Environmental Services Report

i-Tree Benefit Analysis for the Cities of Bellevue, Covington, Florence, Fort Thomas, and Newport, Kentucky

October, 2007

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A Division of The Davey Tree Expert Company

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Northern Kentucky Urban and Community Forestry Council

Kentucky Division of Forestry

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Introduction

The Northern Kentucky Urban and Community Forestry Council recognizes that the importance of the urban forest in the Northern Kentucky region of Boone, Kenton, and Campbell Counties is more than the amenity and aesthetic value of the trees. While the trees provide important amenity values, such as shade, screening, and landscape ornamentation, they also perform the following beneficial functions that can be translated into economic value:

- Removal of air pollutants, including ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter less than 10 microns (PM10).
- Decrease energy costs (*e.g.*, shading and cooling effects of trees).
- Stormwater mitigation.
- Carbon storage and sequestration.
- Increase property value.

This project focused on the quantifiable environmental services of public trees and the significant contributions they make in a community. Environmental services of the urban forest can now be estimated using existing inventory data or field sampling techniques, and then applying mathematical models to the data that have been developed over the past two decades by United States Department of Agriculture (USDA) Forest Service research scientists.

Collectively, the cost and benefit models and other software applications are known as the "*i*-Tree" suite of tools—an accessible set of computerized models and tools in the public domain. The science behind these models is sound and has been published in peer-reviewed journals.

Using *i*-Tree, city, county, park, and urban forest managers can accurately quantify the environmental service benefits urban forests provide, understand and balance the costs of managing an urban forest, and become better prepared for threats to the urban forest such as disease, exotic pests, and severe weather emergencies.

i-Tree's Urban Forest Effects Model (UFORE) was used to estimate the beneficial environmental functions of public trees in five cities in Northern Kentucky—Bellevue, Covington, Florence, Fort Thomas, and Newport. This study defines the public urban forest as all trees in the public areas (streets, parks, municipal buildings) as reported by the five Northern Kentucky cities. Existing public tree inventories in these communities were used to create the data set on which the ecosystem model UFORE was applied.

UFORE also provides information on the urban forest resource and its ecosystem services to improve urban forest management and bolster support of urban forestry programs. The ecosystem/environmental service results (*e.g.*, pollution removal) can be used to help determine the value of the resource to help support urban forest management budgets and integrate urban forestry programs in larger regulatory efforts to improve environmental quality in communities.

In addition to the benefits, the susceptibility of the public urban forest to pest infestations, such as Asian Longhorned Beetle (ALB), Emerald Ash Borer (EAB), and Gypsy Moth, was assessed using the tree inventories provided by the five cities.

Using the UFORE model, the benefits and threats to the urban forest can be quantified. With this information, urban forest managers, elected officials, and citizens can better understand and appreciate their urban forests, and, in turn, support better management of the resource to maximize future benefits and sustainability of public trees.

Methodology

This study used the Urban Forests Effects Model (UFORE) to characterize the public urban forest within the cities of Bellevue, Covington, Florence, Fort Thomas, and Newport in Boone, Campbell, and Kenton Counties in Northern Kentucky.

UFORE uses either existing inventory data or detailed, statistically based sampling and data collection protocols to estimate the structure and environmental effects and values of urban forests. This model is usually applied to all trees within a municipal or county boundary, but can be applied to a single tree or defined subsets of trees, such as street and park trees. This model was developed in the late 1990s by researchers at the USDA Forest Service's Northeastern Research Station in Syracuse, New York.

Existing street and public property tree inventories for cities of Bellevue, Covington, Florence, Fort Thomas, and Newport were used to provide tree input data for this UFORE assessment. No new data collection was performed for this study.

UFORE was used to perform the following analyses:

- Urban forest structure (*e.g.*, species composition, number of trees, diameter at breast height (DBH) distribution, tree health, leaf area, leaf and tree biomass, and species diversity).
- Pollution (*i.e.*, O_3, SO_2, NO_2, CO, and PM10) removed by the urban forest and associated percent of annual air quality improvement and economic value.
- Total carbon stored and net carbon annually sequestered by the urban forest and current economic value.
- Compensatory, or appraised, value of the public urban forest.
- Threat level of exotic insect pests to the urban forest.
- Future projections of air quality benefits if the urban forest population was increased by 5%, 10%, and 15%.

The UFORE model required data that were not available from the existing public tree inventories used for this study. Therefore, the following assumptions and estimations were used:

- Crown height: using tree species and diameter, crown heights were estimated for each tree.
- Crown width: using tree species and diameter, crown widths were estimated for each tree.
- Crown light exposure: the number of sides of a tree receiving sunlight from above, including the top, is determined.

- Percent canopy missing: using typical and actual crown shape of species, crown width, tree height, and height to the base of live crown, the percentage of canopy missing is estimated.

- Crown dieback: the percentage of crown dieback is defined as the amount of recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds to the trunk.

- Species rating: to calculate compensatory tree values, local tree species ratings are used.

- Canopy clearance to buildings and streets: using common and accepted clearance standards for streets, sidewalks, and buildings, canopy clearances were assigned to each tree.

- New tree planting rates: an estimate of 500 new large canopy trees per year for the entire study area was applied to the dataset.

Davey's senior urban foresters and *Certified Arborists* based these assumptions, and created the new UFORE-required and compatible datasets, on professional judgment and experience with tree physiology and standard urban forest management practices.

For more information on the UFORE field sampling procedures, please refer to http://www.ufore.org/UFORE_manual.doc. For detailed information on the methods used in the model to perform the UFORE analyses, please refer to www.ufore.org and the Frequently Asked Questions document in the Appendix of this report.

UFORE Analysis Results

Urban Forest Structure

Species Distribution

The species composition of public trees in the five cities of Bellevue, Covington, Florence, Fort Thomas, and Newport in Northern Kentucky urban forest is shown in Table 1.

Table 1. Species Composition of Northern Kentucky's Urban Forest Based on UFORE

Urban Forest Location	Dominant Species	Other Species Present	
Total Public Urban Forest **Reported 11,867 trees**	callery pear (20%) red maple (10%) honey-locust (6%)	silver maple sugar maple white ash green ash	hawthorn littleleaf linden sweetgum 139 other species were noted
Bellevue **Reported 710 trees**	callery pear (28%) cherry (13%) crabapple (9%)	silver maple red maple honey-locust sugar maple	green ash sweet gum Japanese lilac 46 other species were noted
Covington **Reported 3,928 trees**	callery pear (26%) honey-locust (9%) red maple (8%)	silver maple littleleaf linden white ash sugar maple	hawthorn sycamore Norway maple 74 other species were noted
Florence **Reported 3,269 trees**	callery pear (14%) sugar maple (5%) crabapple (5%)	Japanese zelkova red maple white ask field maple	silver maple Norway spruce pin oak 77 other species were noted
Fort Thomas **Reported 1,686 trees**	callery pear (17%) silver maple (9%) sugar maple (7%)	red maple sweetgum pin oak red oak	green ash Honey-locust Norway maple 73 other species were noted
Newport **Reported 2,274 trees**	red maple (24%) callery pear (18%) honey-locust (6%)	silver maple green ash black locust hawthorn	hackberry mulberry sugar maple 66 other species were noted

There are a reported 11,867 public trees in the combined five cities' public urban forests. The dominant species throughout the public urban forest is callery pear (*Pyrus calleryana*) followed by red maple (*Acer rubrum*) and honey-locust (*Gleditsia triacanthos*).

A total of 710 public trees were inventoried in Bellevue. The dominant tree species is also callery pear followed by cherry (*Prunus* spp.) and crabapple (*Malus* spp.).

A total of 3,928 public trees were inventoried in Covington. The dominant tree species is also callery pear followed by honey-locust and red maple.

A total of 3,269 public trees were inventoried in Florence. The dominant tree species is also callery pear followed by sugar maple (*Acer saccharum*) and crabapple.

A total of 1,686 public trees were inventoried in Fort Thomas. The dominant tree species is also callery pear followed by silver maple and sugar maple.

In the City of Newport, there are an estimated 2,274 public trees. The dominant species is red maple, callery pear, and honey-locust.

Size Class Distribution

A tree's function and value can also be measured by leaf area. Leaf surfaces slow rainwater runoff, remove pollutants from the air, and provide shade and cooling effects. The amount of leaf area correlates to tree size. The leaf area provided by many small trees may equal that of one large tree. Tree size is the diameter of the trunk measured at 4.5 feet from the ground and is referred to as diameter at breast height (DBH). As trees become larger and have more branches and leaves, the leaf area increases. A large tree, one that is typically greater than 12 inches DBH, removes more pollutants, provides more shade, and has much greater value than a small tree. The size class distributions and corresponding percentage of leaf area of the data sets are shown in Figures 1 through 5.

Overall, the public forest in Northern Kentucky is comprised primarily (76%) of small diameter trees (1 to 12 inches DBH) with only 24% of the population greater than 13 inches DBH. These smaller diameter trees contribute 40% of the existing leaf area. In contrast, public trees that are greater than 13 inches DBH contribute 60% of the total leaf area. Figure 1 graphically displays this information.

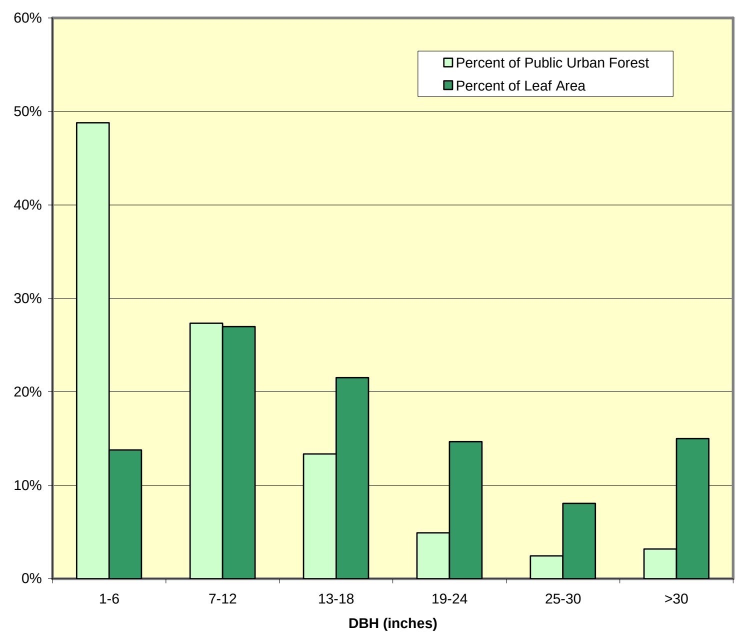


Figure 1. Collective Tree Size and Leaf Area Distribution in the Five Cities' Public Urban Forest

Bellevue

As displayed in Figure 2, the vast majority (81%) of inventoried trees in Bellevue are under 12 inches DBH. These trees contribute 50% of the existing leaf area. In contrast, 19% of public trees are larger than 13 inches DBH and these trees also contribute 50% of the total leaf area.

