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Assessing Urban Forest Effects and Values: the Greater Kansas City Region

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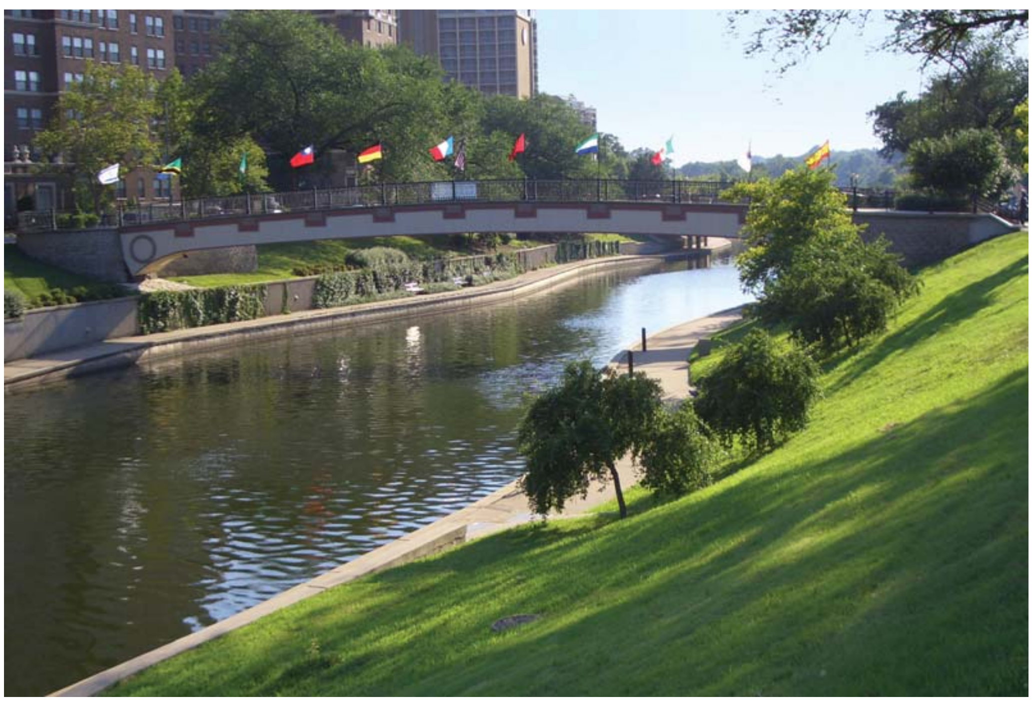

Abstract

An analysis of trees in the greater Kansas City region of Missouri and Kansas reveals that this area has about 249,450,000 trees with tree and shrub canopy that covers 28.3 percent of the region. The most common tree species are American elm, northern hackberry, Osage-orange, honeylocust, and eastern redcedar. Trees in the greater Kansas City region currently store about 19.9 million tons of carbon (72.8 million tons CO_2) valued at $411 million. In addition, these trees remove about 1.0 million tons of carbon per year (3.7 million tons CO_2 per year valued at $20.7 million per year) and about 26,000 tons of air pollution per year ($198.3 million per year). The greater Kansas City region's trees are estimated to reduce annual residential energy costs by $14.0 million per year. The compensatory value of the trees is estimated at $93.4 billion. Loss of the current tree cover in the Blue River watershed of the greater Kansas City region would increase total flow over a 6.5-month period by an average of 2.3 percent (63.4 million ft^3). Information on the structure and functions of the urban forest can be used to inform urban forest management programs and to integrate urban forests within plans to improve environmental quality in the greater Kansas City region.

Cover Photo

Sister Cities Bridge across Brush Creek in the Plaza, Kansas City, MO.
Photo by Charvex, Wikimedia Commons.

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EXECUTIVE SUMMARY

Trees in urban and rural areas contribute significantly to human health and environmental quality by providing various ecosystem services (i.e., the conditions and processes through which natural ecosystems, and the species which make them up, sustain and fulfill human life[1]). To better understand the ecosystem services and values provided by trees, the U.S. Forest Service, Northern Research Station, developed the Urban Forest Effects (UFORE) model, which is now known as i-Tree Eco. Results from i-Tree models are used to advance the understanding of tree and forest resources; improve urban and rural forest policies, planning and management; provide data to support the potential inclusion of trees within environmental regulations; and determine how trees affect the environment and consequently enhance human health and environmental quality in urban and rural areas.

Urban forests provide numerous benefits to society, yet relatively little is known about this important resource in the Kansas City region.

In 2010, the i-Tree Eco model was used to survey and analyze the Kansas City region's urban forest.

The calculated environmental benefits of the urban forest are significant, yet many environmental and social benefits still remain to be quantified.

The i-Tree Eco model is used to help quantify forest structure, function, and values. Forest structure is a measure of various physical attributes of the vegetation, including tree species composition, number of trees, tree density, tree health, leaf area, biomass, and species diversity. Forest functions, which are determined by forest structure, include a wide range of environmental and ecosystem services such as air pollution removal and cooler air temperatures. Forest values are an estimate of the economic worth of the various forest functions.

To help determine the vegetation structure, functions, and values of trees in the greater Kansas City region (hereafter referred to as the Kansas City region), a vegetation assessment was conducted during autumn of 2010. For this assessment, 0.1-acre field plots were sampled and analyzed using the i-Tree Eco model. This report summarizes results and values of (Table 1):

- Forest structure
- Potential risk to trees from various insects or diseases
- Air pollution removal
- Carbon storage
- Annual carbon removal (sequestration)
- Changes in building energy use

In addition, a tree growth projection model was used to estimate annual tree canopy change based on tree data for the Kansas City region. Tree growth was based on various tree characteristics including species (growth rate, longevity, height at maturity), current tree size, crown competition, and tree condition. The model was used to consider several different scenarios to estimate the number of trees that need to be established to meet desired canopy goals in the future. For several scenarios, the ecosystem services of these canopy goals were also summarized (Table 2).

A specialized analysis of the Blue River watershed of the Kansas City region was also completed using the i-Tree Hydro model.[2] i-Tree Hydro is a semi-distributed, physical-based model created to simulate tree effects on stream hydrology using local cover and elevation information, hourly weather data, and hourly stream flow data. This report details the stream flow response to changes in tree and/or impervious cover in the Blue River watershed.

Table 1.—Summary of regional forest features, Kansas City region, 2010

Feature	Measure
Number of trees	249,450,000
Tree and shrub canopy cover	28.3%
Tree canopy cover	18.6%
Most common species	American elm, northern hackberry, Osage-orange, honeylocust, eastern redcedar
Trees < 6 inches diameter (%)	71.0%
Pollution removal, trees	
All 5 pollutants	25,940 tons/year ($198 million/year)
Ozone	15,850 tons/year ($142million/year)
Particulate matter	6,030 tons/year ($36 million/year)
Sulfur dioxide	2,260 tons/year ($5.0 million/year)
Nitrogen dioxide	1,610 tons/year ($14.4 million/year)
Carbon monoxide	200 tons/year ($257,000/year)
Carbon storage	19.9 million tons ($411 million)
Carbon sequestration	1.0 million tons/year ($20.7 million/year)
Building energy reduction	$14.0 million/year
Reduced carbon emissions	$500,800/year
Structural value	$93.4 billion

Ton – short ton (U.S.) (2,000 lbs)

Table 2.—Number of trees to be established to meet cover goals, Kansas City region, 2010[a]

		Cover Goal			
Land Use	Current cover (%)	Maintain cover	Increase cover 5%	Increase cover 10%	Increase cover 20%
Residential	31.4	1,250,000	1,800,000	2,200,000	3,100,000
Golf, Park, Institutional	34.3	350,000	400,000	460,000	610,000
Comm., Utilities, Transport.	9.6	18,000	75,000	138,000	265,000
Agriculture, Vacant	11.8	960,000	1,700,000	2,500,000	4,200,000
Water, Other	49.2	350,000	480,000	640,000	1,000,000
Total	18.6	2,928,000	4,555,000	5,938,000	9,175,000

[a] Estimated number of trees needed to be established annually by land use to achieve various canopy coverage goals in 50 years with 4 percent annual mortality. Most of these trees will likely occur through natural regeneration.

I-TREE ECO MODEL AND FIELD MEASUREMENTS

Urban trees and forests have many functions and values, but currently only a few of these attributes can be assessed due to a limited ability to quantify all of these values through standard data analyses. To help assess the Kansas City region's urban and rural forests, data from 340 field plots located throughout the region were analyzed using the U.S. Forest Service's i-Tree Eco model (formerly known as UFORE).[3] This region was defined as the nine-county area surrounding the city of Kansas City: Cass, Clay, Jackson, Platte, and Ray counties in Missouri, and Johnson, Leavenworth, Miami, and Wyandotte counties in Kansas (Fig. 1).

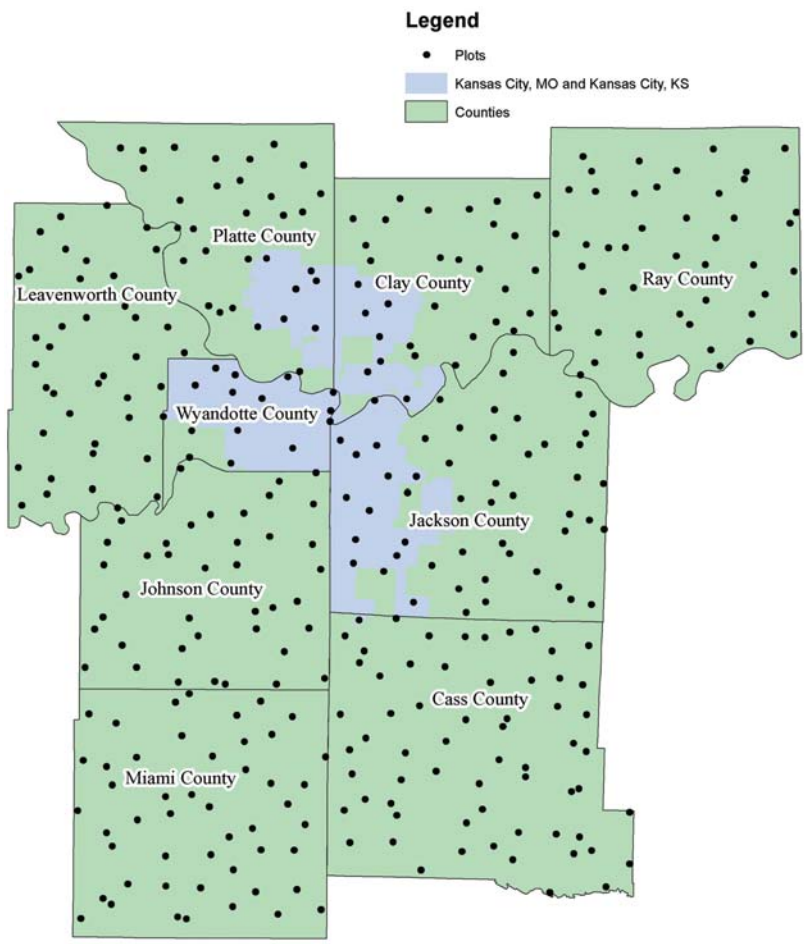


Figure 1.—Map of the study area and field plot distribution, Kansas City region, 2010.

The i-Tree Eco model uses standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify forest structure and its numerous effects, including:

- Forest structure (e.g., species composition, tree density, tree health, leaf area, leaf and tree biomass, species diversity, etc.)
- Amount of pollution removed hourly by the 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 residential building energy use and consequent effects on carbon dioxide emissions from power sources.
- Compensatory value of the forest, as well as the value of air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by Asian longhorned beetles, emerald ash borers, gypsy moth, Dutch elm disease, or thousand cankers disease.

In the field, 0.1-acre plots were selected based on a randomized grid with an average density of approximately one plot for every 8,326 acres. The study is divided into smaller areas based on a land-use classification recorded in the field. The plots were divided among the following land uses (Fig. 2): agriculture and vacant (194 plots, 57.1 percent of area); residential (86 plots, 25.3 percent); “other” (21 plots, 6.2 percent); commercial/utility/transportation (20 plots, 5.9 percent); and golf/park/institutional (19 plots, 5.6 percent). The land use “other” includes water/wetland land-use types as well as those that do not fall into one of the previously mentioned categories.[4]

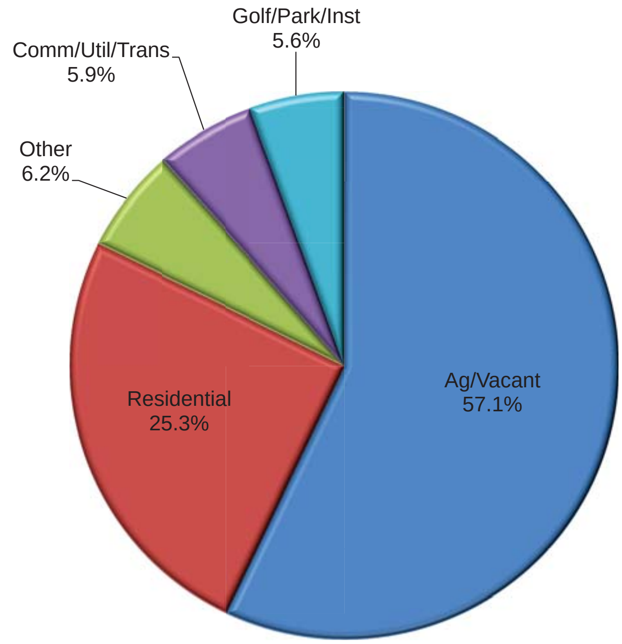


Figure 2.—Land-use distribution, Kansas City region, 2010, for inventoried plots.

Field data were collected by two, two-person teams. Each team consisted of a Davey Resource Group project manager and a Mid-America Regional Council (MARC) intern. Data collection occurred during the leaf-on season of autumn 2010 to properly assess tree canopies. Within each plot, data included land use, ground and tree cover, shrub characteristics, and individual tree attributes of species, stem diameter at breast height (d.b.h.; measured at 4.5 ft, hereafter referred to as stem diameter), tree height,

Field Survey Data

Plot Information

- Land use
- Percent tree cover
- Percent shrub cover
- Percent plantable
- Percent ground cover types
- Shrub species/ dimensions

Tree parameters

- Species
- Stem diameter
- Total height
- Height to crown base
- Crown width
- Percent foliage missing
- Percent dieback
- Crown light exposure
- Distance and direction to buildings from trees

i-Tree

height to base of live crown, crown width, percentage crown canopy missing and dieback, and distance and direction to residential buildings.[4] Trees were recorded as woody plants with a stem diameter greater than or equal to 1 inch. As many species are classified as small tree/large shrub, the 1-inch minimum stem diameter of all species means that many species commonly considered as shrubs will be included in the species tallies when they meet the minimum diameter requirement.

To estimate 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.[5] To adjust for this difference, biomass results for open-grown trees are multiplied by 0.8.[5] 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.[5]

To estimate the gross amount of carbon sequestered annually, average diameter growth from 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 were calculated for carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter less than 10 microns (PM_{10}). Estimates are derived from calculated hourly tree-canopy resistances for O_3, SO_2, and NO_2 based on a hybrid of big-leaf and multi-layer canopy deposition models.[6,7] As the removal of CO 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[8,9] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[10].

Seasonal effects of trees on residential building energy use was calculated based on procedures described in the literature[11] using distance and direction of trees from residential structures, tree height, and tree condition data.

Compensatory values were based on valuation procedures of the Council of Tree and Landscape Appraisers[12], which uses tree species, diameter, condition, and location information.[12]

To learn more about i-Tree Eco methods[3,13] refer to: http://nrs.fs.fed.us/tools/ufore/, or www.itreetools.org.

TREE CHARACTERISTICS OF KANSAS CITY'S REGIONAL FOREST

The Kansas City region has an estimated 249,450,000 trees with a standard error (SE) of 25,410,000. Tree and shrub cover is estimated from the photo-interpretation of Google Earth imagery of 3,000 random points. Tree and shrub cover in the Kansas City region is estimated to cover 28.3 percent of land area.[14] As it is difficult to differentiate between trees and shrubs from aerial imagery, the plot estimates of tree and shrub cover separately were used to differentiate between tree and shrub cover. Based on the field data in conjunction with photo-interpretation[14], tree cover in the Kansas City region is estimated to be 18.6 percent. The number of trees and percent cover by county is displayed in Tables 3 and 4 and Figure 3.

There are an estimated 249,450,000 trees in the Kansas City region with tree and shrub canopy that covers 28.3% of the region.

