emissions from 130,800 automobiles
- Annual C emissions from 65,700 single-family houses

Note: estimates above are partially based on the user-supplied information on human population total for study area

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the UFORE model.

I. City totals for trees

City	*% Tree Cove*	*Number of trees*	*Carbon storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution removal (tons/yr)*	*Pollution Value ($US)*
Calgary, Canada	7.2	11,889,000	445,000	21,422	326	1,611,000
Atlanta, GA	36.8	9,415,000	1,345,000	46,433	1,662	2,534,000
Toronto, Canada	20.5	7,542,000	992,000	40,345	1,212	6,105,000
New York, NY	21.0	5,212,000	1,351,000	42,283	1,677	8,071,000
Baltimore, MD	21.0	2,627,000	596,000	16,127	430	2,129,000
Philadelphia, PA	15.7	2,113,000	530,000	16,115	576	2,826,000
Washington, DC	28.6	1,928,000	523,000	16,148	418	1,956,000
Boston, MA	22.3	1,183,000	319,000	10,509	284	1,426,000
Woodbridge, NJ	29.5	986,000	160,000	5561.00	210	1,037,000
Minneapolis, MN	26.5	979,000	250,000	8,895	305	1,527,000
Syracuse, NY	23.1	876,000	173,000	5,425	109	268,000
Morgantown, WV	35.9	661,000	94,000	2,940	66	311,000
Moorestown, NJ	28.0	583,000	117,000	3,758	118	576,000
Jersey City, NJ	11.5	136,000	21,000	890	41	196,000
Freehold, NJ	34.4	48,000	20,000	545	21	133,000

II. Per acre values of tree effects

City	*No. of trees*	*Carbon storage (tons)*	*Carbon sequestration (lbs/yr)*	*Pollution removal (lbs/yr)*	*Pollution Value ($US)*
Calgary, Canada	66.7	2.5	0.120	3.6	9.0
Atlanta, GA	111.6	15.9	0.550	39.4	30.0
Toronto, Canada	48.3	6.4	0.258	15.6	39.1
New York, NY	26.4	6.8	0.214	17.0	40.9
Baltimore, MD	50.8	11.5	0.312	16.6	41.2
Philadelphia, PA	25.0	6.3	0.190	13.6	33.5
Washington, DC	49.0	13.3	0.410	21.2	49.7
Boston, MA	33.5	9.0	0.297	16.0	40.4
Woodbridge, NJ	66.5	10.8	0.375	28.4	70.0
Minneapolis, MN	26.2	6.7	0.238	16.4	40.9
Syracuse, NY	54.5	10.8	0.338	13.6	16.7
Morgantown, WV	119.7	17.0	0.532	23.8	56.3
Moorestown, NJ	62.0	12.5	0.400	25.2	61.3
Jersey City, NJ	14.3	2.2	0.094	8.6	20.7
Freehold, NJ	38.5	16.0	0.437	33.6	106.6

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are[22]:

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities[23]. Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include[24]:

Strategy	***Result***
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

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19. Total city carbon emissions were based on 2003 U.S. per capita carbon emissions - calculated as total U.S. carbon emissions (Energy Information Administration, 2003, Emissions of Greenhouse Gases in the United States 2003. http://www.eia.doe.gov/oiaf/1605/ggrpt/) divided by 2003 U.S. total population (www.census.gov). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

20. Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) divided by total miles driven in 2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, R.L., Wright, L.L., and Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO2 Emissions. Climatic Change 22:223-238.

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