Photograph 1. Bellevue's urban forest is generally comprised of smaller diameter trees. Given proper maintenance and management, they will increase in size and provide greater benefits from the expanded canopy.

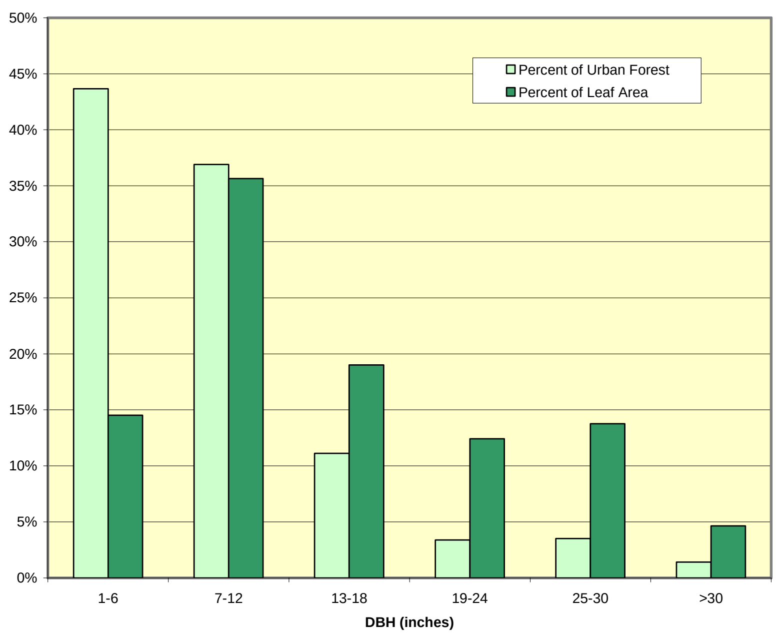
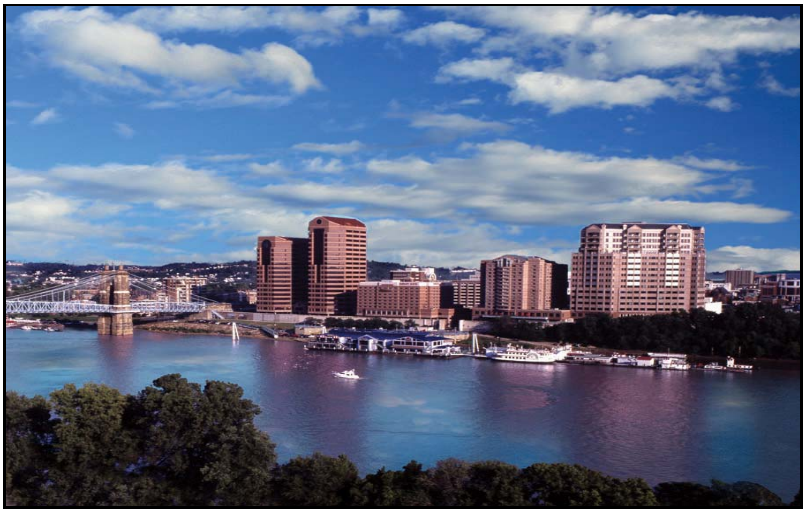


Figure 2. Size and Leaf Area Distribution in the Bellevue Public Urban Forest

Covington

In Covington, as displayed in Figure 3, a large majority (72%) of the inventoried trees are under 12 inches DBH. These smaller trees contribute 44% to the existing leaf area. While only 28% of the trees are larger than 13 inches DBH, these trees contribute 56% of the total leaf area.



Photograph 2. Covington's urban forest is very similar to Bellevue's in that it is generally comprised of smaller diameter trees. Given proper maintenance and management, they will increase in size and provide greater benefits from the expanded canopy.

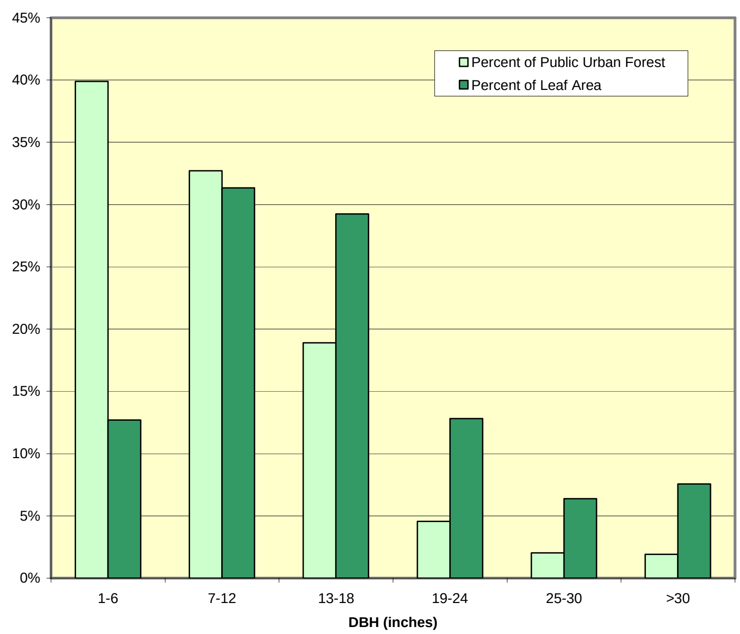


Figure 3. Size and Leaf Distribution in the Covington Public Urban Forest

Florence

Overall, the public forest in Florence is comprised primarily (87%) of small diameter trees (1 to 12 inches DBH) with only 13% of the population larger than 13 inches DBH. These larger trees contribute the greatest percentage of leaf area (58%), while the smaller trees contribute 42% of leaf area. Figure 4 graphically displays this information.

Photograph 3. Florence's urban forest is primarily comprised of smaller diameter trees. Proper maintenance and management of these trees is needed to ensure their continued growth.

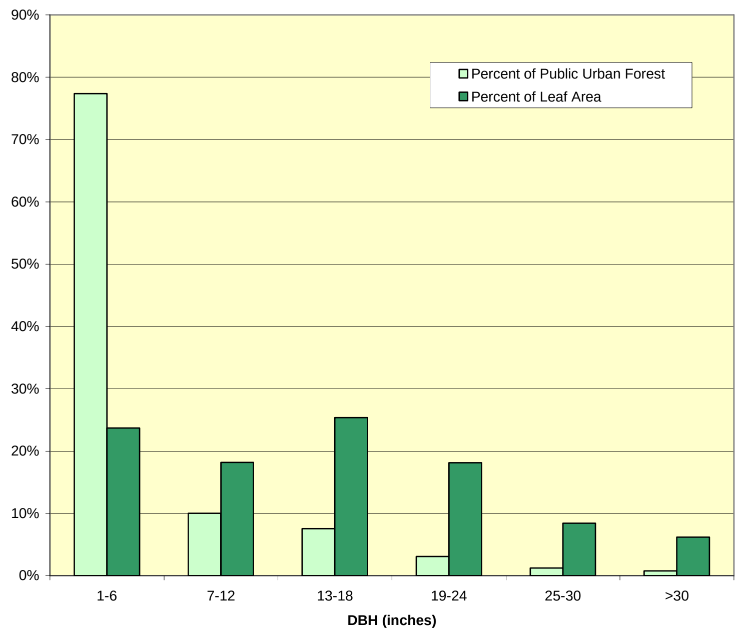


Figure 4. Size and Leaf Area Distribution in the Florence Public Urban Forest

Fort Thomas

Uniquely, Fort Thomas has an almost optimal distribution of trees within the diameter classes. The large trees over 13 inches DHB make up 40% of the total population and contribute 77% of the leaf area as seen in Figure 5.

Photograph 4. Fort Thomas' urban forest is comprised of a balanced distribution of tree sizes. Proper maintenance and management is essential for both the smaller and established trees to continue to sustain the benefits of the expanded canopy.

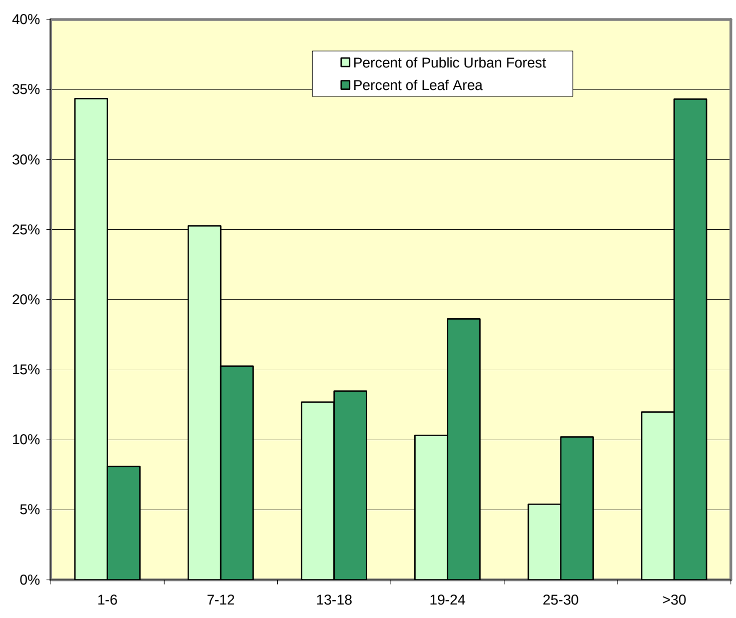


Figure 5. Size and Leaf Area Distribution in the Fort Thomas Public Urban Forest

Newport

As displayed in Figure 6, the vast majority (77%) of inventoried trees in Newport are under 12 inchs DBH. These trees contribute 52% of the existing leaf area. In contrast, 23% of public trees are greater than 13 inches DBH and contribute 48% of the total leaf area.