Trees alone cover 18.6% of the region.

i-Tree

Table 3.—Number of trees by county, Kansas City region, 2010

	Trees		
County	Number	%Pop[a]	Trees/Acre
Cass	43,740,000	17.5	97.3
Clay	26,940,000	10.8	103.1
Jackson	32,540,000	13.1	82.5
Johnson	25,490,000	10.2	83.0
Leavenworth	33,210,000	13.3	110.6
Miami	38,700,000	15.5	102.4
Platte	19,590,000	7.9	71.7
Ray	22,710,000	9.1	61.8
Wyandotte	6,530,000	2.6	65.4
Total	249,450,000	100.0	88.1

[a] Percent of total population

Table 4.—Percent tree/shrub and impervious cover in each county, Kansas City region, 2010

	Tree/Shrub[a]		Impervious[a]		Tree Cover[b]
County	%	SE	%	SE	%
Cass	24.8	1.9	3.4	0.8	17.3
Clay	30.1	2.7	9.2	1.7	19.5
Jackson	36.0	2.3	14.1	1.7	21.5
Johnson	23.7	2.4	16.0	2.0	15.7
Leavenworth	31.1	2.7	3.7	1.1	20.7
Miami	23.6	2.1	2.8	0.8	16.8
Platte	30.4	2.7	4.7	1.2	19.5
Ray	26.0	2.3	3.0	0.9	15.2
Wyandotte	35.0	4.7	24.3	4.2	27.8
Region	28.3	0.8	7.6	0.5	18.6

[a] Based on photo-interpretation[13]
[b] Based on photo-interpretation in conjunction with field estimates[13]

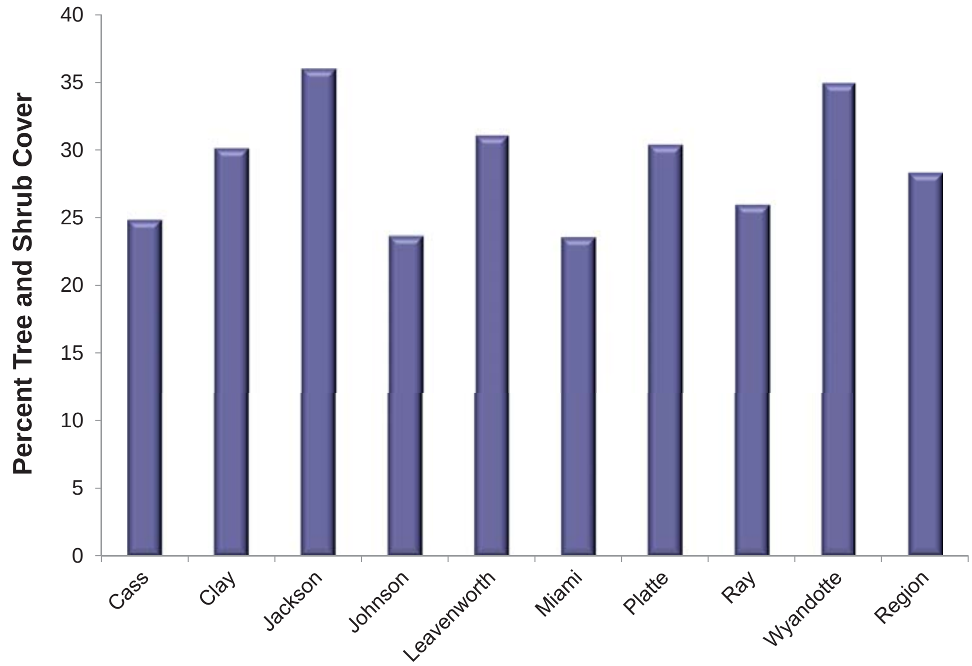


Figure 3.—Percent tree and shrub cover by county and for Kansas City region, 2010.

The five most common species in the region's urban and rural forest were American elm (28.9 percent), northern hackberry (14.0 percent), Osage-orange (7.2 percent), honeylocust (6.7 percent), and eastern redcedar (5.0 percent). The 10 most common species account for 77.9 percent of all trees; their relative abundance is illustrated in Figure 4. The five most common species by county are shown in Table 5. Fifty-one tree species were sampled in the Kansas City region; these species and their relative abundance are presented in Appendix I. More information on species distribution by land use is given in Appendix II.

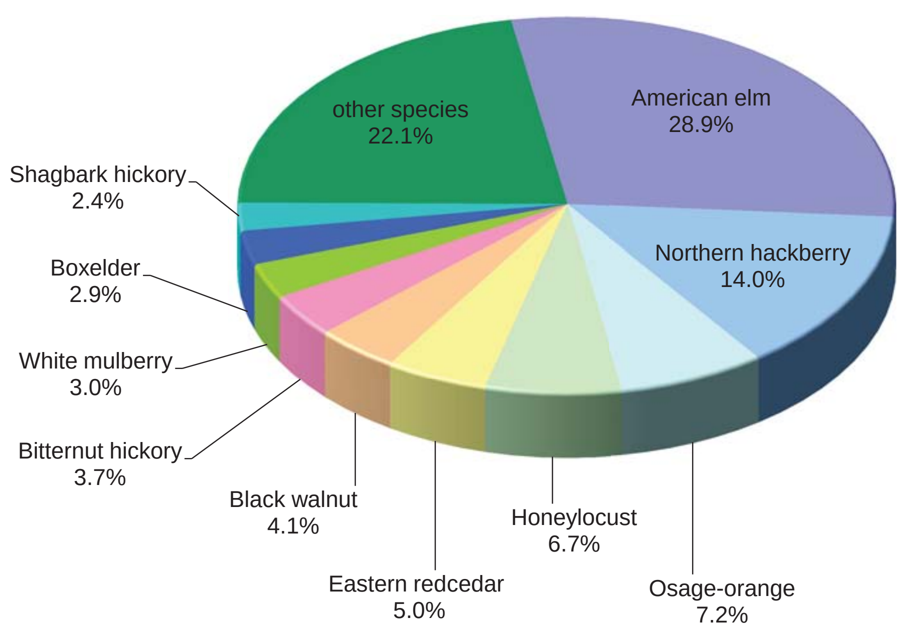


Figure 4.—Tree species composition, Kansas City region, 2010.

Table 5.—Five most common species in each county, Kansas City region, 2010

County	Common Name	Percent of County Population
Cass	American elm	32.5
	Northern hackberry	19.9
	Honeylocust	6.4
	Bitternut hickory	5.5
	Osage-orange	5.5
Clay	American elm	26.5
	Ohio buckeye	11.3
	Northern hackberry	8.5
	Bitternut hickory	6.4
	Osage-orange	5.2
Jackson	American elm	32.3
	Northern hackberry	17.7
	Honeylocust	9.5
	White mulberry	5.7
	White ash	3.5
Johnson	American elm	33.2
	Northern hackberry	16.6
	Osage-orange	16.1
	Green ash	3.9
	Black walnut	3.4
Leavenworth	American elm	38.3
	Eastern redcedar	12.3
	Honeylocust	7.9
	Osage-orange	6.9
	Boxelder	6.6
Miami	American elm	22.7
	Honeylocust	15.5
	Osage-orange	12.2
	Eastern redcedar	11.6
	Northern hackberry	9.6
Platte	American elm	22.8
	Pawpaw	12.9
	Black walnut	12.3
	Northern hackberry	10.5
	Chinkapin oak	7.0
Ray	Northern hackberry	23.0
	American elm	15.5
	Bitternut hickory	7.5
	Shagbark hickory	6.3
	Osage-orange	6.0
Wyandotte	Eastern redcedar	22.0
	American elm	22.0
	Northern hackberry	16.5
	Black willow	14.3
	Black walnut	7.7

The most common species in the Kansas City region:

American elm (28.9%)
Northern hackberry (14.0%)
Osage-orange (7.2%)
Honeylocust (6.7%)
Eastern redcedar (5.0%).

Examining the distribution by county, American elm was the most common species in 7 of 9 counties.

The highest densities of trees occur in "other" areas (320 trees/ac), followed by golf/park/institutional (135 trees/ac), and residential land (122 trees/ac) (Fig. 5). The tree density for the entire Kansas City region is 88.1 trees/ac. The highest densities of trees occur in Leavenworth (111 trees/ac), Clay (103 trees/ac), and Miami (102 trees/ac) counties (Fig. 6). Land uses that contain the greatest percentage of the total tree population are residential (34.9 percent), followed by agriculture and vacant (32.5 percent) and "other" (22.4 percent). More information on the tree species in each land use and their structure and functions is given in Appendix III. Cass County contains the greatest percentage of the total tree population (17.5 percent), followed by Miami (15.5 percent) and Leavenworth (13.3 percent).

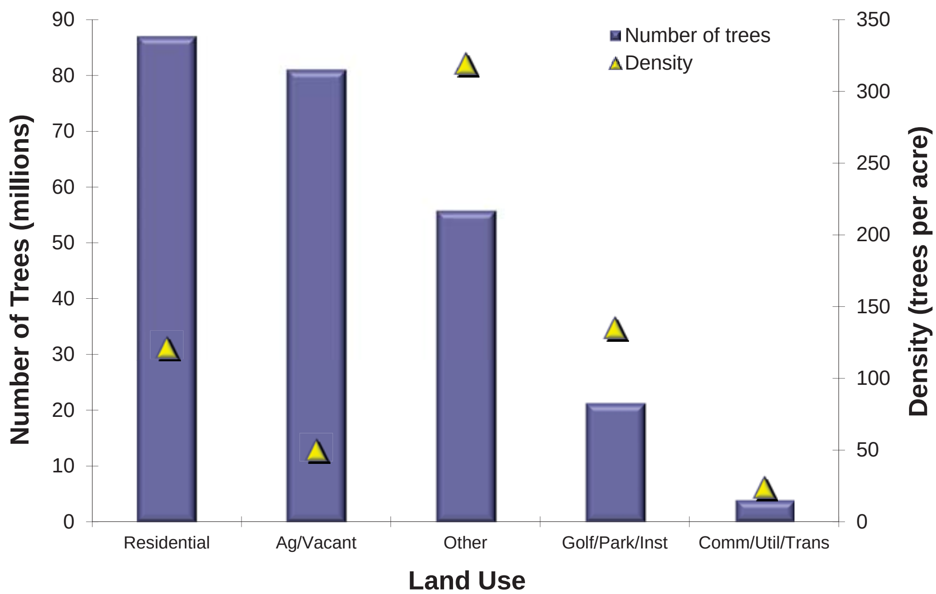


Figure 5.—Number of trees and tree density by land use, Kansas City region, 2010.

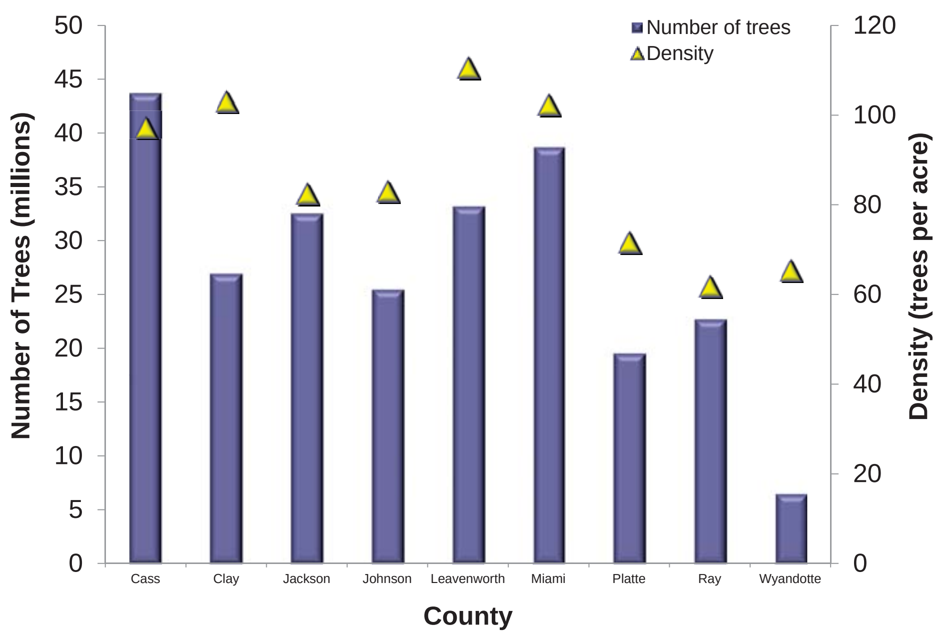


Figure 6.—Number of trees and tree density by county, Kansas City region, 2010.

Leaf area is highest in residential (42.7 percent of total tree leaf area) and agriculture and vacant (33.0 percent) land-use types (Fig. 7). Leaf area index (LAI) is an estimate of the total leaf area (one-sided) divided by land area. As each land use has a different land area, LAI standardizes the canopy depth on an equal area basis. Higher LAIs indicate a greater number of leaves per acre. Land uses that have the highest LAI are "other" (2.7), residential (2.0), and golf/park/institutional (1.7).

Trees that have diameters less than 6 inches account for 71.0 percent of the population. This diameter class also contains 26.3 percent of the total leaf area. Trees that have diameters greater than 18 inches account for 2.8 percent of the population and comprise 19.4 percent of the total leaf area. Though these larger trees are a small percentage of the population, they are an important part of the urban and rural forests in the Kansas City region. Leaf area has a strong correlation with benefits that the trees produce for the ecosystem, such as pollution removal; the percent of abundance and leaf area contributed by each tree diameter class and species are illustrated in Figures 8 and 9.

Tree populations vary in diameter class distribution between the small (<3 inches stem diameter) and large trees (>18 inches stem diameter). Most of the small trees tend to be on agriculture and vacant, residential, or "other" land uses, while most of the large trees tend to be on residential land (see Appendix IV). The small tree population tends to be dominated by American elm, northern hackberry and eastern red cedar, with a distribution that varies among the land-use classes (see Appendix IV). Fourteen percent of the small trees are American elms on "other" lands. Two of the 10 most common small trees are classified as invasive: white mulberry (ninth most common) and Osage-orange (10th). However, in comparing the large versus small tree distribution by species (Appendix IV), these two species had a greater percentage of large trees than small trees, indicating that these species may not be regenerating very well given the number of large trees (or various eradication procedures may be reducing the number of small trees). Two other common species, bur oak and black walnut, had a greater percent of large trees than small trees, which is an indication that there is likely not enough regeneration of these species to sustain the current species population through time.

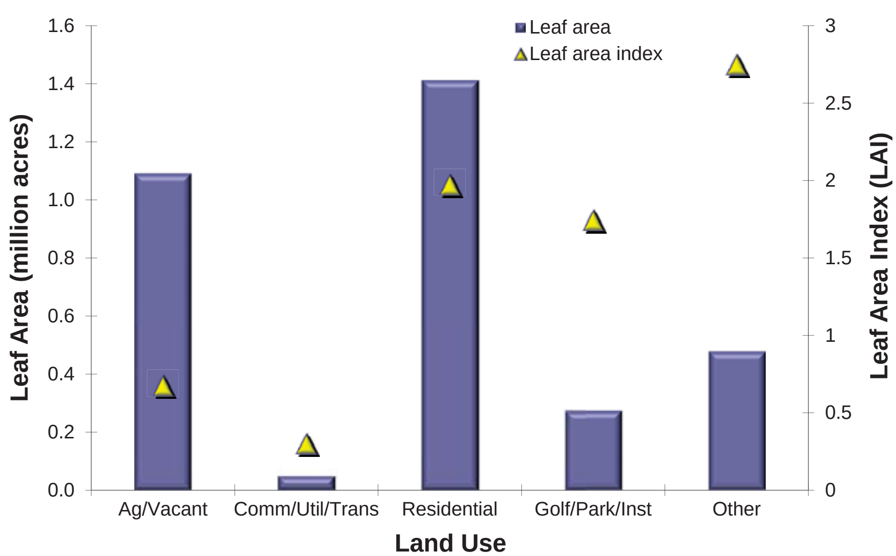


Figure 7.—Total leaf area and leaf area index by land use, Kansas City region, 2010.

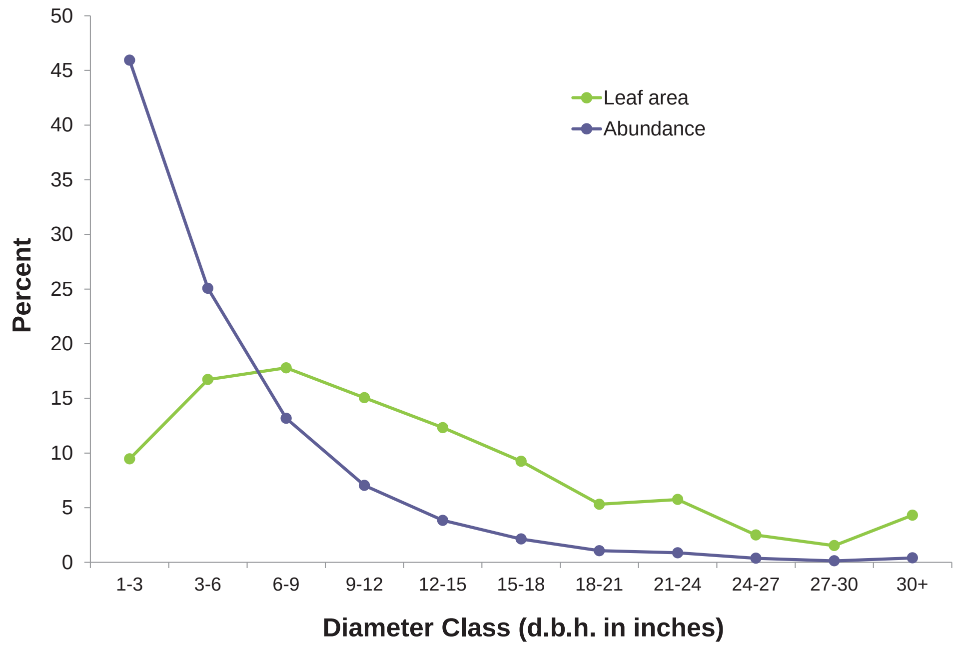


Figure 8.—Percent of total tree population (abundance) and leaf area by tree diameter class, Kansas City region, 2010.

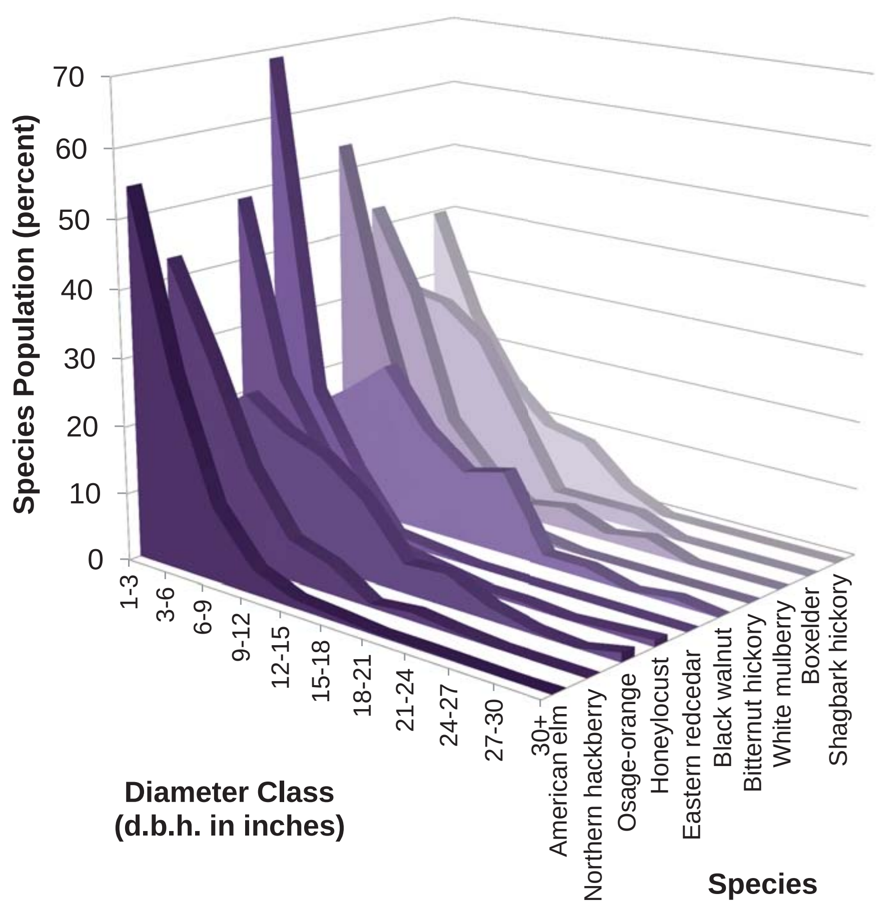


Figure 9.—Percent of species population by diameter class for 10 most common tree species, Kansas City region, 2010.

Urban forests are a mix of native tree species that existed prior to development and exotic species that were introduced by residents or other means.

Urban forests are a mix of native tree species that existed prior to the development of the area and exotic species that were introduced by residents or other means. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but the increase in the number of exotic plants can also pose a risk to native plants if exotic species are invasive and out-compete and displace native species. In the Kansas City region, about 87.9 percent of the trees are native to Missouri or Kansas (Fig. 10). Trees with a native origin outside of North America are mostly from Asia (3.6 percent of species).

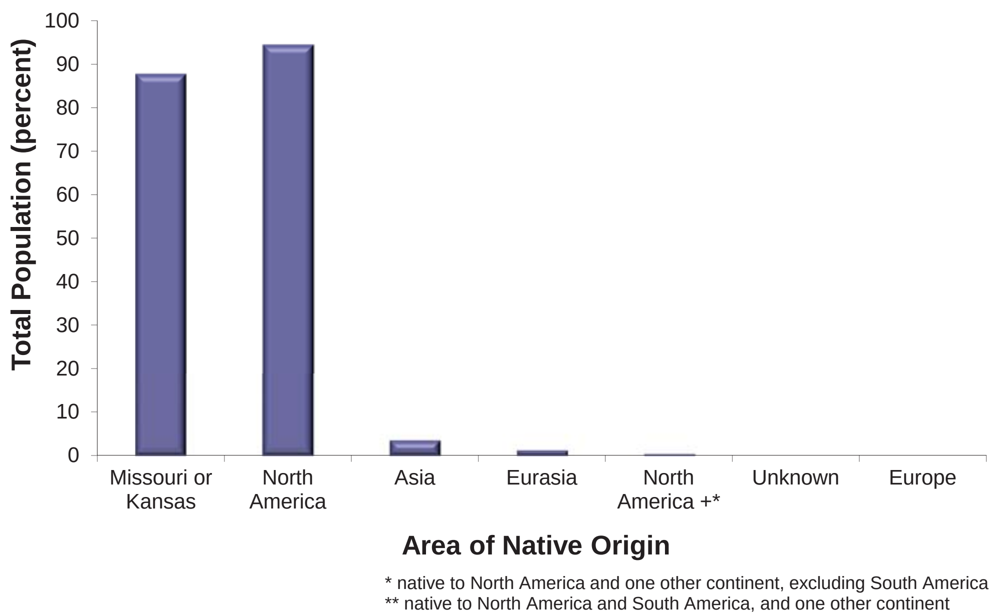


Figure 10.—Percent of tree population by area of native origin, Kansas City region, 2010.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to the native landscape.[15] Several of the tree species sampled in the Kansas City region have been identified on the Missouri invasive species list.[16] These species comprise 10.3 percent of the population: Osage-orange (7.2 percent of the population), white mulberry (3.0 percent), and Siberian elm (0.1 percent). Osage-orange, white mulberry, and Siberian elm are all considered to be potentially invasive (they are invasive in surrounding states) or invasive to the state of Missouri though they may only cause a minimal level of impact. None of the species sampled in the Kansas City region were identified on the Kansas invasive species list.[16]

Amur honeysuckle and other honeysuckle species are nonnative shrub species in Missouri and Kansas. They are present in the Kansas City region, most notably in residential areas and demonstrate invasive characteristics. Due to the fact that these woody shrubs tend to be smaller than 1 inch in stem diameter, they were not included in the tree analysis. However, Amur honeysuckle and other honeysuckle species together make up 3.3 percent of total shrub leaf area and 2.6 percent of total shrub leaf biomass.

TREE AND FOREST COVER AND LEAF AREA

Trees cover about 18.6 percent of the Kansas City region; shrubs cover 9.7 percent of the area. Dominant ground-cover types include herbaceous (79.7 percent), duff/mulch cover (8.2 percent), and bare soil (3.4 percent) (Fig. 11).

Many tree benefits are linked directly to the amount of healthy leaf surface area of the plant. In the Kansas City region, trees that dominate in terms of leaf area are American elm, northern hackberry, and Osage-orange.

Tree species with relatively large individuals contributing leaf area to the population (species with percentage of leaf area much greater than percentage of total population) are black walnut, green ash, and Osage-orange. Smaller trees in the population are Ohio buckeye, pawpaw, and honeylocust (species with percent of leaf area much less than percent of total population). The species must also have constituted at least 1 percent of the total population to be considered as relatively large or small trees in the population.

The importance value (IV) is calculated using a formula that takes into account the relative leaf area and relative abundance (Fig. 12). The most important species in the urban forest, according to calculated IVs, are American elm, northern hackberry, and Osage-orange (Table 6). High importance values do not mean that these trees should necessarily be used in the future, rather that these species currently dominate the urban and rural forest structure.

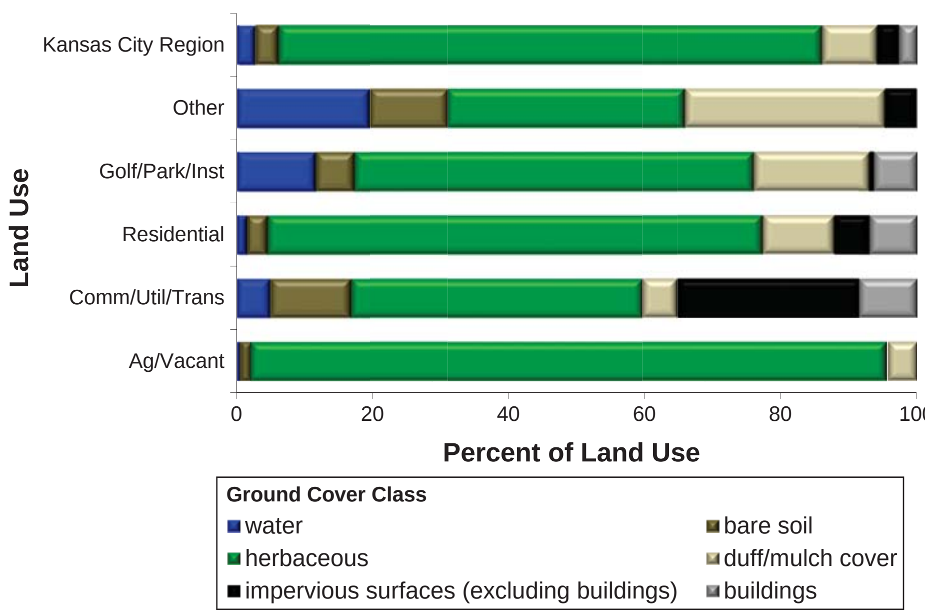


Figure 11.—Percent of the region and land-use areas covered by ground-cover classes, Kansas City region, 2010.

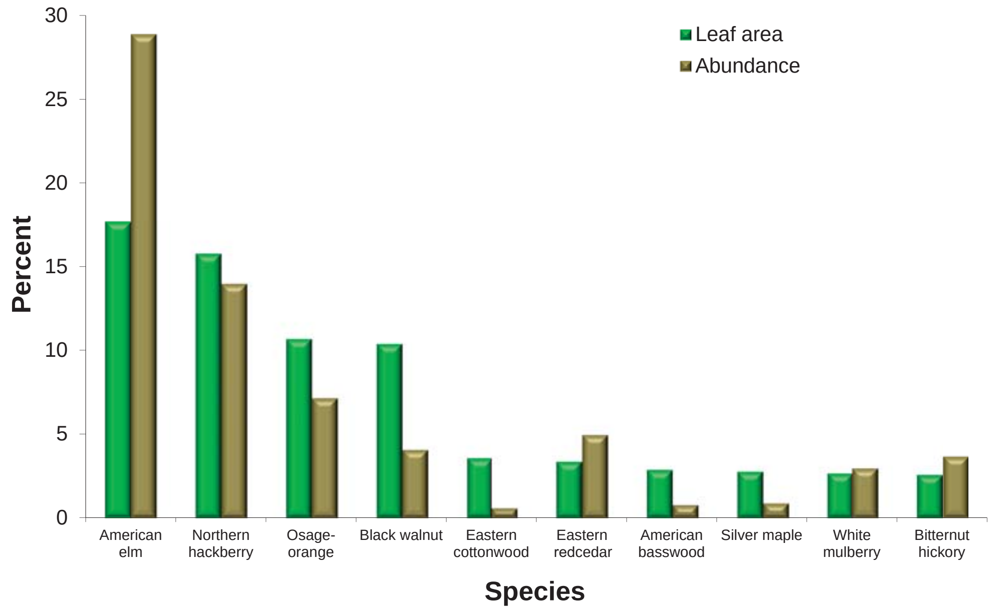


Figure 12.—Percent of total population (abundance) and leaf area for 10 most common tree species, Kansas City region, 2010.

American elm has the greatest importance in the Kansas City region's urban forest based on relative leaf area and relative population.

Table 6.—Percent of total population, percent of total leaf and importance values of species with the greatest importance values, Kansas City region, 2010

Common Name	%Pop[a]	%LA[b]	IV[c]
American elm	28.9	17.7	46.6
Northern hackberry	14.0	15.8	29.8
Osage-orange	7.2	10.7	17.9
Black walnut	4.1	10.4	14.5
Honeylocust	6.7	2.2	8.9
Eastern redcedar	5.0	3.4	8.4
Bitternut hickory	3.7	2.6	6.3
White mulberry	3.0	2.7	5.7
Boxelder	2.9	2.3	5.2
Bur oak	2.1	2.6	4.7

[a] %Pop - percent of total tree population
[b] %LA - percent of total leaf area
[c] Importance Value (IV) = %Pop + %LA

The trees and shrubs in the Kansas City region remove approximately 37,300 tons of air pollution each year, with a societal value of $286 million/year.

General urban forest management recommendations to improve air quality are given in Appendix V.

AIR POLLUTION REMOVAL BY TREES AND FORESTS

Poor air quality is a common problem in the Kansas City region as well as in many other urban areas. It can lead to human health problems, 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 reduce air pollutant emissions from power sources. 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.[17]

The monetary value of pollution removal by trees is estimated using the median externality values for the United States for each pollutant. These values are: nitrogen dioxide (NO_2) = $6,127/ton, particulate matter less than 10 microns (PM_{10}) = $4,091/ton, sulfur dioxide (SO_2) = $1,500/ton, and carbon monoxide (CO) = $870/ton.[18] Recently, these values were adjusted to 2007 values based on the producer's price index[19] and are now: NO_2 = $8,989/ton, PM_{10} = $6,002/ton, SO_2 = $2,201/ton, and CO = $1,277/ton. Externality values for ozone (O_3) are set to equal the value for NO_2.[3]

Pollution removal by trees and shrubs (28.3 percent tree and shrub cover) in the Kansas City area was estimated using the i-Tree Eco model in conjunction with field data and hourly pollution and weather data for the year 2009. Pollution removal by trees and shrubs (Fig. 13) was greatest for O_3 (23,040 tons), followed by PM_{10} (8,381 tons), SO_2 (3,302 tons), NO_2 (2,297 tons), and CO (307 tons). It is estimated that trees only remove 25,900 tons of air pollution (CO, NO_2, O_3, PM_{10}, SO_2) per year with an associated value of $198.3 million (Table 7). The effects of shrub cover (Table 8) in the Kansas City region (9.7 percent cover including shrubs beneath canopies) would remove an additional estimated 11,400 tons/year ($87.4 million/year). Thus, tree and shrub cover combined remove approximately 37,300 tons of pollution/year ($286 million/year).

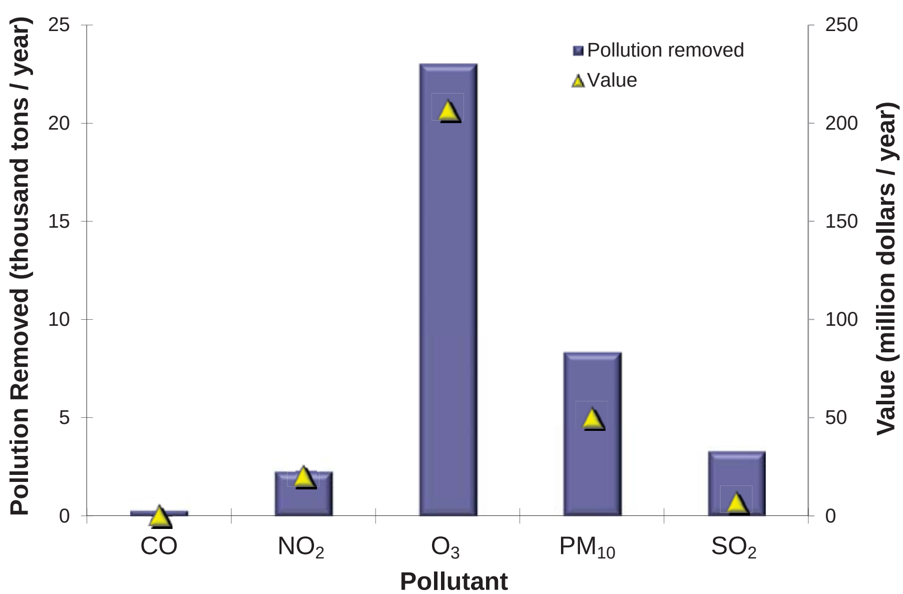


Figure 13.—Annual air pollution removal and value by trees and shrubs, Kansas City region, 2009.

Table 7.—Annual air pollution removal and value by trees, Kansas City region, 2009[a]				
Pollutant	Removal (tons)		Value (U.S. $1,000)	
Ozone	15,850	(3,250-19,000)	142,438	(29,216-170,761)
Particulate matter < 10 microns[b]	6,030	(2,350-9,420)	36,167	(14,128-56,511)
Sulfur dioxide	2,260	(840-3,550)	4,968	(1,852-7,803)
Nitrogen dioxide	1,610	(530-1,790)	14,436	(4,762-16,134)
Carbon monoxide	200		257	
Total	25,940	(7,180-33,960)	198,265	(50,214-251,465)

[a,b] See explanation below Table 8

Table 8.—Annual air pollution removal and value by shrubs, Kansas City region, 2009[a]				
Pollutant	Removal (tons)		Value (U.S. $1,000)	
Ozone	7,190	(1,580-9,800)	64,612	(14,185-88,099)
Particulate matter < 10 microns[b]	2,350	(920-3,680)	14,122	(5,516-22,066)
Sulfur dioxide	1,040	(420-1,830)	2,297	(923-4,031)
Nitrogen dioxide	690	(260-920)	6,207	(2,321-8,259)
Carbon monoxide	110		134	
Total	11,380	(3,280-16,340)	87,371	(23,080-122,588)

[a] Estimated tons of pollution removed by trees in the Kansas City region (2009) and associated monetary value (thousands of dollars); numbers in parentheses represent expected range of values (no range determined for carbon monoxide). Monetary value of pollution removal by trees estimated using median externality values for United States for each pollutant.[18]

[b]Assumes 50 percent resuspension of particles

Pollution removal by tree and shrub cover in 2009 (37,300 tons/year) was 25.2 percent less than pollution removal by tree and shrub cover in 2005 (50,000 tons/year). These data reflect the differences in pollution concentration and meteorology in 2005 and 2009. In general, air temperatures and concentrations of pollutants were higher in the Kansas City region in 2005 than they were in 2009.

In 2005 and 2009, trees in the Kansas City region emitted 260,310 tons of volatile organic compounds (VOCs; 118,348 tons of isoprene, 39,117 tons of monoterpene, and 102,846 tons of other VOCs) and 91,221 tons of VOCs (39,213 tons of isoprene, 14,327 tons of monoterpene, and 37,682 tons of other VOCs), respectively. The differences in emissions between years being due to differences in meteorology (e.g., air temperatures, sunshine). Land uses with the highest VOC emissions were residential, agriculture, and vacant, and “other” for both years. Forty percent of the Kansas City region’s VOC emissions were from the *Quercus* (oak) and *Maclura* (Osage-orange) genera in 2005, while the same genera accounted for 39 percent of the region’s VOC emissions in 2009. Figure 14 illustrates the annual VOC emissions by genera in 2009.

These VOCs are a precursor chemical to O_3 formation. Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. Combining dollar values to determine overall effects should not be done; instead, estimates of VOC impacts on O_3 formation (e.g., via photochemical models) should be contrasted with ozone removal by trees (i.e., O_3 effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce O_3 concentrations[20], but are not considered in this analysis. Modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on O_3 concentrations. General recommendations for air quality improvement with trees are given in Appendix V.