Photograph 5. Newport's urban forest is generally comprised of smaller diameter trees. With proper maintenance and management, they will increase in size and provide greater benefits from the expanded canopy.

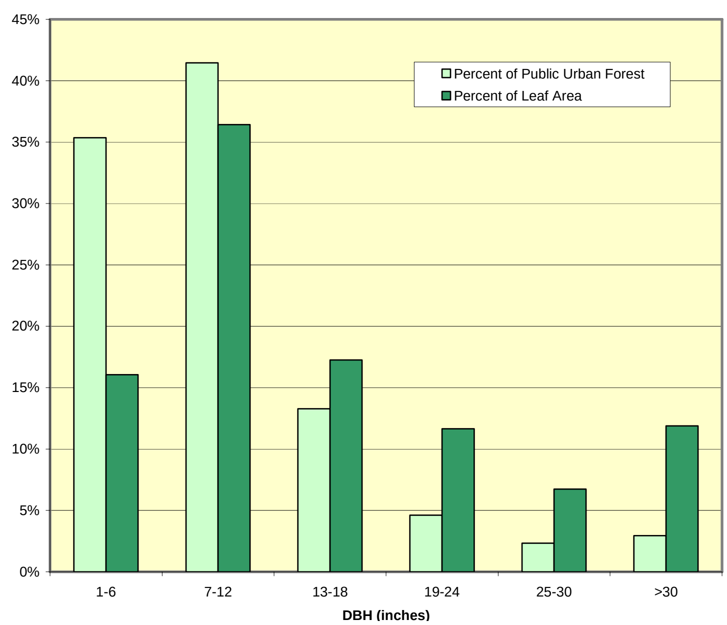


Figure 6. Size and Leaf Area Distribution in the Newport Public Urban Forest

Urban Forest Benefits

The public tree populations in Northern Kentucky communities are a valuable municipal resource. In order to quantify the benefits and assign a value to the cities' municipal forests that participated in this study, this section will focus on those attributes that can be defined.

Descriptions of the functions trees perform and the resulting dollar value to the Northern Kentucky communities are provided in this section. The sum of benefits for the Northern Kentucky public tree resource exceeds $17 million; that is a value of $1,450 per public tree. These benefits are realized on an annual basis. A description of the individual benefits and the benefit calculation is discussed below. The summary of benefits and their values to the region are provided in Table 2.

Table 2. Total Value of Benefits of Public Trees in Five Northern Kentucky Communities

Benefit	Value
CO	$89
O_3	$28,963
NO_2	$6,061
PM10	$7,692
SO_2	$1,829
Carbon	$69,745
Compensatory Value	$17,134,800
Total	**$17,249,179**
Total per Tree	**$1,450**

Air Pollution Removal

The air quality of the urban environment greatly benefits from the presence of trees. Trees absorb gaseous pollutants in the form of ozone (O_3) and nitrogen dioxide (NO_2). Reduction in ozone can also be attributed to the tree shading effect on hardscape surfaces and the transpiration process. Trees intercept volatile organic compounds (VOCs), sulfuric dioxide (SO_2), and small particulate matter (PM10), such as dust, ash, dirt, pollen, soot, and smoke, from the air. Trees decrease energy usage, thus reducing the emission of pollutants from power plants. The reduction in NO_2, SO_2, PM10, and VOCs due to reductions in energy usage is accounted for as air quality improvements.

The pollutants studied in relation to trees include carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), particulate matter less than 10 microns (PM10), and sulfur dioxide (SO_2). The results of air pollutant removal by trees in the Northern Kentucky database are shown in Table 3. The annual removal rate of each pollutant in pounds (lbs) is shown along with the monetary value of pollution removal using the defined average values for the United States for each pollutant.

Table 3. Annual Air Pollution Removal and Associated Economic Value

Sector	Sector	CO	O_3	NO_2	PM10	SO_2	Totals
Bellevue	**Quantity (lbs/year)**	10	479	100	194	124	907
	Value ($/year)	$5	$1,472	$308	$397	$93	$2,275
Covington	**Quantity (lbs/year)**	67	3,150	661	1,306	814	5,998
	Value ($/year)	$30	$9,688	$2,027	$2,676	$612	$15,033
Florence	**Quantity (lbs/year)**	28	1,316	276	462	340	2,422
	Value ($/year)	$12	$4,049	$847	$946	$256	$6,111
Fort Thomas	**Quantity (lbs/year)**	51	2,361	495	938	610	4,455
	Value ($/year)	$23	$7,261	$1,519	$1,921	$458	$11,182
Newport	**Quantity (lbs/year)**	45	2,111	443	854	546	3,999
	Value ($/year)	$20	$6,492	$1,359	$1,751	$410	$10,032
Total	**Quantity (lbs/year)**	202	9,417	1,975	3,754	2,433	17,781
	Value ($/year)	$89	$28,963	$6,061	$7,692	$1,829	$44,634

The inventoried public trees in Northern Kentucky contribute $44,634 annually in terms of air pollution removal, most of which is due to ozone removal.

Carbon Sequestration

Trees absorb carbon dioxide during the process of photosynthesis. Most of this carbon is sequestered or stored in the plant's woody tissue. The rate of carbon dioxide uptake was estimated by the UFORE analysis and the results are shown in Table 4.

The total public urban forest absorbs 85 tons of carbon annually and stores 3,059 tons of carbon. The Bellevue's public tree subset absorbs 5 tons annually and stores 137 tons of carbon, Covington's public trees absorb 30 tons annually and store 906 tons; Florence's public trees absorb12 tons annually and store 338 tons; Fort Thomas's public trees absorb 20 tons annually and store 1,113 tons; and Newport's public trees absorb 18 tons annually and store 565 tons of carbon.

These are net values that account for respiration and other natural carbon emissions due to metabolic activity of the trees. Certain species, such as oaks (*Quercus* spp.) and sweetgum (*Liquidamber styraciflua*), are higher emitters than other species.

Table 4. Annual Absorption and Storage of Carbon by the Public Urban Forest

	Carbon Absorption (tons/year)	Carbon Storage (tons)	Estimated Market Value*
Bellevue Trees	5	137	$3,124
Covington Trees	30	906	$20,657
Florence Trees	12	338	$7,706
Fort Thomas Trees	20	1,113	$25,376
Newport Trees	18	565	$12,882
Total	**85**	**3,059**	**$69,745**

*Based on a USFS estimated of $22.80/ton

Compensatory Value

Trees can be evaluated based on industry accepted appraisal methods that account for the species, size, condition, and location of the tree. These appraisal methods can be used for insurance claims against losses due to trespass, vandalism, and accidents that destroy or partially damage landscape trees. UFORE estimates the compensatory value for all the trees in the total public urban forest at $17,134,800—Bellevue's public trees at $814,300, Covington's public trees at $5,396,300, Florence's public trees at $2,145,900, Fort Thomas's public trees at $5,683,400, and Newport's public trees at $3,094,900. Table 5 summarizes the compensatory values for all five cities.

Table 5. Compensatory Value of the Urban Forest

Area	Compensatory Value
Bellevue Trees	$ 814,300
Covington Trees	$ 5,396,300
Florence Trees	$ 2,145,900
Fort Thomas Trees	$ 5,683,400
Newport Trees	$ 3,094,900
Total	**$ 17,134,800**

Urban Forest Insect Threats

The planted and natural forest cover is a large and distinctive component of the natural resources in Northern Kentucky. This study focused on the public tree component of the total urban forest, but in addition, there are many private landscape trees and naturally occurring woodlands that add to the total forest canopy cover. Collectively, the urban forest resources provide many environmental, educational, and aesthetic benefits to the region. However, this important resource is not without threats to its health and sustainability, and the sources of these threats are both natural and human-induced.

Among the most significant natural threats to Northern Kentucky's urban forest can be exotic insect infestations. Understanding this issue and planning appropriate management policies and practices is related to understanding the value of species diversity. The more diverse a public forest is, the less likely the impact of exotic insect infestation will be significant. The most prevalent and/or devastating of these threats will be briefly described followed by an analysis of each community's susceptibility to each pest.

Asian Longhorned Beetle

The Asian longhorned beetle (*Anoplophora glabripennis*) is classified as a pest in the United States and in their homeland of China. Longhorned beetles live for one year. They are 1 to 1.5 inches long, and their backs are black with white spots. The beetles' long antennae are black and white and extend up to 1 inch beyond the length of their bodies. According to the USDA, the beetles have the potential to destroy millions of hardwood trees.

Due to efforts that included quarantines and eradication, infestations have been confined to New York and Chicago. The spread of these pests is always a concern and certain steps are being taken to prevent this; however, the spread of infestations is still possible in other areas, including Northern Kentucky. Monitoring of the urban forest can provide early detection of an infestation, and allow a city to take action to prevent it from becoming severe and causing significant damage or requiring expensive treatment or tree removal. The species of trees that are most likely to host an ALB infestation are listed in Table 6.