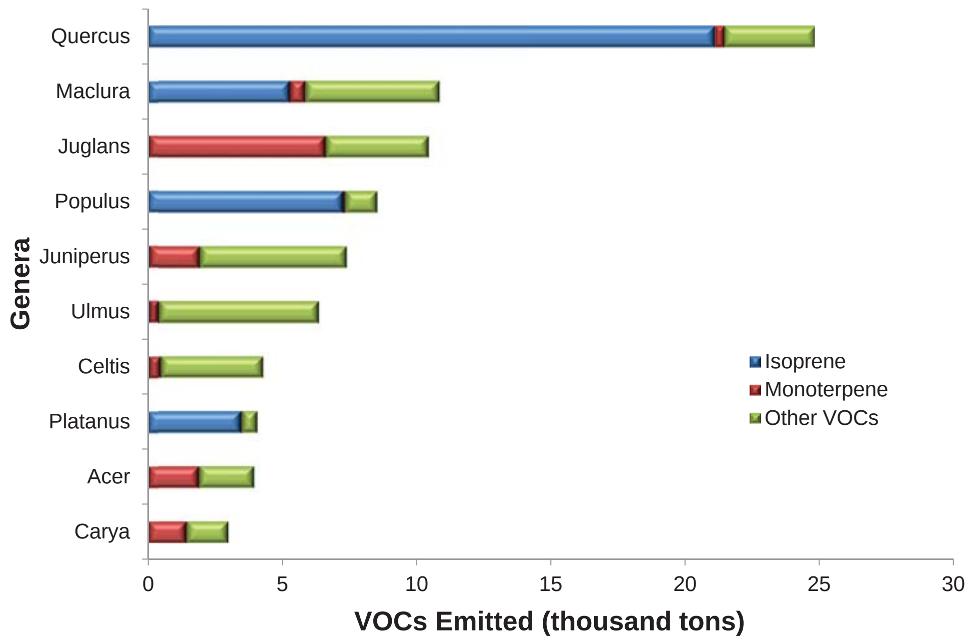


Figure 14.—Annual volatile organic compound (VOC) emissions by genera with highest total emissions, Kansas City region, 2009.

CARBON STORAGE AND SEQUESTRATION

Urban forests may play important roles in capturing and storing carbon dioxide from the atmosphere. Net carbon sequestration is positive in healthy and actively growing trees, but can be negative if emission of carbon from decomposition is greater than sequestration by healthy trees.

Climate change is an issue of global concern to many people. Tree and forest resources can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by reducing energy use in buildings, and consequently reducing carbon dioxide emissions from fossil-fuel and wood-based power sources.[21]

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new tissue growth every year. The amount of carbon annually sequestered is greater for healthier trees and larger diameter trees. Gross sequestration by trees in the Kansas City region is about 1.0 million tons of carbon/yr (3.7 million tons/year of CO_2) with an associated value of $20.7 million/year (Fig. 15).[22] Net carbon sequestration in the Kansas City region is estimated at about 667,000 tons/year (2.4 million tons/yr of CO_2) based on estimated carbon loss due to tree mortality and decomposition.

Carbon storage by trees is another way trees can influence global climate change. As trees grow, they store more carbon by holding it in their accumulated tissue. When 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 could be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions.[23] When trees die, using the wood in long-term wood products or using wood to heat buildings or produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power sources.

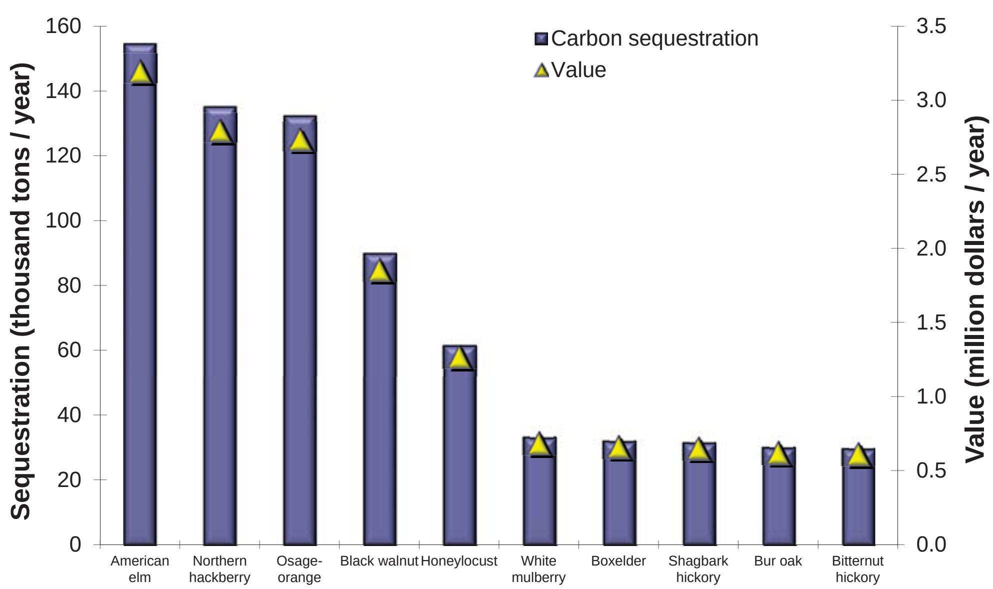


Figure 15.—Annual carbon sequestration and value for the tree species with the greatest total sequestration, Kansas City region, 2010.

Carbon storage:
Carbon currently held in tree tissue (roots, stems, and branches) in the Kansas City region's urban forest is 19.9 million tons valued at $411 million.

Carbon sequestration:
The estimated amount of carbon removed annually by the Kansas City region's trees is 1.0 million tons/year with a value of $20.7 million annually.

Trees in the Kansas City region store an estimated 19.9 million tons of carbon (72.8 million tons of CO_2) ($411 million). Of all the species sampled, Osage-orange stores the most carbon (approximately 18.7 percent of total carbon stored) and American elm annually sequesters the most carbon (15.4 percent of all sequestered carbon). Total and average carbon storage and sequestration by diameter class are illustrated in Figures 16 and 17.

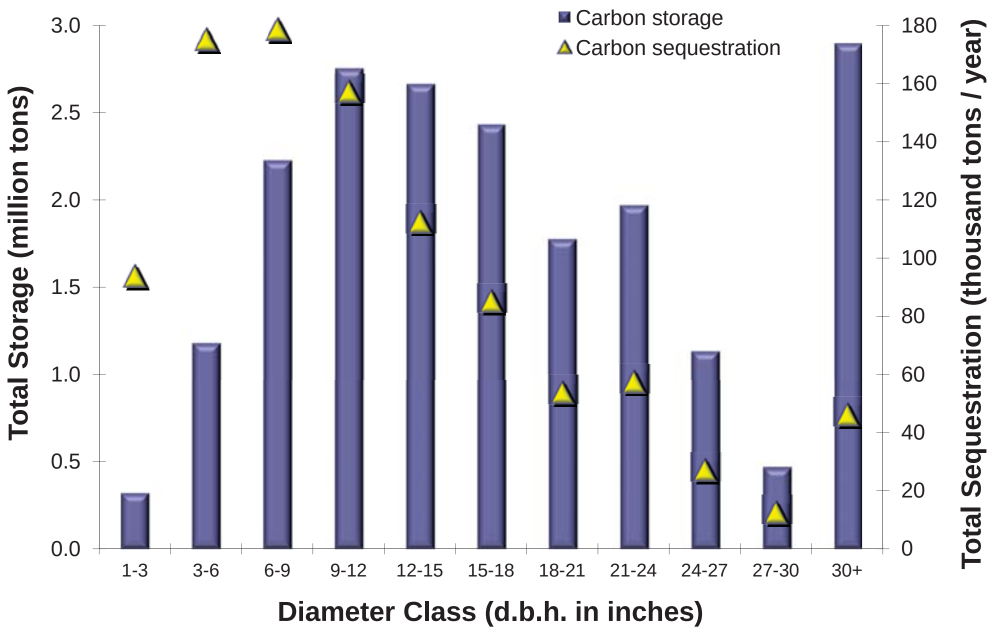


Figure 16.—Total carbon storage and sequestration by diameter class, Kansas City region, 2010.

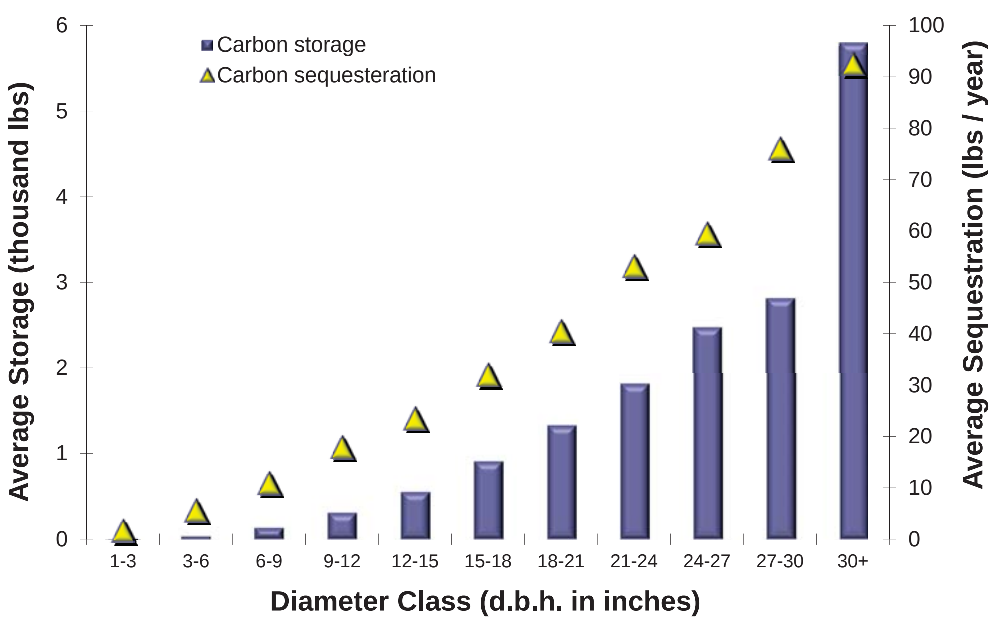


Figure 17.—Average carbon storage and sequestration by diameter class, Kansas City region, 2010.

Photo by Mid-America Regional Council, used with permission.

TREES AFFECT ENERGY USE IN BUILDINGS

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. To enhance or sustain evaporative cooling by trees in the Kansas City region, many trees are or may need to be irrigated. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space-conditioned residential buildings.[11]

Based on average energy costs in 2009, trees in the Kansas City region reduce energy costs from residential buildings by an estimated $14.0 million annually. Trees also provide an additional $500,800 in value per year by reducing amount of carbon released by fossil-fuel based power sources (a reduction of 24,100 tons of carbon emissions or 88,500 tons of carbon dioxide). Energy savings are illustrated in Tables 9 and 10. This study did not attempt to estimate energy conservation benefits associated with commercial or institutional buildings or from urban heat island reduction.

Table 9.—Annual energy savings (MBTUs, MWHs, or tons) due to trees near residential buildings, Kansas City region, 2010

	Heating	Cooling	Total
MBTU[a]	572,800	n/a	572,800
MWH[b]	8,800	53,600	62,400
Carbon avoided (tons)	11,100	13,000	24,100

[a] MBTU – Million British Thermal Units (not used for cooling)
[b] MWH – Megawatt-hour

Table 10.—Annual monetary savings[c] (dollars) in residential energy expenditures during heating and cooling seasons, Kansas City region, 2010

	Heating	Cooling	Total
MBTU[a]	7,716,000	n/a	7,716,000
MWH[b]	880,000	5,377,000	6,257,000
Carbon avoided	231,000	269,800	500,800

[a] MBTU – Million British Thermal Units (not used for cooling)
[b] MWH – Megawatt-hour
[c] Based on 2009 statewide energy costs[24]

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds.

Interactions between buildings and trees save an estimated $14.0 million/year in heating and cooling costs.

Lower energy use in residential buildings reduced carbon emissions from power plants by 24,100 tons/year ($500,800/year).

i-Tree

STRUCTURAL AND FUNCTIONAL VALUES

Urban forests have a structural value based on the characteristics of the trees themselves.

Urban forests also have functional values based on the ecosystem functions the trees perform.

Large, healthy, long-lived trees provide the greatest structural and functional values.

Urban and rural forests have a structural value based on the tree itself, including compensatory value (e.g., the cost of having to replace the tree with a similar tree) and a carbon storage value. The compensatory value[12] of the trees (Fig. 18) and forests in the Kansas City region is about $93.4 billion. The structural value of an urban or rural forest tends to increase with a rise in the number and size of healthy trees.

Urban and rural forests also have functional values (either positive or negative) based on the functions the tree performs. 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. There are many other functional values of the tree and forest resource, though they are not quantified here (e.g., reduction in air temperatures and ultraviolet radiation, improvements in water quality, aesthetics, wildlife habitat, etc.). Through proper management, tree and forest values can be increased. However, the values and benefits also can decrease as the amount of healthy tree cover declines.

Structural values:

- Compensatory value: $93.4 billion
- Carbon storage: $411 million

Annual functional values:

- Carbon sequestration: $20.7 million
- Pollution removal: $198 million
- Reduced energy costs: $14.0 million

More detailed information on the trees and forests in the Kansas City region can be found at http://nrs.fs.fed.us/data/urban, http://nrs.fs.fed.us/data/urban/state/?state=KS and http://nrs.fs.fed.us/data/urban/state/?state=MO. Additionally, information on tree statistics by diameter class can be found in Appendix VI and priority planting areas are detailed in Appendix VII.

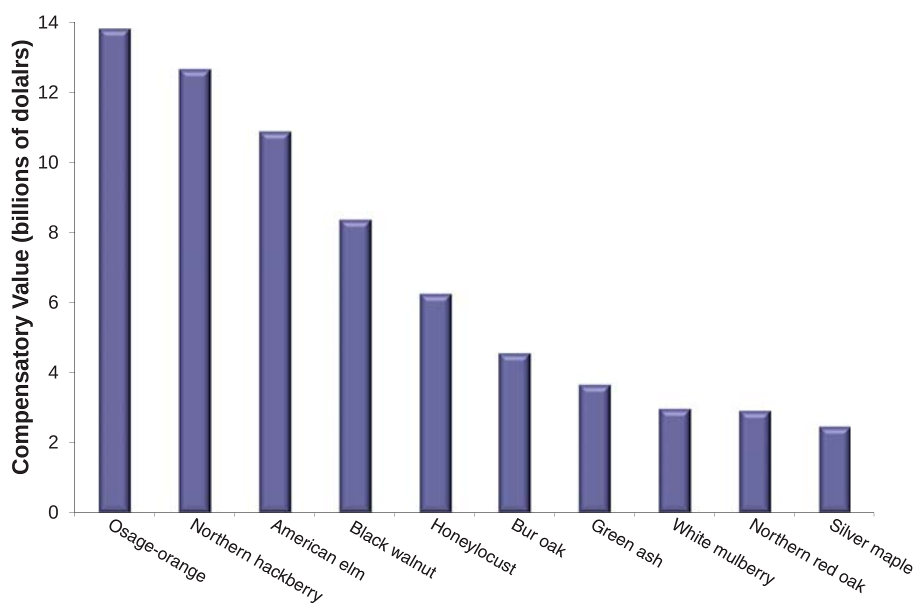


Figure 18.—Tree species with the greatest compensatory value, Greater Kansas City region, 2010.

POTENTIAL INSECT AND DISEASE IMPACTS

Various insects and diseases can infest urban and rural forests, potentially killing trees and reducing the health, value, and sustainability of the forest resource. As various pests have differing tree hosts, the potential damage or risk of each pest will differ. Five exotic pests/diseases were analyzed for their potential impact: Asian longhorned beetle, gypsy moth, emerald ash borer, Dutch elm disease, and thousand cankers disease (Fig. 19). Species host lists used for these pests/diseases can be found at: http://nrs.fs.fed.us/tools/ufore/.

Asian longhorned beetle

Photo by Kenneth R. Law
USDA APHIS PPQ, www.invasive.org

The Asian longhorned beetle (ALB)[25] is an insect that bores into and kills a wide range of hardwood species. This beetle was discovered in 1996 in Brooklyn, NY, and has subsequently spread to Long Island, Queens, and Manhattan. In 1998, the beetle was discovered in the suburbs of Chicago, IL, and successfully declared eradicated in 2006. Beetles have also been found in Jersey City, NJ (2002), Toronto/Vaughan, Ontario (2003), and Middlesex/Union counties, NJ (2004). In 2007, the beetle was found on Staten and Prall's Island, NY. Most recently, beetles were detected in Worcester, MA (2008). While this beetle is not currently in the Kansas City region, it does represent a potential loss to the area of $28.6 billion in compensatory value (42.1 percent of live tree population).

The gypsy moth (GM)[26] is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. Currently GM is located in northeast Missouri and is moving further west annually. This pest could potentially result in damage to or a loss of $16.8 billion in compensatory value of the Kansas City region's trees (11.4 percent of live tree population).

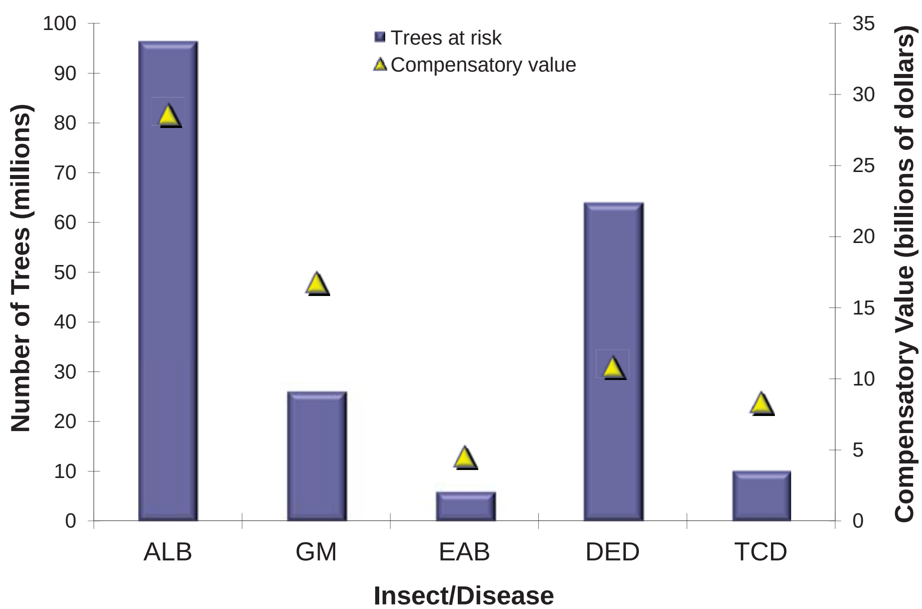


Figure 19.—Number of trees at risk and associated compensatory value for various insects/diseases, Kansas City region, 2010.

Emerald ash borer

Photo by David Cappaert
Michigan State University,
www.invasive.org

Since being discovered in Detroit in 2002, emerald ash borer (EAB)[27] has killed millions of ash trees in Illinois, Indiana, Kentucky, Maryland, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, Quebec, Virginia, West Virginia, and Wisconsin. EAB has only been detected in southeastern Missouri but could already be in the Kansas City region or transferred anytime. EAB has the potential to affect 2.6 percent of the area's live tree population ($4.6 billion in compensatory value).

American elm, one of the most important street trees in the 20th century, has been devastated by the Dutch elm disease (DED). Since first reported in the 1930s, it has killed over 50 percent of the native elm population throughout the entire United States.[28] Although some elm species have shown varying degrees of resistance, the Kansas City region possibly could lose 27.9 percent of its trees to this disease ($10.9 billion in structural value).

The thousand cankers disease is a recently discovered insect-disease complex that kills several species of walnuts, including black walnut. It is known to occur primarily in the western states of Washington, Oregon, California, Idaho, Utah, Arizona, New Mexico, and Colorado. It also has been recently discovered in Tennessee[29], the first state in the east where thousand cankers disease has been found. Trees often are killed within 3 years after initial symptoms are noticed. Tree mortality is the result of attack by the walnut twig beetle and subsequent canker development around beetle galleries caused by associated fungi.[30] In the urban and rural forests of the Kansas City region there are 10.2 million black walnuts (compensatory value of $8.4 billion) that could be lost to this disease.

Photo by Curtis Utley, CSUE, Bugwood.org

Black walnuts recently killed by thousand cankers disease.

TREE CANOPY COVER CHANGE

Tree cover in the Kansas City region is 18.6 percent, but the canopy will continually change based on numerous factors, including tree mortality, tree growth, and new tree establishment. A tree population projection model was used to estimate annual tree canopy change based on current tree data for the Kansas City region. The model was used to consider several different scenarios to show the number of trees that need to be established to meet desired tree canopy goals in the future. For several scenarios, the benefits of these canopy goals were also estimated. For details on methods and more detailed results, see Appendix VIII.

For the Kansas City region, the population projection model was used to estimate the number of new trees required annually to maintain existing tree canopy cover or to increase canopy cover by 5, 10, or 20 percent over 10, 25, or 50 years. The scenarios below are based on an average population mortality of 4 percent.

In Appendix VIII, additional scenario results are detailed that cover results for average mortality rates of 2, 3, and 5 percent. Multiple mortality rates are estimated as the true average mortality rate for the region is unknown and the multiple estimates will illustrate a range of possible values. Long-term monitoring of tree populations can help determine actual average mortality rates for the Kansas City region.

Two other scenarios are detailed in Appendix VIII:

1) Annual tree establishment needed to sustain tree cover given an emerald ash borer infestation that kills off all ash trees in 10 years

2) Annual tree establishment needed to sustain tree cover given a thousand cankers disease outbreak that kills off all black walnut trees in 10 years

Having too many trees in one age class can lead to a significant canopy cover loss in a relatively short time period as many of these trees can die within a relatively short time frame.

Note that the estimated number of trees required is not the number of trees needed to be planted as many new trees are established annually through natural regeneration, particularly in more rural areas. Human activities in urban areas (development, mowing) often preclude the establishment of tree cover. Decreasing activities such as mowing, as well as sustaining pervious surfaces can facilitate more natural regeneration.

Model Scenarios

In modeling tree establishment rates for the Kansas City region, each land use was modeled separately. Table 11 details the estimated annual tree establishment rates needed (number of trees per year) in each land use to either maintain or increase tree cover 10, 25, or 50 years in the future given an average 4 percent tree mortality rate. It should be noted that increasing canopy cover in too short of a time frame can lead to nonsustainable canopy cover levels. Though planting too many trees in a short time can reach a canopy goal, canopy cover will surpass the goal through time. Having too many trees in one age class can lead to a significant canopy cover loss in a relatively short time period as many of these trees can die within a relatively short time frame. Also, for shorter time frames, estimated canopy growth can offset the need to establish new trees, thus tree planting estimates will be relatively low. However, if no new trees are established, the population will become unstable in the long run as there will be missing age classes in the future to sustain canopy cover (e.g., if no new trees were ever established, tree cover would be sustained for a while due to canopy growth, but eventually the tree cover would drop to zero). Thus, long-term estimates of establishment (e.g., 50-year estimates) are likely the most reasonable estimates for tree establishment. However, most of the trees to be established in the region will likely not need to be planted, but will occur through natural regeneration.

Table 11.—Estimated number of trees to be established annually for various cover and year scenarios, Kansas City region, assuming a 4 percent annual mortality

Scenario	10 Years	25 Years	50 Years
Agriculture & Vacant Land Use 2010 canopy cover: 11.8%			
Maintain canopy cover	0	40,000	960,000
Increase cover by 5%	1,900,000	1,400,000	1,700,000
Increase cover by 10%	5,500,000	2,500,000	2,500,000
Increase cover by 20%	13,000,000	5,400,000	4,200,000
Commercial, Utilities, & Transportation Land Use 2010 canopy cover: 9.6%			
Maintain canopy cover	0	0	18,000
Increase cover by 5%	130,000	40,000	75,000
Increase cover by 10%	600,000	160,000	138,000
Increase cover by 20%	1,450,000	435,000	265,000
Golf, Park, & Institutional Land Use 2010 canopy cover: 34.3%			
Maintain canopy cover	0	28,000	350,000
Increase cover by 5%	0	180,000	400,000
Increase cover by 10%	300,000	280,000	460,000
Increase cover by 20%	760,000	480,000	610,000
Residential Land Use 2010 canopy cover: 31.4%			
Maintain canopy cover	0	43,000	1,250,000
Increase cover by 5%	400,000	900,000	1,800,000
Increase cover by 10%	2,200,000	1,650,000	2,200,000
Increase cover by 20%	6,400,000	3,300,000	3,100,000
Water & Other Land Use 2010 canopy cover: 49.2%			
Maintain canopy cover	0	0	350,000
Increase cover by 5%	0	0	480,000
Increase cover by 10%	0	0	640,000
Increase cover by 20%	500,000	470,000	1,000,000
All Land Uses 2010 canopy cover: 18.6%			
Maintain canopy cover	0	111,000	2,928,000
Increase cover by 5%	2,165,000	2,520,000	4,555,000
Increase cover by 10%	8,500,000	4,590,000	5,938,000
Increase cover by 20%	22,090,000	10,085,000	9,175,000

The projections of annual tree establishment are rough estimates based on average growth and mortality rates. As growth rates increase, the number of trees needed to be established decreases as canopy growth offsets the need for more new trees. Given the existing assumptions about growth and mortality, canopy cover can be sustained for about 10 years with no new trees added as existing growth can compensate for the loss of canopy due to mortality during this period. However, if no new trees are established during this period, the canopy cover will decline more rapidly in the future due to a lack of trees in this age class. No new trees being established during any year is not an issue as many trees are established due to natural regeneration, but this regeneration varies by land-use type.

Ecosystem Services from Increased Tree Cover

Werner Park, Merriam KS.
Photo by Mid-America Regional Council, used with permission.

Increasing or sustaining tree canopy cover through time will produce environmental benefits for the Kansas City region. As an example, the benefits provided by the regional forest over the next 25 years was estimated for the model scenario of increasing canopy cover by 10 percent (increasing tree cover from 18.6 to 28.6 percent by establishing about 4.6 million trees per year with an average 4 percent mortality rate). Three ecosystem services were estimated: air pollution removal, carbon sequestration, and volatile organic compound (VOC) emissions.

For air pollution removal, annual air pollution removal over the 25 years was summed to estimate the total air pollution removal effects during the 25-year period. This simulation used the meteorological and pollution conditions of 2009 for all simulation years. Total pollution removal over the 25-year period is estimated at 1.0 million tons ($7.8 billion at nondiscounted current value), increasing from 26,000 tons per year ($198 million/year) in 2009 to 46,000 ton per year in 25 years ($349 million/year).

For carbon sequestration, the estimated tree population and diameter distribution in year 25 was used to estimate future carbon storage. This result was contrasted with the current carbon estimate to determine carbon sequestration over the 25 year period. Total carbon storage was estimated to increase from 19.9 million tons to 29.3 million tons, for a 25-year sequestration rate of 9.4 million tons ($194 million).

For VOC emissions, annual emissions over the 25 years were summed to estimate the total VOC emissions during the 25-year period. This simulation used the meteorological conditions of 2009 for all simulation years. Total VOC emissions over the 25-year period are estimated at 3.1 million tons, increasing from 91,000 ton per year in 2009 to 135,000 ton per year in 25 years. These values will fluctuate annually based on local air temperatures, but assume constant 2009 meteorological conditions over the next 25 years.

All of the projected estimates of the number of new trees required and their associated ecosystem services should be considered rough estimates due to the numerous assumptions needed to attain these estimates. The numbers provided here are first-order estimates and will likely change through time as mortality, growth, and establishment rates in the Kansas City region differ from projected rates. However, these estimates provide a broad estimate of potential needs and impacts of attaining future canopy goals.

BLUE RIVER WATERSHED ANALYSIS

The Blue River watershed (184,958 acres) in the Kansas City region was analyzed using the i-Tree Hydro model.[2] The i-Tree Hydro model (formerly known as UFORE-Hydro) simulates the stream flow hydrograph using hourly precipitation data, digital elevation data (Fig. 20), and land-cover parameters. The model flow is calibrated against actual stream flow values. Model methods and calibration information are detailed in Appendix IX.

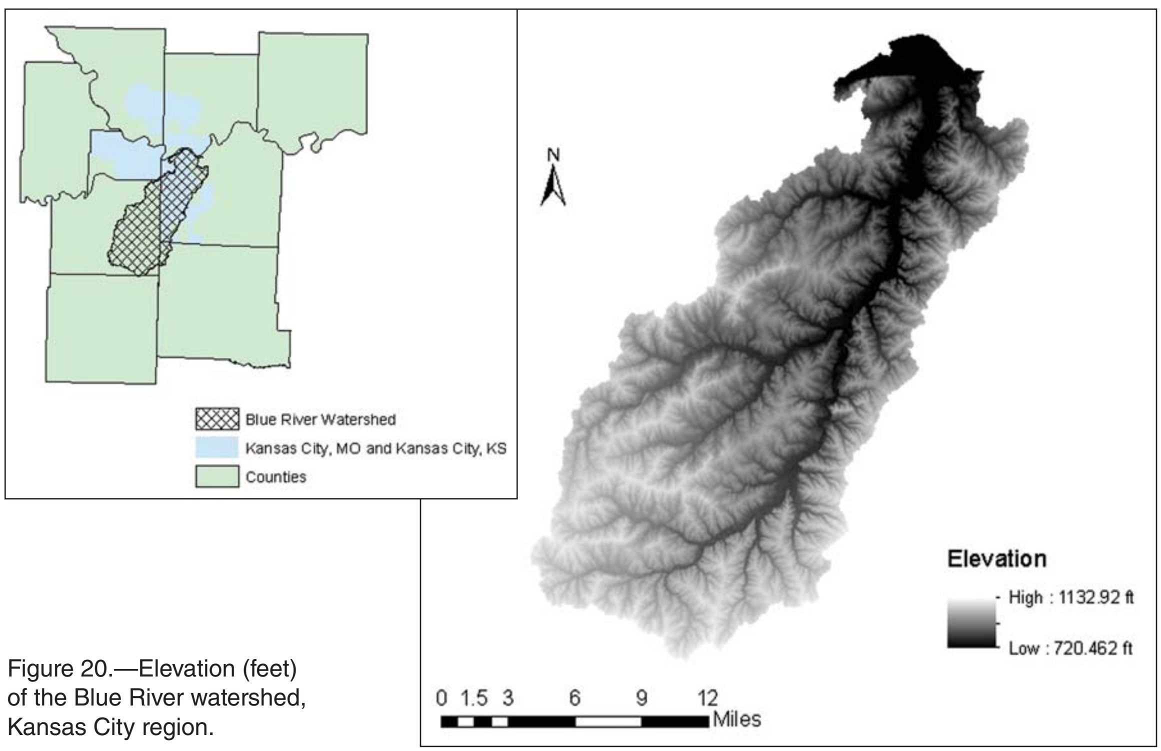


Figure 20.—Elevation (feet) of the Blue River watershed, Kansas City region.

Loss of the current tree cover in the Blue River watershed of the greater Kansas City region would increase flow over a 6.5-month period by an average of 2.3 percent (63.4 million ft^3).

Tree Cover Effects

Loss of current tree cover in the Blue River watershed would increase total flow during the simulation period by an average of 2.3 percent (63.4 million ft^3). Increasing canopy cover from 34.6 percent to 40 percent would reduce overall flow by another 0.4 percent (10,800,000 ft^3) during this 6.5-month period (Fig. 21). Increasing tree cover reduces flow from both pervious and impervious areas (Fig. 22).

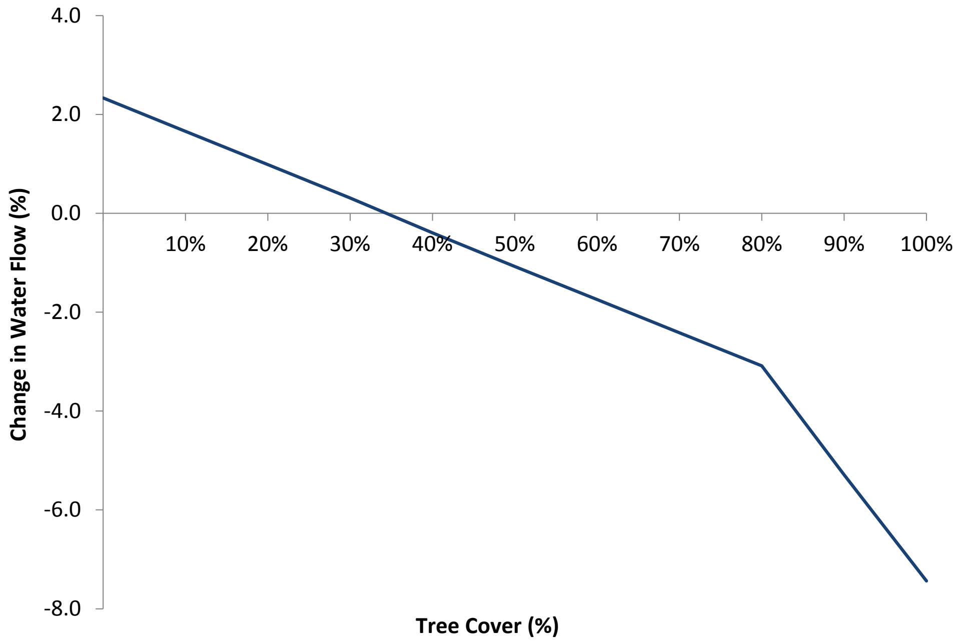


Figure 21.—Percent change in total flow with changes in percent tree cover, Blue River watershed.

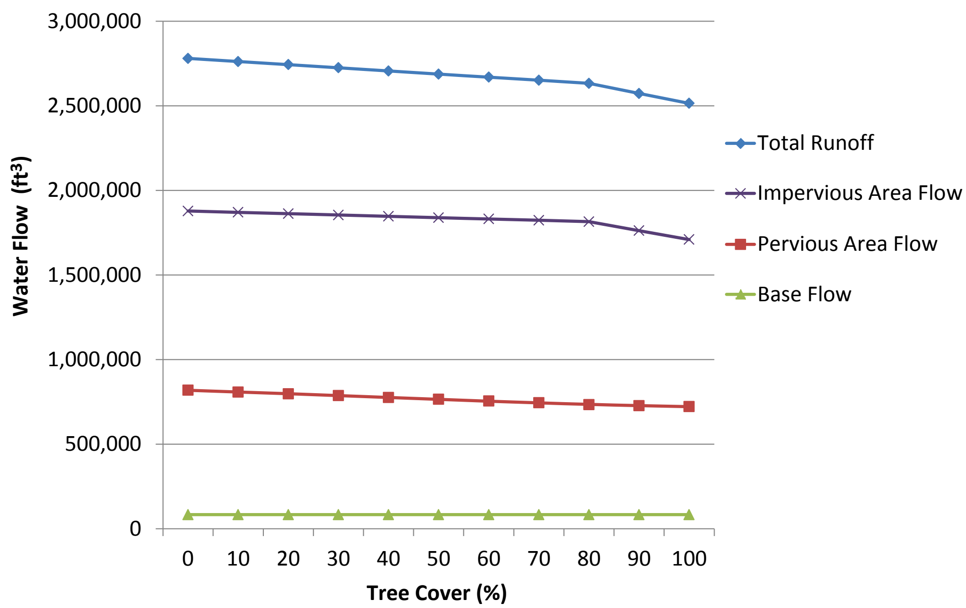


Figure 22.—Changes in total runoff and components of total runoff (pervious area flow, impervious area flow, and base flow) with changes in percent tree cover in the Blue River watershed (Impervious cover held at 31.5 percent).