Table 6. Tree Species Susceptible to Asian Longhorned Beetle

Common Name	Scientific Name	Common Name	Scientific Name
Acer negundo	box-elder	*Fraxinus pennsylvanica*	green ash
Acer platanoides	Norway maple	*Fraxinus* spp.	other ash species
Acer pseudoplatanus	sycamore maple	*Platanus acerifolia*	London planetree
Acer rubrum	red maple	*Platanus occidentalis*	American sycamore
Acer saccharinum	silver maple	*Platanus* spp.	other sycamore species
Acer saccharum	sugar maple	*Populus balsamifera*	balsam poplar
Acer x freemanii	Freeman's maple	*Populus deltoids*	eastern cotton-wood
Aesculus glabra	Ohio buckeye	*Populus nigra*	black poplar
Aesculus hippocastanum	horse chestnut	*Populus* spp.	other poplar species
Aesculus pavia	red buckeye	*Salix babylonica*	weeping willow
Albizia julibrissin	silk tree	*Salix matsudana*	corkscrew willow
Betula nigra	river birch	*Salix nigra*	black willow
Betula papyrifera	paper birch	*Salix* spp.	other willow species
Betula pendula	European white birch	*Sorbus Americana*	mountain ash
Betula spp.	other birch species	*Ulmus Americana*	American elm
Celtis occidentalis	common hackberry	*Ulmus parvifolia*	Chinese elm
Fraxinus americana	white ash	*Ulmus pumila*	Siberian elm
Fraxinus excelsior	European ash	*Ulmus rubra*	slippery elm
Fraxinus nigra	black ash	*Ulmus* spp.	other elm species

In the five cities' total public urban forest, there are 4,003 susceptible trees, which represents 34% of the total public tree population. Table 7 summarizes the threat of ALB collectively to Northern Kentucky and to the five cities individually.

Table 7. Susceptible Populations of Trees to Asian Longhorned Beetle

	Numbers of Trees Susceptible	Percentage of Population
Bellevue	160	23%
Covington	1,292	33%
Florence	847	26%
Fort Thomas	630	37%
Newport	1,074	47%
Total	**4,003**	**34%**

Potentially, all five cities could lose a significant percentage of the public urban forest if ALB were present in the region. Bellevue is the least susceptible with only 23% of the tree population at risk and Newport has the great susceptibility at 47%. These statistics indicate that routine monitoring and greater species diversity would be prudent preventive measures to guard against and buffer an ALB infestation.

Emerald Ash Borer

Emerald ash borer (EAB) (*Agrilus planipennis Fairmaire*) is an exotic beetle that has caused the death of millions of ash trees in Michigan, Ohio, and Indiana. The adults do little damage; however, the larvae feed on the inner bark of ash trees, disrupting the tree's ability to transport water and nutrients. Currently, there are no effective or cost-efficient preventive measures or treatment for EAB infestations, especially for large forest tracts.

Northern Kentucky has a high population of ash species that would be decimated if the EAB became established. It is recommended that the region cooperate with the Kentucky Division of Forestry to monitor for the presence of EAB, and become educated on the steps necessary should EAB be confirmed in the region.

As of May 23, 2007, the Ohio Department of Agriculture has placed Hamilton County, Ohio under EAB quarantine, marking this as Ohio's southern-most point of infestation. The proximity of this infestation to Northern Kentucky makes EAB a significant cause for concern for the future health, condition, and extent of Northern Kentucky's forests.

The species that are susceptible to EAB infestation include: white ash (*Fraxinus americana*); European ash (*Fraxinus excelsior*); black ash (*Fraxinus nigra*); green ash (*Fraxinus pennsylvanica*); and other ash species (*Fraxinus* spp.). In the total public urban forest, there are 706 ash trees, which represent 6% of the tree population. Table 8 summarizes the threat of EAB to the five cities individually and the collective urban forest.

Table 8. Susceptible Populations of Trees to Emerald Ash Borer

	Numbers of Trees Susceptible	Percentage of Population
Bellevue	24	3%
Covington	226	6%
Florence	201	6%
Fort Thomas	106	6%
Newport	149	7%
Total	**706**	**6%**

The analysis indicates that all of the communities have a relatively low susceptibility (3% to 7%) to EAB; other communities in the Tri-State region report ash as comprising 10-20% of their public forests. Considering the high percentage of ash in Northern Kentucky on non-public property, such as residential landscapes and private woodlands, monitoring for EAB and taking immediate and appropriate action if detected are recommended management steps.

European Gypsy Moth

The European gypsy moth (*Lymantria dispar* L.) has been well established in the northeast United States since 1987. It is one of the most damaging pests of hardwood forests and urban landscapes, defoliating a million or more forested acres annually. This insect has spread into parts of West Virginia and Ohio, but has not yet become established in Kentucky. Its presence has been confirmed and is being treated in Cincinnati.

Gypsy moth caterpillars feed on approximately 500 different plant species. Older larvae will sometimes eat several species of hardwood that the younger larvae will avoid. However, when food is scarce, the larvae will feed on almost any vegetation.

The European gypsy moth repeatedly defoliates trees. Healthy trees can withstand one or two defoliations, but repeated defoliations by gypsy moths weaken trees to the point of death. There are effective control measures for this insect, and it is recommended that the region work with the Kentucky Division of Forestry to coordinate monitoring traps to determine the presence and population levels of gypsy moth in Northern Kentucky. The species of trees susceptible to European gypsy moth infestation are provided in Table 9.

Table 9. Tree Species Susceptible to European Gypsy Moth

Common Name	Scientific Name	Common Name	Scientific Name
Acer campestre	hedge maple	*Pinus strobus*	eastern white pine
Acer ginnala	Amur maple	*Pinus sylvestris*	scotch pine
Acer griseum	paperbark maple	*Pinus virginiana*	Virginia pine
Acer negundo	box-elder	*Populus balsamifera*	balsam poplar
Acer nigrum	black maple	*Populus deltoids*	eastern cotton-wood
Acer palmatum	Japanese maple	*Populus nigra*	black poplar
Acer platanoides	Norway maple	*Populus* spp.	other poplar species
Acer pseudoplatanus	sycamore maple	*Prunus cerasifera*	cherry plum
Acer rubrum	red maple	*Prunus serotina*	black cherry
Acer saccharinum	silver maple	*Prunus serrulata*	Japanese flowering cherry
Acer saccharum	sugar maple	*Prunus subhirtella*	winter-flowering cherry
Acer truncatum	Shantung maple	*Prunus virginiana*	choke cherry
Acer x freemanii	Freeman's maple	*Prunus* spp.	other cherry species
Acer spp.	other maple species	*Quercus acutissima*	sawtooth oak
Alnus incana	speckled alder	*Quercus alba*	white oak
Betula pendula	European white birch	*Quercus bicolor*	swamp white oak
Carya cordiformis	bitter-nut hickory	*Quercus coccinea*	scarlet oak
Carya glabra	sweet pignut hickory	*Quercus imbricaria*	shingle oak
Carya ovata	shag-bark hickory	*Quercus muehlenbergii*	Chinquapin oak
Carya spp.	other hickory species	*Quercus nigra*	water oak
Crataegus phaenopyrum	Washington hawthorn	*Quercus palustris*	pin oak
Crataegus viridis	green hawthorn	*Quercus phellos*	willow oak
Crataegus spp.	other hawthorn species	*Quercus prinus*	rock chestnut oak
Liquidambar styraciflua	sweetgum	*Quercus robur*	English oak
Malus pumila	paradise apple	*Quercus rubra*	northern red oak
Malus spp.	other crabapple species	*Quercus velutina*	black oak
Picea abies	Norway spruce	*Salix babylonica*	weeping willow
Picea glauca	white spruce	*Salix matsudana*	corkscrew willow
Picea omorika	Serbian spruce	*Salix nigra*	black willow
Picea pungens	blue spruce	*Salix* spp.	other willow species
Picea spp.	other spruce species	*Tilia americana*	American basswood
Pinus mugo	swiss mountain pine	*Tilia cordata*	littleleaf linden
Pinus nigra	Austrain pine	*Tilia tomentosa*	silverleaf linden
Pinus resinosa	red pine	*Tsuga canadensis*	eastern hemlock

In the total public urban forest, there are 5,722 susceptible trees, which represent 48% of the tree population. Table 10 summarizes the threat to European gypsy moth to the five cities individually and the collective public tree population.

Table 10. Susceptible Populations of Trees to European Gypsy Moth

	Numbers of Trees Susceptible	Percentage of Population
Bellevue	336	47%
Covington	1,762	45%
Florence	1,563	48%
Fort Thomas	939	56%
Newport	1,122	49%
Total	**5,722**	**48%**

This exotic pest is a threat to approximately 50% of each city's public tree population. These statistics indicate that each city should routinely monitor for gypsy moth and take proactive measures if detected. It has been the experience in Cincinnati and other communities that early detection allows for quick and targeted responses that are highly effective in protecting the greater urban forest.

Urban Forest Benefits Based on Growth Projections

The previous sections of this report provided information on the current services, benefits, and values of the existing tree population in the select cities of Northern Kentucky. The combined public tree population, based on its current size, canopy, species composition, and other structural components, provides over $17 million in annual benefits.

A natural question to ask next is, "What would be the scope of the benefits if the current urban forest was increased?" The intriguing answers to this question may provide justification and motivation to support greater planting efforts in Northern Kentucky cities and counties.

UFORE uses a growth projection model that can be applied to the existing tree population dataset to reflect various increases in canopy cover for future projection purposes and to calculate the corresponding benefits. For this project, it was determined that scenarios of 5%, 10%, and 20% increases in street tree canopy cover will be used for demonstrating the increased environmental services and benefits with increased future canopy cover.

Growth Projection Methodology and Assumptions

The U. S. Forest Service's UFORE growth model is referred to as the UFORE Population Projector. It begins with an existing tree population and canopy cover, and then adds a set number of new trees planted annually over a period of years until the target percent of increased canopy is reached. Knowing that tree populations are dynamic (trees grow and die over time), these assumptions are made:

- Average growth rate of the tree population is 0.34 inches per year.
- Average mortality rate of the tree population is 3.0% per year.
- Current canopy cover is 4.3% of the study area.
- Increased canopy targets will be achieved over a 100-year period.

Not all benefits previously reported for the existing tree population are duplicated when using the UFORE Population Projector. Those that are calculated relate primarily to air quality services and benefits. Those that can be reported and value-quantified are summarized as:

- Carbon Storage.
- Avoided Carbon Emissions.
- Selected Components of Air Pollution Removal.

The following sections will present the projected benefits if the Northern Kentucky urban forest, as defined by this study, is increased by 5%, 10%, and 15%.