Impervious Cover Effects

Removal of current impervious cover would reduce total flow during the simulation period by an average of 65.4 percent (1.78 billion ft^3). Increasing impervious cover from 31.5 percent to 40 percent of the watershed would increase total flow another 53.7 percent (1.46 billion ft^3) during this 6.5-month period (Fig. 23). Increasing impervious cover reduces base flow and pervious runoff while significantly increasing flow from impervious surfaces (Fig. 24).

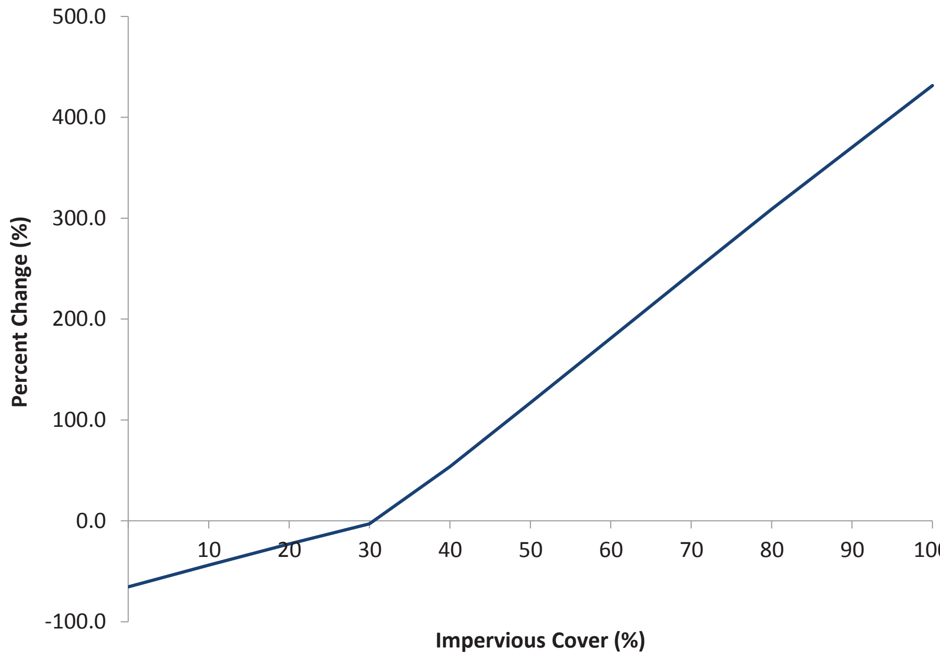


Figure 23.—Percent change in total flow with changes in percent impervious cover, Blue River watershed.

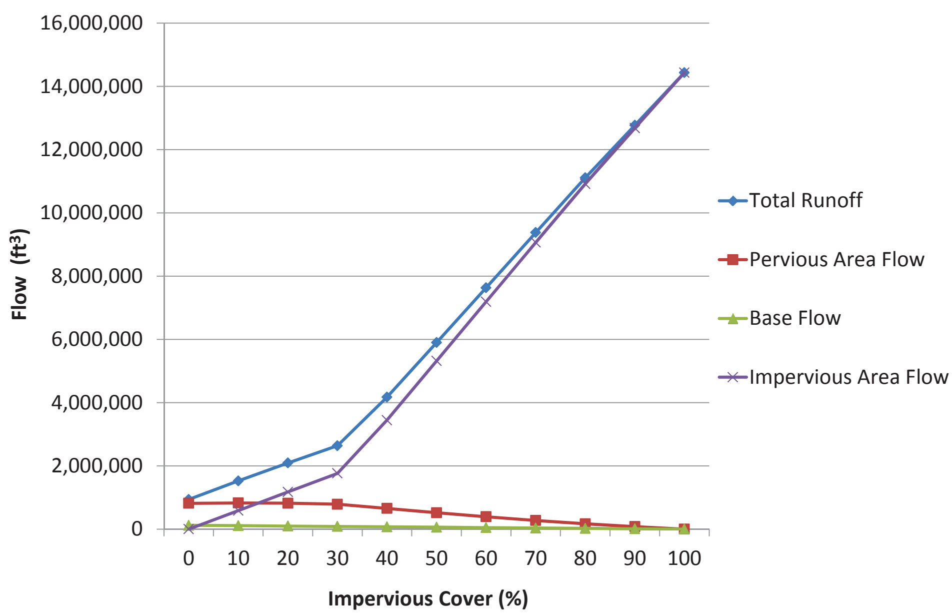


Figure 24.—Changes in total runoff and components of total runoff (pervious area runoff, impervious area runoff and base flow) with changes in percent impervious cover in the Blue River watershed (tree cover maintained at 34.6 percent).

Increasing tree cover will reduce stream flow, but the dominant cover type influencing stream flow is impervious surfaces. Under current cover conditions, increasing impervious cover had a 32 times greater impact on flow relative to tree cover. Increasing impervious cover by 1 percent averaged a 3.2 percent increase in stream flow, while increasing tree cover by 1 percent averaged only a 0.1 percent decrease in stream flow. The interactions between changing both tree and impervious cover are illustrated in Figures 25 and 26 for total flow during the simulation period and for changes in percent flow.

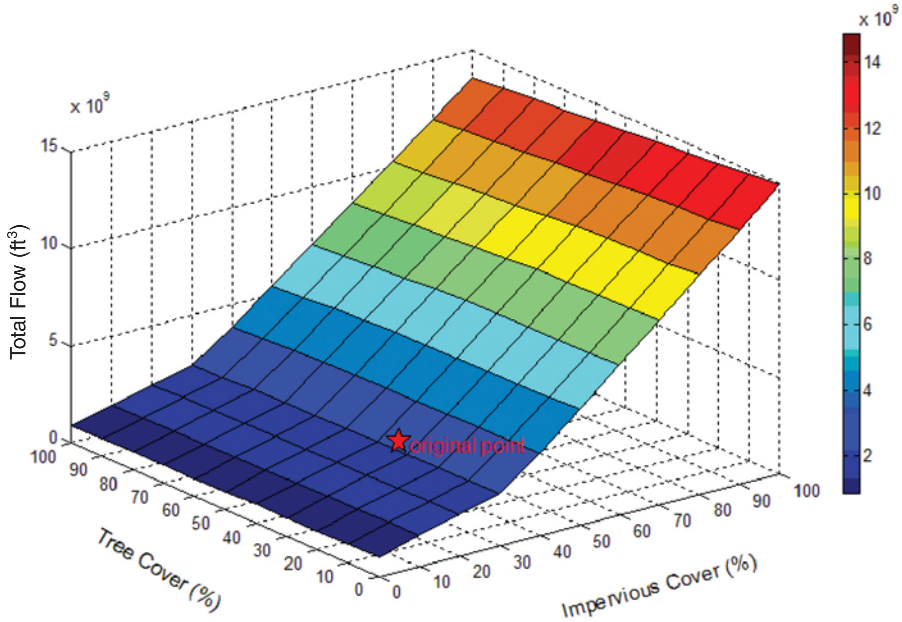


Figure 25.—Changes in total flow during simulation period based on changes in percent impervious and percent tree cover, Blue River watershed. Red star indicates current conditions.

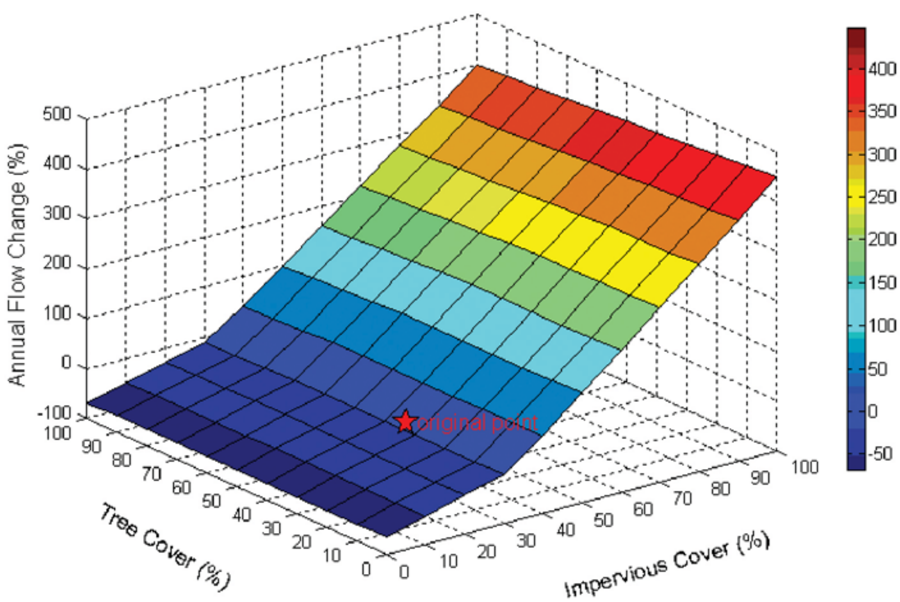


Figure 26.—Percent change in total flow during simulation period based on changes in percent impervious and percent tree cover, Blue River watershed. Red star indicates current conditions.

Table 12.—Estimated reduction in chemical constituents in Blue River watershed due to existing tree cover during simulation period based on median and mean pooled event mean concentration values		
	Reduction (t)	
Constituent	Median	Mean
Total suspended solids	107.8	155.0
Biochemical oxygen demand	22.7	27.9
Chemical oxygen demand	88.4	104.4
Total phosphorus	0.5	0.6
Soluble phosphorus	0.2	0.3
Total Kjeldhal nitrogen[a]	2.9	3.4
Nitrite and nitrate	1.1	1.3
Copper	21.9	26.7

[a] Sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+)

Indian Creek, a major tributary of the Blue River.
Photo by Mid-America Regional Council, used with permission.

During the simulation period, the total rainfall recorded was 26.4 inches. Since that amount is assumed to have fallen over the entire 184,958 acre watershed, a total of 17.7 billion cubic feet of rain fell on the watershed during the simulation time. The total modeled flow in the Blue River watershed throughout the simulation time for the base case scenario (no landscape change) was 2.72 billion ft^3. The total flow is made up of surface runoff and baseflow (water that travels underground to the stream). Runoff from impervious and pervious areas are the biggest contributors to stream flow with 68.1 percent and 28.8 percent of total flow generated from impervious and pervious runoff respectively. Base flow was estimated to generate 3.1 percent of total flow. Areas of tree canopies intercepted about 9.5 percent of the total rainfall, but as only 34.6 percent of watershed is under tree cover, interception of total precipitation in the watershed by trees was only 3.3 percent (581 million ft^3). Areas of short vegetation, including shrubs, intercepted about 3.7 percent of the total rainfall, but as only 37.6 percent of watershed in under short vegetation, interception of total precipitation in the watershed by short vegetation was only 1.4 percent (245 million ft^3). About 80 percent of total precipitation is estimated to re-enter the atmosphere through evaporation or evapotranspiration before it enters the stream.

Based on these changes in flow rates and national EMC values, the current tree cover is estimated to reduce total suspended solids during the simulation period by around 108 to 155 tons. Other chemical constituents are also reduced (Table 12).

CONCLUSION

Data from this report provide the basis for a better understanding of the urban and rural forest resource and the ecosystem services and values provided by this resource. Managers and citizens can use these data to help improve long-term management plans and policies to sustain a healthy tree and forest population and ecosystem services for future generations. Improved planning and management to sustain healthy tree populations can lead to improved environmental quality and quality of life for residents of the Kansas City region.

More information on trees in the Kansas City region can be found at: http://nrs.fs.fed.us/data/urban.

APPENDIX I. SPECIES SAMPLED IN THE KANSAS CITY REGION

Table 13.—Tree species sampled in the regional forest, Kansas City region, 2010

Genus	Species	Common Name	Number of Trees	Pop %	Leaf Area %	IV[a]	Med Dbh (in)	Ave Dbh (in)	Basal Area (ft^2)	Value ($ Millions)
Acer	*negundo*	boxelder	7,160,350	2.9	2.3	5.2	5.1	6.0	2,322,715	2,133.9
Acer	*platanoides*	Norway maple	166,520	0.1	0.8	0.9	4.0	13.0	247,492	496.7
Acer	*rubrum*	red maple	582,820	0.2	0.5	0.7	5.8	7.1	222,970	478.0
Acer	*saccharinum*	silver maple	2,331,280	0.9	2.8	3.7	9.0	11.6	3,196,224	2,461.7
Acer	*saccharum*	sugar maple	666,080	0.3	0.3	0.6	5.5	4.9	128,514	243.0
Aesculus	*glabra*	Ohio buckeye	3,996,480	1.6	0.0	1.6	1.7	1.9	142,969	188.2
Asimina	*triloba*	pawpaw	3,496,920	1.4	0.3	1.7	1.5	1.6	88,544	172.4
Betula	*nigra*	river birch	1,082,380	0.4	0.1	0.5	2.3	2.4	55,402	90.1
Carya	*alba*	mockernut hickory	666,080	0.3	0.1	0.4	2.5	2.5	38,146	34.3
Carya	*cordiformis*	bitternut hickory	9,158,590	3.7	2.6	6.3	2.7	3.9	1,486,742	1,742.3
Carya	*illinoinensis*	pecan	333,040	0.1	0.1	0.2	5.0	5.3	66,755	82.5
Carya	*laciniosa*	shellbark hickory	499,560	0.2	0.1	0.3	1.7	3.4	78,562	64.2
Carya	*ovata*	shagbark hickory	6,077,970	2.4	2.2	4.6	3.9	5.4	1,753,518	1,859.6
Catalpa	*speciosa*	northern catalpa	83,260	0.0	0.1	0.1	16.5	16.5	131,239	87.4
Celtis	*occidentalis*	northern hackberry	34,969,160	14.0	15.8	29.8	3.5	4.8	8,090,512	12,669.4
Crataegus	*phaenopyrum*	Washington hawthorn	166,520	0.1	0.0	0.1	2.0	2.5	9,082	9.1
Diospyros	*virginiana*	common persimmon	249,780	0.1	0.3	0.4	7.5	7.5	109,896	174.7
Fraxinus	*americana*	white ash	2,248,020	0.9	1.2	2.1	3.5	5.5	659,280	894.2
Fraxinus	*pennsylvanica*	green ash	3,996,480	1.6	2.5	4.1	5.3	7.1	1,988,200	3,662.4
Gleditsia	*triacanthos*	honeylocust	16,651,980	6.7	2.2	8.9	3.1	5.0	5,183,017	6,255.8
Gymnocladus	*dioicus*	Kentucky coffeetree	499,560	0.2	0.3	0.5	5.0	7.2	225,241	505.0
Juglans	*nigra*	black walnut	10,157,710	4.1	10.4	14.5	7.9	8.8	6,400,426	8,377.8
Juniperus	*virginiana*	eastern redcedar	12,488,990	5.0	3.4	8.4	2.3	3.1	1,210,884	1,558.6
Liriodendron	*tulipifera*	tulip tree	83,260	0.0	0.4	0.4	11.5	11.5	65,392	138.1
Maclura	*pomifera*	Osage-orange	17,900,880	7.2	10.7	17.9	7.4	8.7	12,625,269	13,825.0
Magnolia	*x soulangiana*	saucer magnolia	166,520	0.1	0.2	0.3	8.5	8.5	73,566	129.6
Malus	*species*	apple spp	915,860	0.4	0.4	0.8	2.8	4.3	161,665	262.6
Morus	*alba*	white mulberry	7,576,650	3.0	2.7	5.7	3.6	5.2	2,221,671	2,971.3
Ostrya	*virginiana*	eastern hophornbeam	2,914,100	1.2	0.6	1.8	2.5	2.8	197,079	272.9
Other	*species*	other species	832,600	0.3	0.0	0.3	4.0	7.1	419,601	0.0
Pinus	*strobus*	eastern white pine	249,780	0.1	0.1	0.2	5.5	5.5	49,953	100.6
Platanus	*occidentalis*	American sycamore	1,082,380	0.4	2.6	3.0	7.5	12.0	1,307,847	1,376.6
Populus	*deltoides*	eastern cottonwood	1,581,940	0.6	3.6	4.2	19.5	16.9	3,201,952	1,964.8
Prunus	*cerasifera*	cherry plum	166,520	0.1	0.0	0.1	6.5	6.5	44,503	91.5
Prunus	*persica*	peach	166,520	0.1	0.0	0.1	4.0	6.0	44,049	48.9
Prunus	*serotina*	black cherry	2,830,840	1.1	0.6	1.7	4.0	4.8	581,445	559.4
Prunus	*serrulata*	Kwanzan cherry	249,780	0.1	0.2	0.3	9.5	9.8	147,587	183.9
Pyrus	*calleryana*	callery pear	333,040	0.1	0.1	0.2	7.0	6.8	103,992	174.6
Quercus	*alba*	white oak	1,248,900	0.5	0.5	1.0	8.5	9.4	896,406	1,641.7
Quercus	*bicolor*	swamp white oak	166,520	0.1	0.0	0.1	3.0	5.0	33,150	66.0
Quercus	*imbricaria*	shingle oak	1,248,900	0.5	0.8	1.3	9.3	8.0	643,933	922.8

continued

Table 13.—continued

Genus	Species	Common Name	Number of Trees	Pop %	Leaf Area %	IV[a]	Med Dbh (in)	Ave Dbh (in)	Basal Area (ft^2)	Value ($ Millions)
Quercus	*macrocarpa*	bur oak	5,328,630	2.1	2.6	4.7	3.4	6.2	2,596,484	4,558.8
Quercus	*muehlenbergii*	chinkapin oak	5,495,150	2.2	1.0	3.2	2.5	3.9	869,880	1,194.9
Quercus	*palustris*	pin oak	1,332,160	0.5	1.3	1.8	8.0	10.0	1,281,509	2,198.4
Quercus	*rubra*	northern red oak	2,248,020	0.9	1.6	2.5	4.7	8.8	2,046,024	2,916.5
Quercus	*stellata*	post oak	83,260	0.0	0.0	0.0	3.5	3.5	7,266	6.9
Quercus	*velutina*	black oak	166,520	0.1	0.2	0.3	3.0	10.0	151,220	265.9
Salix	*alba*	white willow	83,260	0.0	0.0	0.0	19.5	19.5	181,646	72.9
Salix	*nigra*	black willow	2,830,840	1.1	1.0	2.1	2.9	4.3	531,313	392.6
Tilia	*americana*	American basswood	1,998,240	0.8	2.9	3.7	7.0	8.4	1,361,145	1,940.5
Ulmus	*americana*	American elm	72,103,080	28.9	17.7	46.6	2.8	3.9	11,717,067	10,894.0
Ulmus	*pumila*	Siberian elm	333,040	0.1	0.1	0.2	2.0	4.0	51,769	34.9

[a] IV = importance value (% population + % leaf area)

Table 14.—Shrub species[a] by land use, Kansas City region, 2010

				Per Unit Area		City Total	
Land Use	Genus	Species	Common Name	Leaf Area (ft^2/ac)	Leaf Biomass (lb/ac)	Leaf Area (ac)	Leaf Biomass (tons)
Ag / Vacant	*Cornus*	*racemosa*	gray dogwood	4,901.69	47.92	181,756.88	38,691.54
	Cercis	*canadensis*	eastern redbud	1,090.81	14.31	40,447.80	11,551.32
	Rosa	*multiflora*	multiflora rose	934.29	14.31	34,643.42	11,551.63
	Symphoricarpos	*orbiculatus*	coralberry	749.94	8.58	27,808.63	6,928.38
	Juniperus	*virginiana*	eastern redcedar	303.23	17.25	11,245.52	13,929.70
	Toxicodendron	*radicans*	poison ivy	208.53	3.19	7,731.76	2,578.21
	Ostrya	*virginiana*	eastern hophornbeam	207.79	2.77	7,704.58	2,242.88
	Asimina	*triloba*	pawpaw	172.72	5.93	6,404.83	4,792.16
	Elaeagnus	*angustifolia*	Russian olive	138.92	2.12	5,152.04	1,717.81
	Maclura	*pomifera*	Osage-orange	87.47	1.80	3,244.42	1,454.17
	Lonicera	*maackii*	amur honeysuckle	71.00	0.71	2,631.62	578.41
	Carya	*ovata*	shagbark hickory	66.47	1.00	2,466.06	805.22
	Carya	*cordiformis*	bitternut hickory	52.10	0.67	1,932.32	541.64
	Celtis	*occidentalis*	northern hackberry	49.49	0.53	1,835.95	425.86
	Rhus	*glabra*	smooth sumac	48.31	0.54	1,791.48	440.46
	Morus	*alba*	white mulberry	37.77	0.56	1,401.06	456.88
	Ulmus	*americana*	American elm	27.14	0.40	1,008.17	326.61
	Gleditsia	*triacanthos*	honeylocust	25.66	0.55	951.34	444.50
	Alnus	*serrulata*	hazel alder	17.42	0.26	647.40	210.18
	Quercus	*alba*	white oak	10.59	0.16	392.89	127.12
	Acer	*saccharinum*	silver maple	9.54	0.11	353.35	82.91
	Prunus	*serotina*	black cherry	8.06	0.12	298.99	103.43
	Quercus	*muehlenbergii*	chinkapin oak	7.14	0.14	264.40	116.24
	Ribes	*missouriense*	Missouri gooseberry	5.49	0.08	202.62	67.60
	Ulmus	*pumila*	Siberian elm	1.18	0.02	42.01	13.01

continued

Table 14.—continued

Land Use	Genus	Species	Common Name	Per Unit Area Leaf Area (ft^2/ac)	Per Unit Area Leaf Biomass (lb/ac)	City Total Leaf Area (ac)	City Total Leaf Biomass (tons)
	Aesculus	*glabra*	Ohio buckeye	0.00	0.00	0.00	0.00
Total				9,232.69	124.08	342,354.58	100,177.91
Comm/Util/Trans	*Wisteria*	*species*	wisteria spp	15,357.92	235.18	58,708.49	19,576.12
	Cornus	*racemosa*	gray dogwood	2,315.09	22.63	8,851.12	1,883.95
	Cercis	*canadensis*	eastern redbud	654.33	8.58	2,500.65	714.36
	Ligustrum	*species*	privet spp	526.04	9.80	2,011.39	815.29
	Juniperus	*virginiana*	eastern red cedar	235.23	13.38	899.44	1,113.97
	Buxus	*species*	boxwood spp	74.36	1.14	284.17	94.79
	Symphoricarpos	*orbiculatus*	coralberry	21.08	0.24	81.54	20.09
	Carya	*ovata*	shagbark hickory	14.68	0.22	56.83	18.34
Total				19,198.77	291.17	73,391.17	24,236.89
Residential	*Cornus*	*racemosa*	gray dogwood	10,725.52	104.86	176,303.38	37,530.64
	Lonicera	*species*	honeysuckle spp	3,380.98	34.11	55,575.26	12,209.60
	Cercis	*canadensis*	eastern redbud	3,012.11	39.51	49,511.43	14,140.19
	Symphoricarpos	orbiculatus	coralberry	2,553.28	29.22	41,969.94	10,456.69
	Lonicera	*maackii*	amur honeysuckle	2,387.22	24.09	39,239.48	8,620.82
	Rosa	*multiflora*	multiflora rose	1,134.28	17.37	18,646.17	6,217.01
	Juniperus	*virginiana*	eastern redcedar	542.46	30.86	8,917.84	11,046.83
	Celtis	*occidentalis*	northern hackberry	530.09	5.65	8,712.75	2,021.84
	Taxus	species	yew spp	414.74	13.30	6,817.49	4,761.55
	Elaeagnus	*angustifolia*	Russian olive	342.35	5.25	5,626.47	1,876.45
	Staphylea	*species*	bladdernut spp	214.49	3.28	3,526.12	1,175.64
	Carya	*cordiformis*	bitternut hickory	155.77	2.01	2,559.96	717.88
	Crataegus	*phaenopyrum*	Washington hawthorn	152.77	2.36	2,510.54	843.49
	Morus	alba	white mulberry	130.73	1.96	2,149.77	700.97
	Maclura	*pomifera*	Osage-orange	108.90	2.24	1,791.48	802.62
	Ribes	*missouriense*	Missouri gooseberry	63.82	0.98	1,050.18	349.76
	Picea	*glauca*	white spruce	63.21	2.08	1,040.29	744.57
	Ligustrum	*obtusifolium*	border privet	58.94	1.10	968.63	392.75
	Viburnum	prunifolium	black haw	55.28	0.85	909.33	302.92
	Syringa	*vulgaris*	common lilac	53.84	1.06	884.62	380.81
	Quercus	*palustris*	pin oak	48.66	0.90	800.60	322.68
	Asimina	*triloba*	pawpaw	47.31	1.62	778.37	581.79
	Picea	*abies*	Norway spruce	43.74	1.49	719.06	534.25
	Carya	ovata	shagbark hickory	33.11	0.50	543.62	177.69
	Ilex	*glabra*	inkberry	32.54	0.89	536.21	319.03
	Ulmus	*americana*	American elm	31.28	0.46	513.97	166.79
	Acer	*saccharum*	sugar maple	28.53	0.35	469.49	125.93
	Betula	*nigra*	river birch	17.03	0.27	279.22	96.77
	Berberis	species	barberry spp	15.42	0.23	254.51	84.49
	Fraxinus	*americana*	white ash	14.16	0.16	232.27	58.97

continued

Table 14.—continued

Land Use	Genus	Species	Common Name	Per Unit Area Leaf Area (ft²/ac)	Per Unit Area Leaf Biomass (lb/ac)	City Total Leaf Area (ac)	City Total Leaf Biomass (tons)
	Salix	*nigra*	black willow	13.20	0.17	217.45	61.34
	Gymnocladus	*dioicus*	Kentucky coffeetree	12.68	0.20	207.56	69.41
	Pyrus	*species*	pear spp	11.89	0.18	195.21	65.15
	Rosa	rugosa	rugosa rose	10.54	0.16	172.97	57.70
	Gleditsia	*triacanthos*	honeylocust	9.45	0.21	155.67	72.49
	Rhus	*glabra*	smooth sumac	4.88	0.05	79.07	19.69
	Physocarpus	*species*	ninebark spp	3.83	0.06	61.78	20.92
	Euonymus	*kiautschovica*	creeping strawberry bush	3.31	0.05	54.36	18.03
	Acer	palmatum	Japanese maple	1.96	0.03	32.12	8.00
	Prunus	*serotina*	black cherry	1.48	0.03	24.71	8.39
	Acer	*saccharinum*	silver maple	1.39	0.02	22.24	5.38
	Fraxinus	*pennsylvanica*	green ash	1.22	0.02	19.77	5.83
	Rhododendron	*azalea*	azalea	1.18	0.04	19.77	17.26
	Hibiscus	syriacus	rose-of-sharon	0.00	0.00	0.00	0.00
Total				26,469.44	330.21	435,098.62	118,190.98
Golf/Park/Inst	*Symphoricarpos*	*orbiculatus*	coralberry	8,073.62	92.38	29,320.89	7,305.05
	Elaeagnus	*angustifolia*	Russian olive	5,159.35	79.00	18,737.59	6,247.57
	Cornus	*racemosa*	gray dogwood	3,874.13	37.87	14,069.87	2,994.99
	Wisteria	*species*	wisteria spp	3,229.87	49.46	11,729.84	3,911.10
	Staphylea	*species*	bladdernut spp	2,448.99	37.50	8,893.13	2,965.57
	Carya	*cordiformis*	bitternut hickory	290.16	3.74	1,052.65	295.41
	Rosa	*multiflora*	multiflora rose	184.26	2.82	669.64	223.13
	Carya	*illinoinensis*	pecan	40.64	0.58	148.26	45.78
	Lonicera	*maackii*	amur honeysuckle	11.28	0.12	42.01	9.00
Total				23,312.27	303.47	84,661.40	23,997.59
Other	*Cornus*	*racemosa*	gray dogwood	13,526.14	132.24	54,292.81	11,557.47
	Cercis	*canadensis*	eastern redbud	6,998.93	91.80	28,092.80	8,023.07
	Rosa	*multiflora*	multiflora rose	4,663.37	71.41	18,717.83	6,241.40
	Lonicera	*maackii*	amur honeysuckle	2,812.07	28.37	11,287.53	2,479.74
	Alnus	*serrulata*	hazel alder	1,724.27	25.75	6,921.27	2,250.22
	Symphoricarpos	*orbiculatus*	coralberry	1,688.42	19.32	6,777.95	1,688.48
	Asimina	*triloba*	pawpaw	1,496.93	51.43	6,009.47	4,495.29
	Carya	*cordiformis*	bitternut hickory	1,300.16	16.74	5,218.75	1,463.02
	Ostrya	*virginiana*	eastern hophornbeam	1,087.32	14.53	4,363.79	1,270.62
	Juniperus	*virginiana*	eastern redcedar	560.06	31.86	2,248.61	2,784.92
	Fraxinus	*pennsylvanica*	green ash	548.17	7.32	2,199.19	640.01
	Ulmus	*americana*	American elm	322.13	4.80	1,292.33	419.41
	Ribes	*missouriense*	Missouri gooseberry	203.08	3.11	815.43	271.81
	Carya	*illinoinensis*	pecan	201.25	2.86	808.02	250.55
	Quercus	*macrocarpa*	bur oak	189.19	3.83	758.60	334.18
	Rhus	*aromatica*	fragrant sumac	188.84	3.94	758.60	344.84

continued

Table 14.—continued

Land Use	Genus	Species	Common Name	Per Unit Area Leaf Area (ft^2/ac)	Per Unit Area Leaf Biomass (lb/ac)	City Total Leaf Area (ac)	City Total Leaf Biomass (tons)
	Quercus	*rubra*	northern red oak	184.92	3.02	741.30	263.75
	Crataegus	*species*	hawthorn spp	161.70	1.20	649.87	104.13
	Celtis	*occidentalis*	northern hackberry	157.91	1.69	632.58	147.06
	Acer	*negundo*	boxelder	100.89	1.89	405.24	165.21
	Rhus	*glabra*	smooth sumac	62.64	0.70	252.04	61.82
	Fraxinus	*americana*	white ash	50.18	0.58	202.62	51.03
	Other	*species*	other species	4.62	0.07	19.77	6.18
Total				38,233.19	518.47	153,463.93	45,314.22
CITY TOTAL				16,756.84	220.42	1,088,969.70	311,917.57

[a] shrubs are defined as woody plants with stem diameter at 4.5 feet less than 1-inch.

APPENDIX II. TREE SPECIES DISTRIBUTION

This appendix illustrates species distributions. The species distributions for each land use are illustrated (Figs. 27-34) for up to 20 most common species in the land-use category. More detailed information on species by land use can be found at: http://nrs.fs.fed.us/data/urban.

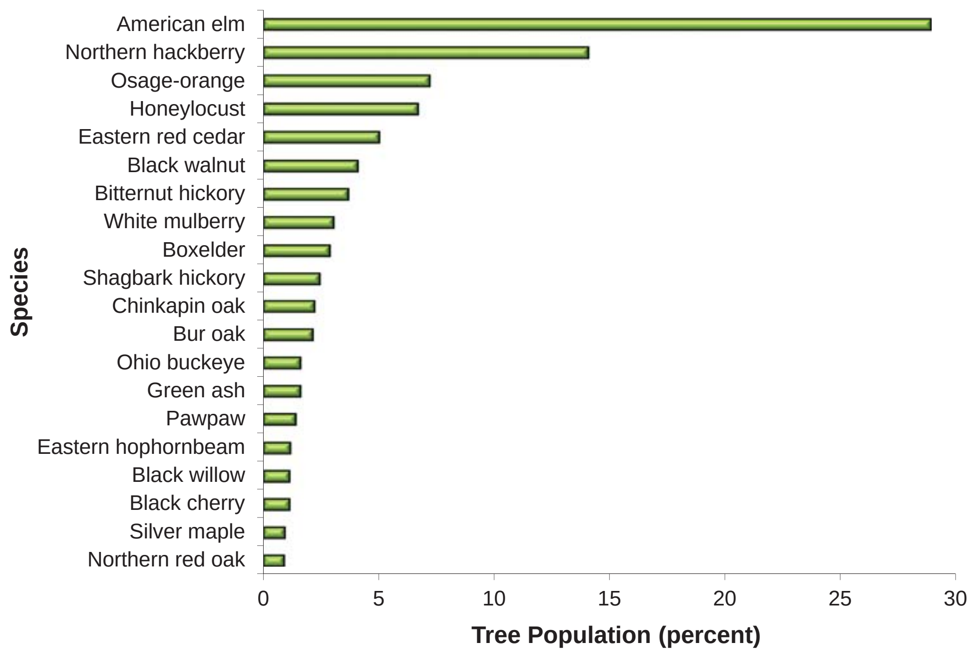


Figure 27. —The 20 most common tree species as a percent of the total tree population, Kansas City region, 2010.

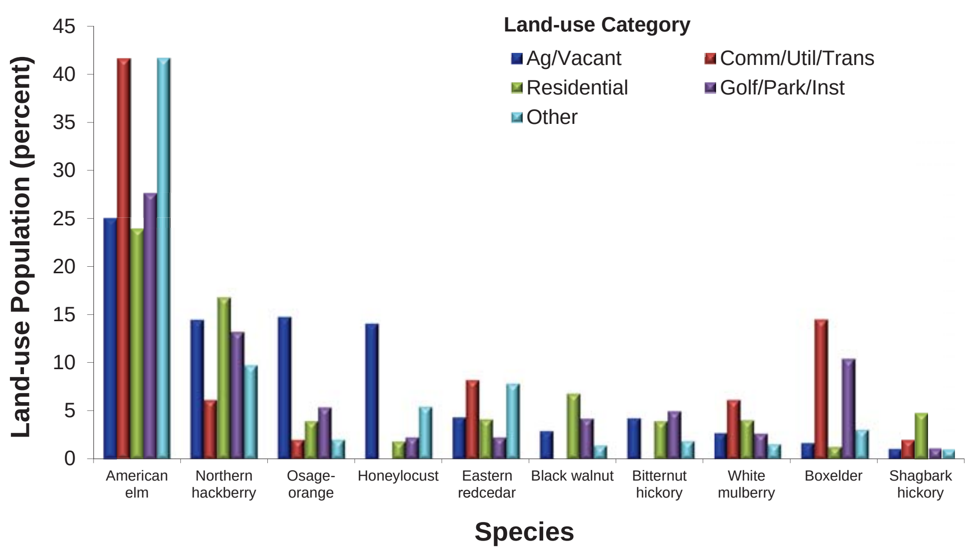


Figure 28.—The percent land-use population occupied by the 10 most common tree species, Kansas City region, 2010.

For example, American elm comprises 42 percent of the tree population on the commercial/utility/transportation land use.