Results of a 5% Canopy Cover Increase

If the current canopy coverage is increased from 4.3% to 9.3%, there is a significant increase in air quality benefits. Table 11 shows a 200% increase in the amount and value of carbon storage and air pollution removal. On average, increasing tree canopy coverage 5% will result in a 150% increase in the annual value of air quality services.

Table 11. Comparison of Selected Benefits of a 5% Canopy Increase

	Carbon Storage (tons/year)	Estimated Market Value	Avoided Carbon Emissions (tC/year)	Estimated Market Value	Air Pollution Removal (tons/year)	Estimated Market Value	Total Value
Existing Public Trees	3,058	$69,722	N/A	N/A	2.9	$14,561	$84,283
5% Canopy Increase (at end year)	6,160	$139,871	58	$1,323	6.3	$31,621	$172,815
Average per year	4,507	$102, 759	32	$730	4.9	$24,669	$128,158

Figures 7 and 8 are UFORE generated charts graphically displaying the increasing carbon storage quantities and air pollution values over time as the expanded urban tree canopy grows and matures to 9.3%.

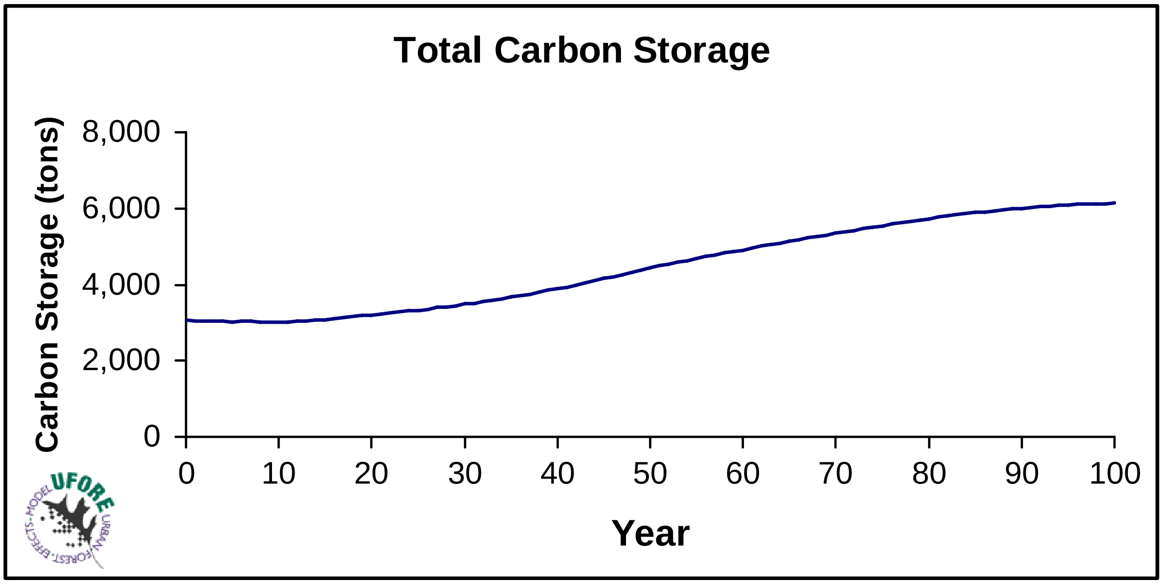


Figure 7. Total Carbon Storage Based on an Increase of 5% in the Urban Canopy Coverage

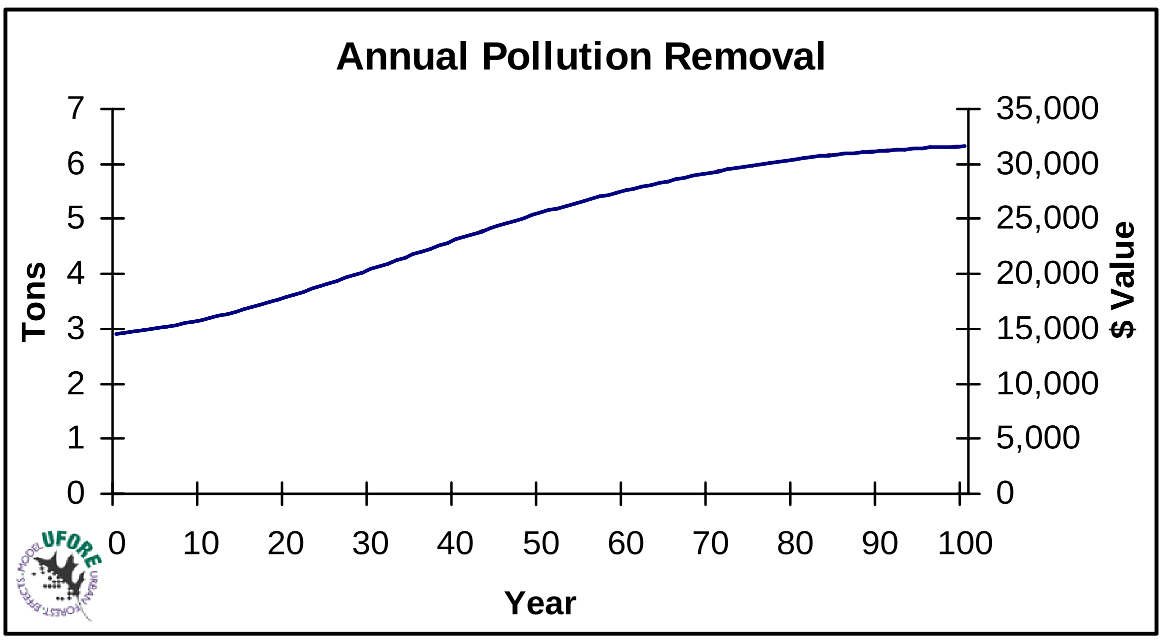


Figure 8. Annual Pollution Removal Based on an Increase of 5% in the Urban Canopy Coverage

Results of a 10% Canopy Cover Increase

If the current canopy coverage is increased from 4.3% to 14.3%, there is a significant increase in air quality benefits. Table 12 shows a 300% increase in the amount and value of carbon storage and air pollution removal. On average, increasing tree canopy coverage 10% will result in a 190% increase in the annual value of air quality services.

Table 12. Comparison of Selected Benefits of a 10% Canopy Increase

	Carbon Storage (tons/year)	Estimated Market Value	Avoided Carbon Emissions (tC/year)	Estimated Market Value	Air Pollution Removal (tons/year)	Estimated Market Value	Total Value
Existing Public Trees	3,058	$69,722	N/A	N/A	2.9	$14,561	$84,283
10% Canopy Increase (at end year)	9,347	$211,345	88	$2,006	9.7	$48,676	$262,027
Average per year	5,835	$133,017	49	$1,116	6.7	$33,584	$167,717

Figures 9 and 10 are UFORE generated charts graphically displaying the increasing carbon storage quantities and air pollution values over time as the expanded urban tree canopy grows and matures to 14.3%.

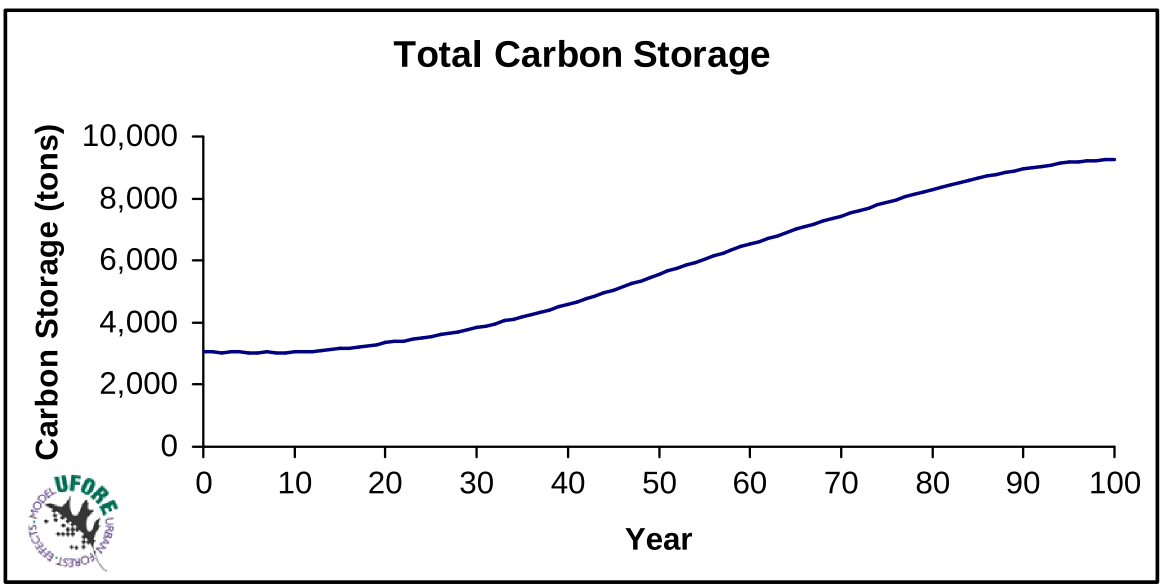


Figure 9. Total Carbon Storage Based on an Increase of 10% in the Urban Canopy Coverage

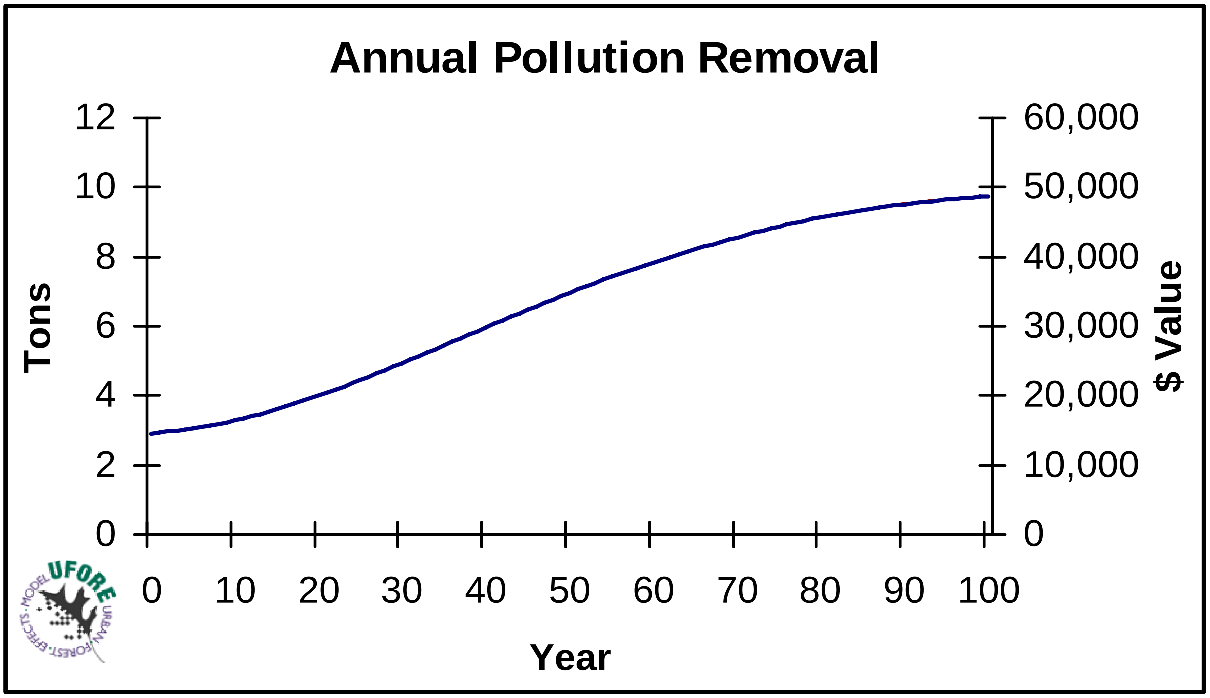


Figure 10. Annual Pollution Removal Based on an Increase of 10% in the Urban Canopy Coverage

Results of a 15% Canopy Cover Increase

If the current canopy coverage is increased from 4.3% to 19.3%, there is a significant increase in air quality benefits. Table 13 shows a 400% increase in the amount and value of carbon storage and air pollution removal. On average, increasing tree canopy coverage 15% will result in a 230% increase in the annual value of air quality services.

Table 13. Comparison of Selected Benefits of a 15% Canopy Increase

	Carbon Storage (tons/year)	Estimated Market Value	Avoided Carbon Emissions (tC/year)	Estimated Market Value	Air Pollution Removal (tons/year)	Estimated Market Value	Total Value
Existing Public Trees	3,058	$69,722	N/A	N/A	2.9	$14,561	$84,283
15% Canopy Increase (at end year)	12,534	$282,820	116	$2,652	13.1	$65,731	$351,203
Average per year	7,163	$163,275	65	$1,487	8.5	$42,500	$207,262

Figures 11 and 12 are UFORE generated charts graphically displaying the increasing carbon storage quantities and air pollution values over time as the expanded urban tree canopy grows and matures to 19.3%.

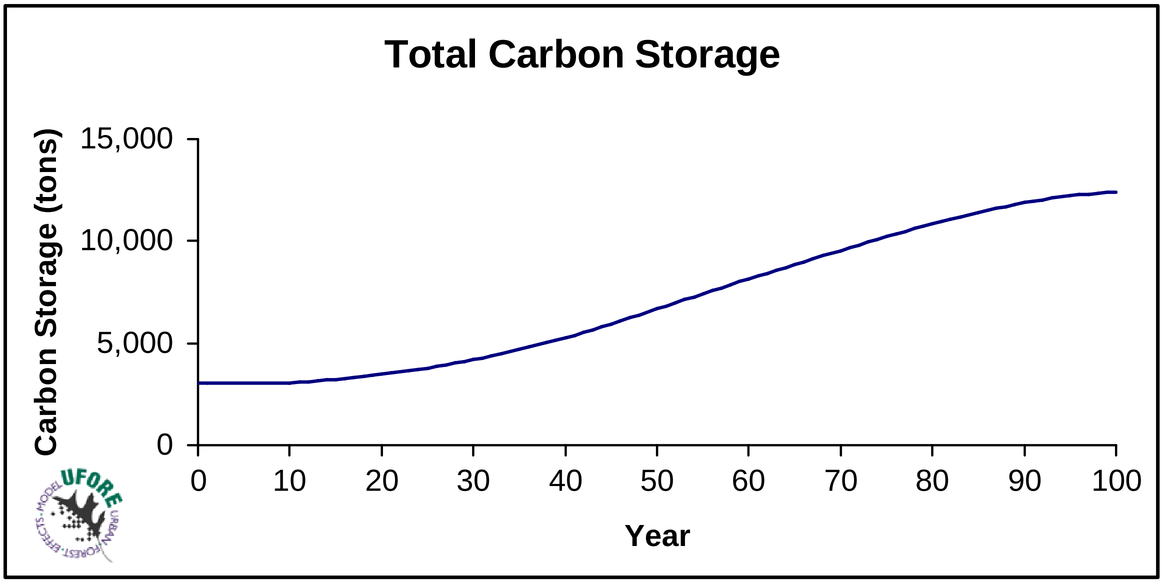


Figure 11. Total Carbon Storage Based on an Increase of 15% in the Urban Canopy Coverage

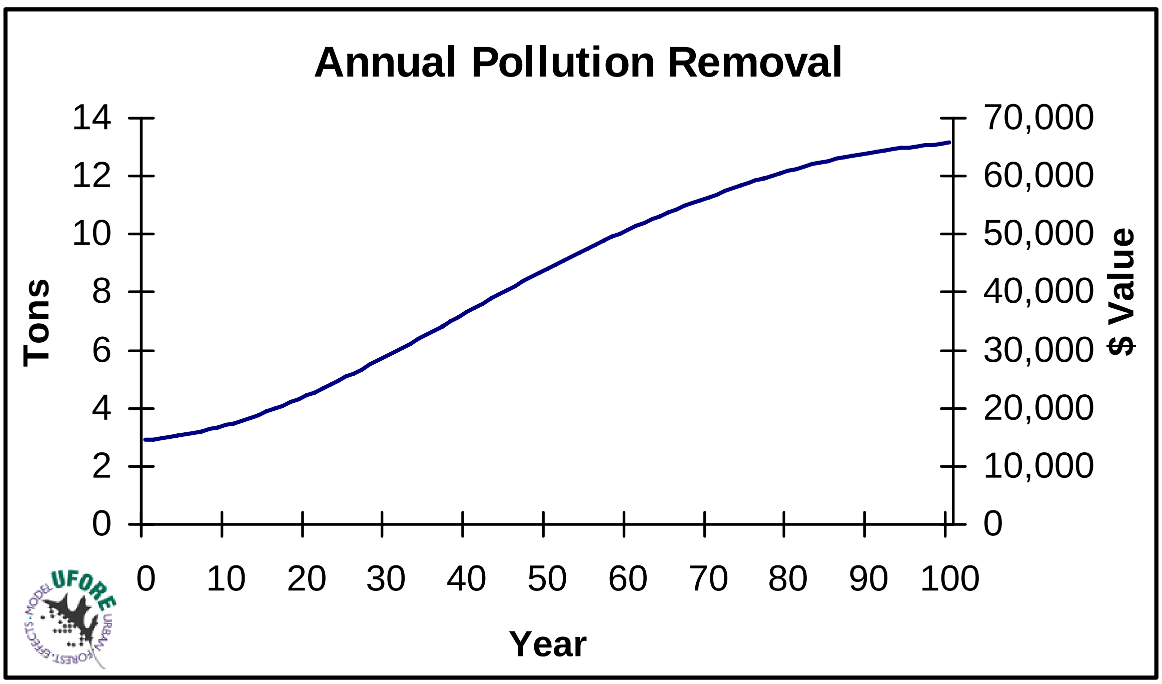


Figure 12. Annual Pollution Removal Based on an Increase of 15% in the Urban Canopy Coverage

Conclusion

Street trees and other public trees are a significant component of Northern Kentucky's urban environment and are an integral part of Bellevue, Covington, Florence, Fort Thomas, and Newport's city infrastructure, no less so than their streets, utilities, and sidewalks. The current calculated replacement value of this UFORE study's public tree resource is approximately $17 million. Unlike other infrastructure components, the tree population, when properly cared for, will increase in value as the trees mature.

The Northern Kentucky Urban and Community Forestry Council believes the public tree population provides benefits and value to Northern Kentucky communities far in excess of the time and money invested in it for planting, pruning, protection, and removal. Additionally, the shade and beauty and sense of place contributed by the urban forest to each community enhance the quality of life and add to the uniqueness of each city and neighborhood.

The concept that trees can be viewed as a resource for a community to utilize based on the net savings that trees provide to the community can be described as a *biogenic utility*. As this report illustrated, the benefits that the public tree population provides are quite substantial. This idea can be presented to the residents and decision makers of Northern Kentucky as a resource worthy of investment in the form of increased funding for a city's municipal forestry program. This would allow expansion of program planning, and an increase in funds for planting, maintenance, and management of the public tree resource. One objective of viewing trees as a biogenic utility is to link the funding allocated toward the management of the public tree population to the benefits that the trees provide.

As with any other utility, users would need to support the planting, maintenance, and use of the public tree population. The implementation of this concept would require redefining the notion of public trees as strictly an amenity to that of an asset. This study will hopefully aid that educational effort by quantifying the benefits of the public tree resource.

The Council believes that the value public trees contribute to the quality of life for Northern Kentucky citizens, businesses, workers, and visitors should be demonstrated, thereby gaining wider public demand and support for municipal urban forestry programs. The Council hopes that using the analysis of this study and information from other projects and sources that all cities in Northern Kentucky can leverage more support from community partners, both monetarily and by increasing tree protection and conservation-oriented actions.

Appendix A
Community Summaries

Total Population Data Summary

Leaf Area (ft2) 31,551,616.22
Leaf Biomass (lbs) 435110.50
Carbon Storage (lbs) 6115754.28
Carbon Seq. (lbs/yr) 169548.90
Tree Value (US $) $17,133,793.00

Insect	#'s Susceptible	% Susceptible
Asian Longhorn Beetle	4003	33.7%
Emerald Ash Borer	706	5.9%
Gypsy Moth	5722	48.2%

POLLUTION REMOVED					
CO (lbs)	O3 (lbs)	NO2 (lbs)	PM10 (lbs)	SO2 (lbs)	TOTAL (lbs)
201.704	9417.402	1974.849	3753.437	2433.589	17781.4

REMOVAL VALUE (U.S. $)					
CO	O3	NO2	PM10	SO2	TOTAL
$ 89.43	$ 28,962.94	$ 6,060.99	$ 7,691.95	$ 1,828.51	$ 44,633.82

VOC EMISSIONS			
ISOPRENE (lbs)	MONOTERP. (lbs)	OVOC (lbs)	TOTAL VOC (lbs)
3,312.539	793.430	1732.248	5838.008

Bellvue Data Summary

Leaf Area (ft2)	1631289.4
Leaf Biomass (lbs)	22131.406
Carbon Storage (lbs)	273390.26
Carbon Seq. (lbs/yr)	9882.29
Tree Value (US $)	$814,306.00

Insect	#'s Susceptible	% Susceptible
Asian Longhorn Beetle	160	22.5%
Emerald Ash Borer	24	3.4%
Gypsy Moth	336	47.3%

POLLUTION REMOVED					
CO (lbs)	O3 (lbs)	NO2 (lbs)	PM10 (lbs)	SO2 (lbs)	TOTAL (lbs)
10.253	478.717	100.451	194.008	123.785	907.215

REMOVAL VALUE (U.S. $)					
CO	O3	NO2	PM10	SO2	TOTAL
4.54	1,472.37	308.12	397.43	92.95	2,275.42

VOC EMISSIONS			
ISOPRENE (lbs)	MONOTERP. (lbs)	OVOC (lbs)	TOTAL VOC (lbs)
118.521	23.762	86.804	229.086

Covington Data Summary

Leaf Area (ft2)	10780480
Leaf Biomass (lbs)	145538.184
Carbon Storage (lbs)	1811727.52
Carbon Seq. (lbs/yr)	59089.65
Tree Value (US $)	$5,396,329.00

Insect	#'s Susceptible	% Susceptible
Asian Longhorn Beetle	1292	32.9%
Emerald Ash Borer	226	5.8%
Gypsy Moth	1762	44.9%

POLLUTION REMOVED					
CO (lbs)	O3 (lbs)	NO2 (lbs)	PM10 (lbs)	SO2 (lbs)	TOTAL (lbs)
67.474	3150.323	660.559	1306.031	814.001	5998.387

REMOVAL VALUE (U.S. $)					
CO	O3	NO2	PM10	SO2	TOTAL
29.90	9,687.67	2,027.32	2,676.19	611.59	15,032.68

VOC EMISSIONS			
ISOPRENE (lbs)	MONOTERP. (lbs)	OVOC (lbs)	TOTAL VOC (lbs)
987.250	201.450	573.600	1762.290

Florence Data Summary

Leaf Area (ft2)	3974769.2
Leaf Biomass (lbs)	60831.012
Carbon Storage (lbs)	676003.218
Carbon Seq. (lbs/yr)	24430.05
Tree Value (US $)	$2,145,888.00

Insect	#'s Susceptible	% Susceptible
Asian Longhorn Beetle	847	25.9%
Emerald Ash Borer	201	6.1%
Gypsy Moth	1563	47.8%

POLLUTION REMOVED					
CO (lbs)	O3 (lbs)	NO2 (lbs)	PM10 (lbs)	SO2 (lbs)	TOTAL (lbs)
28.190	1316.181	276.096	461.796	340.230	2422.493

REMOVAL VALUE (U.S. $)					
CO	O3	NO2	PM10	SO2	TOTAL
12.50	4,049.18	847.36	946.27	255.63	6,110.96

VOC EMISSIONS			
ISOPRENE (lbs)	MONOTERP. (lbs)	OVOC (lbs)	TOTAL VOC (lbs)
470.070	195.630	254.870	920.570

Fort Thomas Data Summary

Leaf Area (ft2)	7995407.1
Leaf Biomass (lbs)	109074.064
Carbon Storage (lbs)	2225484.668
Carbon Seq. (lbs/yr)	40693.55
Tree Value (US $)	$5,683,369.00

Insect	#'s Susceptible	% Susceptible
Asian Longhorn Beetle	630	37.4%
Emerald Ash Borer	106	6.3%
Gypsy Moth	939	55.7%

POLLUTION REMOVED					
CO (lbs)	O3 (lbs)	NO2 (lbs)	PM10 (lbs)	SO2 (lbs)	TOTAL (lbs)
50.567	2360.948	495.058	937.597	610.055	4454.225

REMOVAL VALUE (U.S. $)					
CO	O3	NO2	PM10	SO2	TOTAL
22.42	7,260.46	1,519.38	1,921.23	458.37	11,181.85

VOC EMISSIONS			
ISOPRENE (lbs)	MONOTERP. (lbs)	OVOC (lbs)	TOTAL VOC (lbs)
1196.78	217.40	433.32	1847.51

Newport Data Summary

Leaf Area (ft2)	7169671.1
Leaf Biomass (lbs)	97535.24
Carbon Storage (lbs)	1129148.64
Carbon Seq. (lbs/yr)	35453.35
Tree Value (US $)	$3,094,900.00

Insect	#'s Susceptible	% Susceptible
Asian Longhorn Beetle	1074	47.2%
Emerald Ash Borer	149	6.6%
Gypsy Moth	1122	49.3%

POLLUTION REMOVED					
CO (lbs)	O3 (lbs)	NO2 (lbs)	PM10 (lbs)	SO2 (lbs)	TOTAL (lbs)
45.219	2111.251	442.686	854.405	545.518	3999.079

REMOVAL VALUE (U.S. $)					
CO	O3	NO2	PM10	SO2	TOTAL
20.03	6,492.38	1,358.65	1,760.77	409.87	10,031.71

VOC EMISSIONS			
ISOPRENE (lbs)	MONOTERP. (lbs)	OVOC (lbs)	TOTAL VOC (lbs)
539.90	154.98	383.66	1,078.55

Appendix B
UFORE Model's Frequently Asked Questions

Frequently Asked Questions about the UFORE model (www.ufore.org)

What is UFORE?

UFORE, which stands for Urban Forest Effects, is a science-based, peer-reviewed computer model designed to calculate urban forest ecosystem services and values based on field data inputs and available data sets from external sources (*e.g.,* weather and pollution data sets). UFORE can calculate urban forest structure and several ecosystem services and values for any area of any size.

UFORE is a compilation of three programs:

1) Field plot selector–allows users to easily locate field plots on maps using GIS.
2) Data collection program–a field data collection program for use on a personal digital assistant (PDA) running Windows CE.
3) UFORE application–an interface that allows the user to operate the two programs cited above, collect and enter field data (either through the PDA or on paper forms), have data analyzed, and generate and export standard graphs and tables. A user's manual is also available through the help menu.

Why was UFORE developed?

UFORE was developed in the 1990s to standardize a protocol for collecting and analyzing data in urban areas. The need for this tool became apparent following the first urban ecosystem assessment studies in Oakland, Chicago, and other U. S. cities.

What does UFORE calculate?

- Urban forest structure by strata (*e.g.,* land-use types), including species composition, tree density, diameter distribution, tree health, leaf and tree biomass, and species diversity.
- Amount of pollution removed (hourly) by the urban forest, and associated percent improvement in air quality. Pollution removal is calculated for carbon monoxide, nitrogen dioxide, ozone, particulate matter (< 10 microns), and sulfur dioxide.
- Volatile organic compounds (VOC) emissions from the urban forest (hourly) and the relative impact of tree species on net ozone and carbon monoxide formation throughout the year.
- Total carbon stored and net annual carbon sequestration by the urban forest.
- Tree effects on building energy use and consequent emissions from power plants.
- Compensatory value of the forest, air pollution removal value, and carbon storage and sequestration values.
- Potential impact of infestations by gypsy moth, Asian longhorned beetle, Dutch elm disease, and emerald ash borer.
- Changes in streamflow (hourly) due to urban trees and impervious surfaces.
- Changes in water quality (hourly) due to urban trees and impervious surfaces, including total nitrogen, nitrate and nitrite, total Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, total suspended solids, dissolved solids, lead, copper, zinc, cadmium, chromium, nickel, biological dissolved oxygen, chemical dissolved oxygen, alkalinity, and oil and grease.

Who uses UFORE?

UFORE has a diverse group of users—from scientists and university students who want to study the effects of urban forests on the environment, to local city planners who are exploring the use of trees on pollution mitigation and mapping underserved areas of their communities where trees would be the most useful, to managers who want to know and better manage their resource, to public groups that want to understand the values of urban forests and bolster support for urban tree planting and urban forestry programs.

Why should I use UFORE?

UFORE provides necessary information on the urban forest resource and its ecosystem services to improve urban forest management and garner support for urban forestry programs. Data on urban forest structure and health can aid in establishing appropriate budget levels and workload allocation, while information on tree cover can help define areas where new tree plantings would be more beneficial. Pest information can help detect existing vulnerabilities to insects and pathogens that could devastate the urban forest. The ecosystem service results can be used to determine the value of the resource and support integrating urban forest programs in larger regulatory efforts to improve environmental quality.

How can UFORE be used in regulatory efforts to improve environmental quality?

Results from UFORE also can help determine the effect of trees on aspects of the environment that are regulated by the U. S. Environmental Protection Agency. As the Clean Air and Clean Water Acts impose regulations that affect urban areas, the regulations affect urban development, funding, and management at local and state levels. As trees affect the environment, the ability to quantify these effects could lead to the incorporation of urban vegetation management strategies (and potential funding) to help meet these environmental regulations. Urban trees can be incorporated as an emerging measure with State Implementation Plans to meet clean air regulations (www.fs.fed.us/ne/syracuse/Emerging%20Measures%20Summary.pdf).

Urban trees also could be used to potentially meet clean water regulations associated with Total Maximum Daily Loads (www.epa.gov/owow/tmdl/intro.html) and stormwater programs (www.epa.gov/region6/water/npdes/sw/ms4/).

How have UFORE results helped communities?

Numerous communities, both nationally and internationally, have used UFORE to assess ecosystem services and aid in improved urban forest management. One of the best examples of how UFORE results have helped a community comes from New Jersey. There, based in part on UFORE results, Conectiv Electric Utility negotiated to have a $1 million air pollution fine donated to the New Jersey Tree Foundation for a massive Urban Air-shed Reforestation project in the Camden area. Trained volunteers are planting 3-inch caliper shade trees in the communities most affected by the air pollution (www.na.fs.fed.us/urban/states2003/nj/nj.htm).

How does UFORE work?

UFORE uses locally collected field data along with readily available external data sources (*e.g.,* weather and pollution data) to quantify basic tree functions and ecosystem services. However, some basic field measurements that are used to quantify urban forest structure must be collected on the ground (*e.g.,* species, diameter, crown height and width, crown condition) from randomly located plots. Data from the plots are then statistically extrapolated upward to estimate totals and standard errors for the entire study area or strata (*e.g.,* land-use types) within the study area.

Is field data collection necessary?

Yes. Field data are necessary to accurately quantify the urban forest structure. Quantifying carbon, VOC emissions, energy effects, and other services require data on individual trees for accurate estimates. Quantifying ecosystem services only with aerial data would provide only coarse estimates of these services. Using local field data along with local weather and pollution data sets provides a more accurate assessment of the local urban forest structure and services.

Is there any new functionality planned for UFORE?

Updates to the functionality of UFORE will be available via the Internet as UFORE will be continually developed and refined with new capabilities through time. There are three new modules in development.

1) UFORE-Hydro. This is a GIS-based program that estimates changes in streamflows and water quality based on changes in tree cover and impervious surface cover attributes within a watershed. The model is calibrated against actual streamflow data and is designed specifically to estimate vegetation effects.
2) UFORE-Species. This is a functional species selection program that was developed in cooperation with Horticopia (www.horticopia.com). From a database with information on thousands of trees, trees are rated for their relative ability for air pollution removal, VOC emissions, air quality improvement, carbon storage, air temperature reduction, shading, building energy conservation, and allergenicity. Users are asked to rate the importance of each of these functions to determine the best species given the users' ratings. The program rankings are based on relative tree functions at maturity and local hardiness zone to aid in tree selection in the area to maximum ecosystem services from trees and improve environmental quality in cities.
3) UFORE Growout. This program uses the output from UFORE to project future tree population totals, canopy cover, and carbon storage based on user inputs of estimated mortality rates. Populations can be projected over a 100-year period. The program also can be used to determine annual tree planting/establishment rates needed to sustain a specific tree canopy cover.

What cities have been analyzed using UFORE?

- Atlanta, GA
- Baltimore, MD
- Beijing, China
- Boston, MA
- Brooklyn, NY
- Calgary, Alberta
- Freehold, NJ
- Fuenlabrada, Spain
- Greenville-Spartanburg, SC
- Houston, TX
- Hefei, China
- Jersey City, NJ
- Kent, OH
- Minneapolis, MN
- Morgantown, WV
- Moorestown, NJ
- New York, NY
- Ningbo, China
- Oakville, Ontario
- Philadelphia, PA
- Porto Alegre, Brazil
- San Francisco, CA
- San Juan, PR
- Santiago, Chile
- Syracuse, NY
- Toronto, Ontario
- Washington, DC
- Wilmington, DE
- Woodbridge, NJ

Current cities being analyzed are:

- Baton Rouge, LA
- Fredericton, New Brunswick
- Gainesville, FL
- Scranton, PA
- Shenzhen, China

How much does UFORE cost?

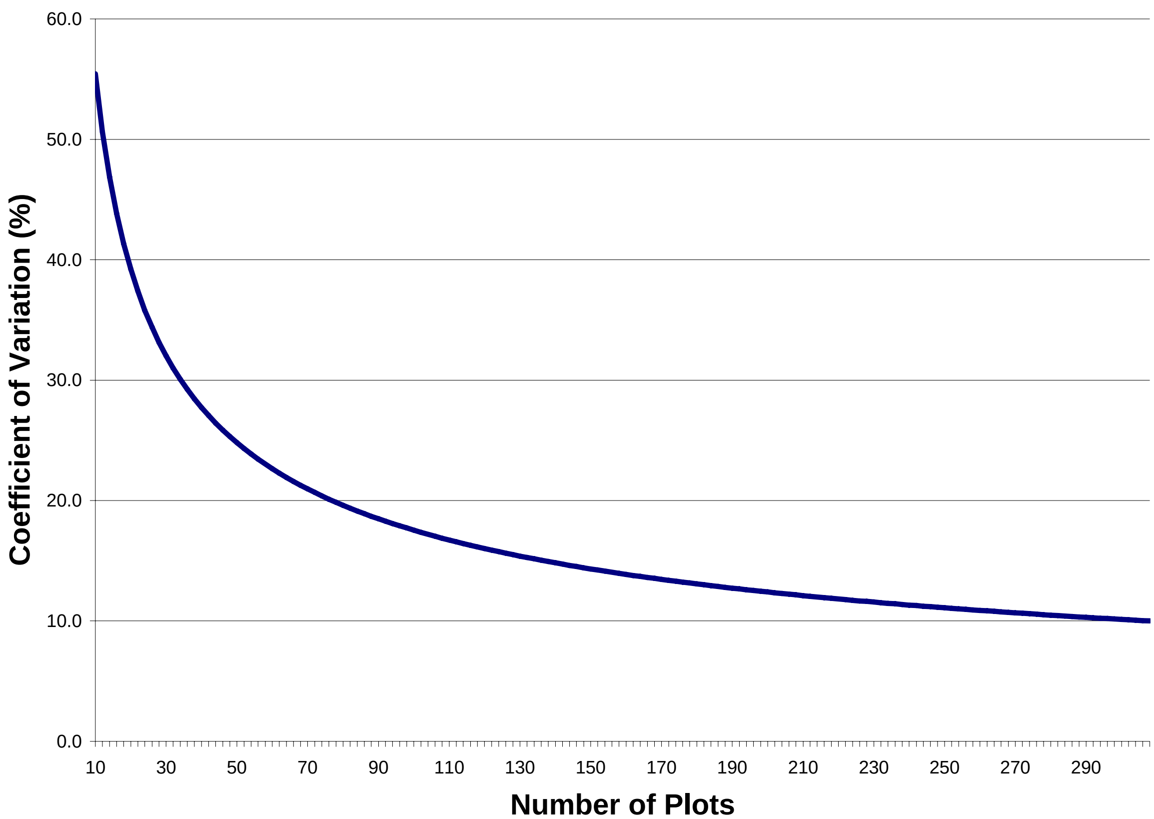
UFORE is a public-domain program distributed at no cost.

What does the typical city analysis cost?

As a general rule, a two-person crew can collect data on 150 to 200 one-tenth-acre plots during a 3-month summer season. The cost for the data collection would depend on how much the crew is paid and the local transportation cost to get to the plots. Other costs incurred by conducting an analysis relate to equipment and local office support costs for project setup, analysis, and reporting. Some costs are incurred for quality assurance measures (training and plot data checks).

How many field plots will I need to analyze my city?

The number of plots is up to the user. Increasing the number of plots and/or size of the plots will typically lead to lower variances and increased certainty in the results, but it also tends to increase the cost of the project. The following is a rough estimate of the coefficient of variation (standard error divided by total expressed as a percentage) of the total number of trees in a city based on the number of plots sampled.



What do I have to do to run a UFORE analysis?

Read the i-Tree Software Suite User's Manual found under the UFORE program help menu or at the Resource/Learning Center on the i-Tree website (www.itreetools.org) to determine the data collection and analysis procedures. The basic steps are:

1) Determine your study area
2) Distribute sample points for plot location
3) Collect the field data
4) Use UFORE to analyze the data
5) Use UFORE to generate tables and charts
6) Export data for local report generation
Training sessions and technical support are available (see www.itreetools.org).

Can I use existing inventory data?

Existing inventory data can be used if the proper crown parameters are measured on each tree, along with information on species, diameter at breast height (4.5 feet), and crown condition (see i-Tree Software Suite User's Manual). Species codes must also be converted to UFORE species codes (see www.itreetools.org).

Can UFORE data be mapped?

Yes. Examples of types of GIS maps that can be produced using UFORE data are given within the UFORE program.

Does UFORE calculate cost-benefit ratios?

No. UFORE estimates dollar benefits of ecosystem services based on economic literature. To estimate the cost-benefit ratio, good estimates of management costs of the entire urban forest would be needed. These data are not yet available, but UFORE-Growout is being developed to project costs and benefits through time based on user inputs of costs.

Can UFORE be used for street trees and non-urban areas?

Yes. UFORE has been used to assess street trees and nonurban areas. If proper tree data are collected, UFORE can calculate leaf area and biomass, air pollution removal, VOC emissions, carbon storage and sequestration, and compensatory value on a per-tree basis. However, the STRATUM model is designed to analyze street tree populations and can be used to assess this resource.

As UFORE is designed to calculate tree effects based on an area sample, the model can be used for nonurban areas of any size. One limitation of using the model outside of urban areas is that some local input data sets (*e.g.*, pollution and weather data) are more limited outside of urban areas.

Who developed UFORE?

UFORE was developed by a team of scientists and technicians from the Forest Service's Northeastern Research Station, Davey Resource Group, SUNY College of Environmental Science and Forestry, and Clemson University with support from these partner groups and Forest Service State and Private Forestry's Urban and Community Forestry and Northeastern Area programs.

Where can I obtain additional information about UFORE?

For additional information, visit www.itreetools.org, www.ufore.org, or www.fs.fed.us/ne/syracuse/Tools/UFORE.htm.