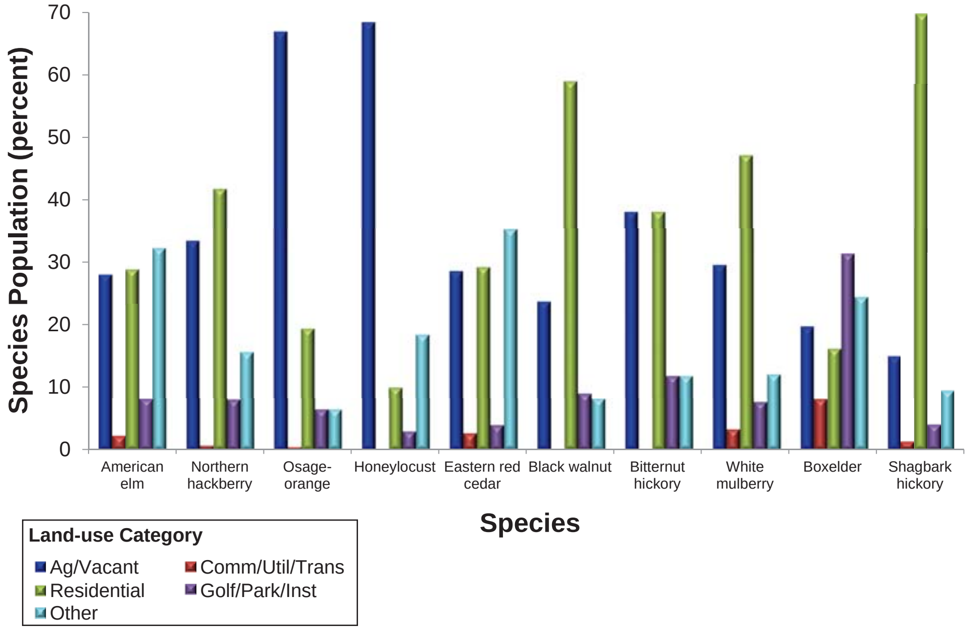


Figure 29.—The percent county population occupied by the 10 most common tree species, Kansas City region, 2010.

For example, 32 percent of American elm are found within the "other" land use.

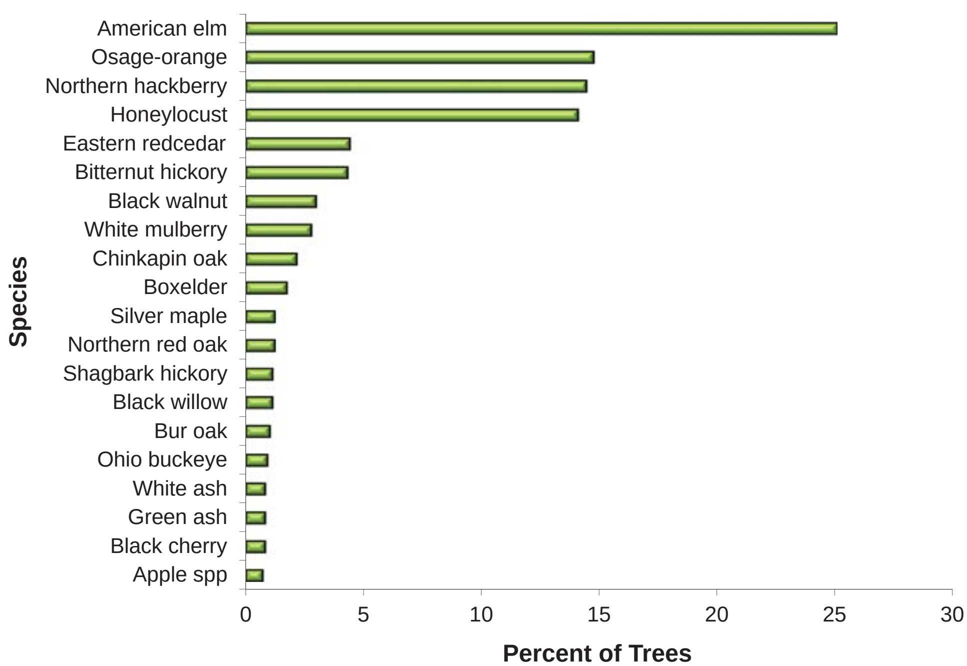


Figure 30.—Percent of trees in agriculture and vacant category of land use, Kansas City region, 2010.

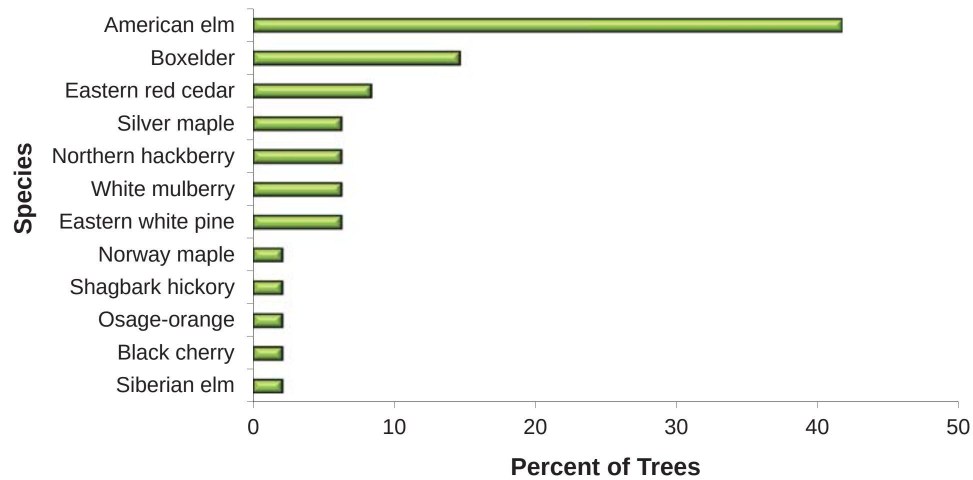


Figure 31.—Percent of trees in commercial/utility/transportation category of land use, Kansas City region, 2010.

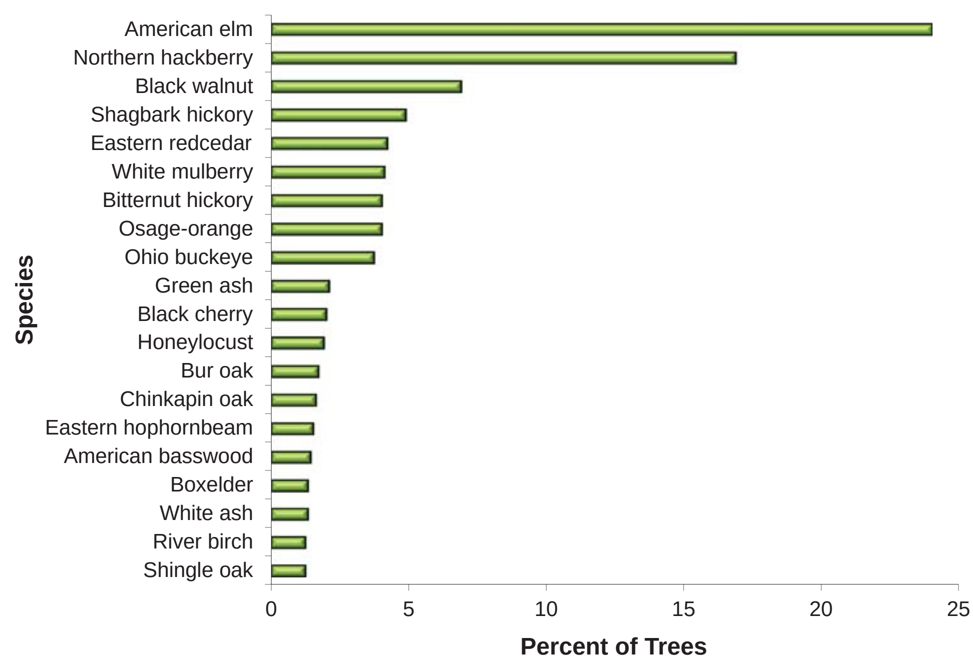


Figure 32.—Percent of trees in residential category of land use, Kansas City region, 2010.

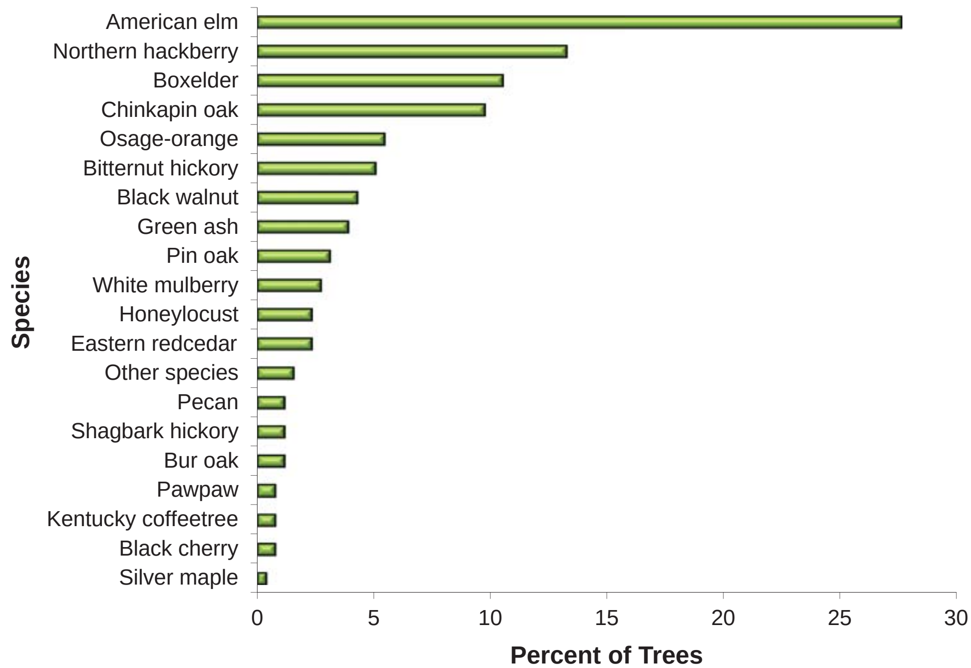


Figure 33.—Percent of trees in golf/park/institutional category of land use, Kansas City region, 2010.

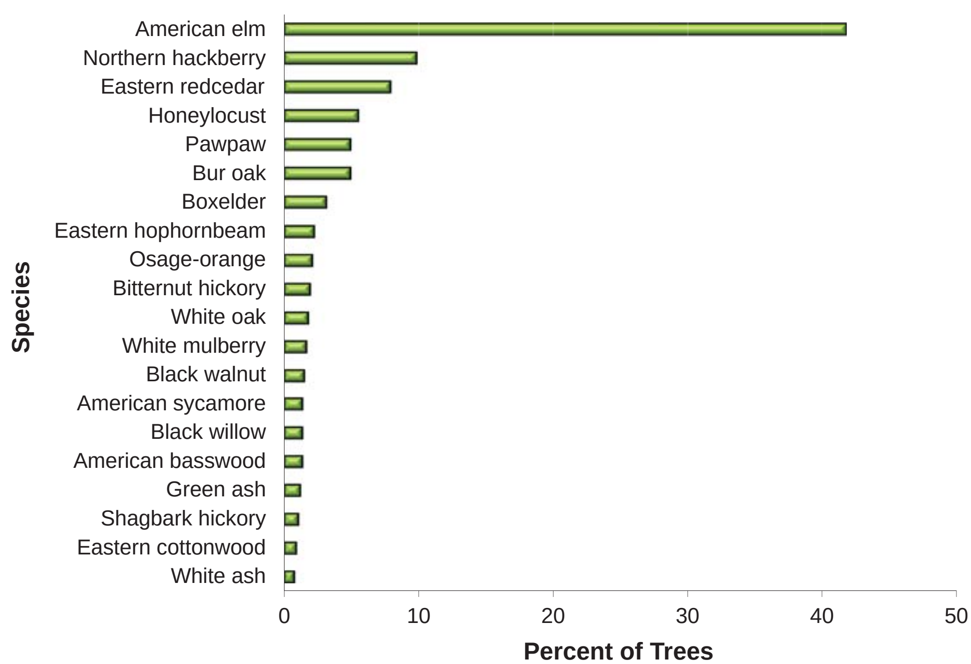


Figure 34.—Percent of trees in “other” category of land use, Kansas City region, 2010.

APPENDIX III. TREE STRUCTURE AND FUNCTIONS BY LAND USE

This appendix details various structural and functional values for each species by land-use class (Table 15) and overall values for each land use class (Table 16). More information can be found at: http://nrs.fs.fed.us/data/urban.

Table 15.—Tree structure and functions by land use, Kansas City region, 2010

Common Name	Number of Trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)	Net Carbon Seuestration (tons/year)	Leaf Area (ac)	Leaf Biomass (tons)	Structural Value ($US)
Agriculture and Vacant							
American elm	20,315,415	595,034	41,005	38,382	186,247	60,424	2,631,810,452
Osage-orange	11,989,425	2,067,386	75,001	69,063	232,469	104,247	6,957,891,480
Northern hackberry	11,739,645	858,783	44,773	42,382	217,167	50,403	4,123,999,544
Honeylocust	11,406,606	482,099	29,919	28,240	39,729	18,558	2,383,879,835
Eastern redcedar	3,580,176	69,244	4,201	4,145	45,940	56,925	482,652,938
Bitternut hickory	3,496,916	89,473	8,768	8,664	25,186	7,063	468,581,508
Black walnut	2,414,537	651,012	24,460	21,904	123,858	44,279	2,060,144,290
White mulberry	2,248,017	124,184	7,258	7,008	24,788	8,089	545,075,325
Chinkapin oak	1,748,458	34,379	3,043	2,613	8,779	3,865	205,358,193
Boxelder	1,415,418	131,831	5,454	5,293	11,800	4,815	233,808,826
Silver maple	999,119	305,742	5,886	2,527	19,258	4,521	359,280,597
Northern red oak	999,119	479,218	9,130	5,910	28,275	10,050	1,258,653,533
Shagbark hickory	915,859	135,427	6,275	5,558	14,841	4,848	352,165,069
Black willow	915,859	78,612	5,170	5,113	18,245	5,156	291,933,289
Bur oak	832,599	48,090	3,473	3,434	19,667	8,658	324,217,544
Ohio buckeye	749,339	1,813	563	560	-	-	25,411,717
White ash	666,079	109,685	5,398	5,277	24,357	6,174	458,084,950
Green ash	666,079	49,223	2,316	2,281	11,539	3,357	360,954,356
Black cherry	666,079	49,020	3,314	3,171	8,386	2,901	164,764,667
Apple spp	582,819	2,526	604	600	844	281	19,971,163
Pawpaw	499,559	1,687	428	426	1,690	1,265	18,224,010
Shellbark hickory	416,299	18,096	1,196	1,183	4,124	964	61,711,928
Eastern hophornbeam	333,040	427	165	164	944	275	9,848,222
Eastern cottonwood	249,780	370	131	131	935	301	3,122,246
Other species	166,520	8,666	-	-433	-	-	-
White oak	166,520	169,377	4,715	4,597	8,107	2,631	645,862,752
Shingle oak	166,520	43,598	1,659	1,629	2,830	1,246	139,542,543
Pin oak	166,520	244,681	4,899	4,730	5,616	2,267	698,757,172
Siberian elm	166,520	6,504	503	498	2,439	741	31,654,795
Sugar maple	83,260	11,568	723	715	1,379	370	58,366,817

continued

Table 15.—continued

Common Name	Number of Trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)	Net Carbon Seuestration (tons/year)	Leaf Area (ac)	Leaf Biomass (tons)	Structural Value ($US)
Pecan	83,260	5,919	491	487	744	231	31,074,978
Washington hawthorn	83,260	826	146	145	148	50	5,473,407
Post oak	83,260	778	147	146	130	50	6,935,489
White willow	83,260	51,381	1,600	1,564	1,221	345	72,908,702
Total	81,095,140	6,926,659	302,814	278,107	1,091,682	415,351	25,492,122,336
Commercial-Utility-Transportation							
American elm	1,665,198	69,580	7,206	6,751	24,472	7,940	416,347,407
Boxelder	582,819	27,844	3,201	3,162	4,781	1,951	89,142,946
Eastern redcedar	333,040	1,027	181	180	1,174	1,455	9,887,113
Silver maple	249,780	32,979	1,565	1,542	7,994	1,877	128,503,805
Northern hackberry	249,780	16,402	536	-129	795	185	33,003,248
White mulberry	249,780	1,317	336	334	1,380	450	10,576,988
Eastern white pine	249,780	5,201	771	766	2,925	839	100,585,101
Norway maple	83,260	1,462	345	343	540	130	13,688,995
Shagbark hickory	83,260	46,927	2,195	2,162	4,898	1,600	126,206,890
Osage-orange	83,260	34,434	-	-9,468	-	-	-
Black cherry	83,260	13,818	1,214	1,204	940	325	55,265,372
Siberian elm	83,260	48	42	42	204	62	1,300,936
Total	3,996,475	251,040	17,592	6,889	50,105	16,814	984,508,799
Residential							
American elm	20,898,237	951,407	68,268	25,150	241,182	78,247	4,875,883,090
Northern hackberry	14,653,744	575,084	64,715	62,090	196,776	45,671	5,227,860,209
Black walnut	5,994,713	833,507	53,061	48,714	163,656	58,508	4,632,215,586
Shagbark hickory	4,246,255	181,253	17,308	6,519	41,617	13,596	889,326,900
Eastern redcedar	3,663,436	45,474	5,008	4,791	34,882	43,224	496,414,537
White mulberry	3,580,176	314,344	20,528	18,265	51,110	16,678	1,833,170,144
Bitternut hickory	3,496,916	135,509	14,061	13,412	33,516	9,399	709,267,452
Osage-orange	3,496,916	1,283,797	42,903	32,227	86,657	38,860	5,145,590,265
Ohio buckeye	3,247,136	12,820	3,314	2,513	195	64	162,780,668
Green ash	1,831,718	207,331	10,410	9,595	48,960	14,245	2,032,582,484
Black cherry	1,748,458	69,070	7,338	3,185	8,406	2,908	290,365,372
Honeylocust	1,665,198	644,847	15,156	-64,952	15,110	7,058	1,826,734,629

continued

Table 15.—continued

Common Name	Number of Trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)	Net Carbon Seuestration (tons/year)	Leaf Area (ac)	Leaf Biomass (tons)	Structural Value ($US)
Bur oak	1,498,678	394,341	14,157	-4,817	38,895	17,123	2,080,875,431
Chinkapin oak	1,415,418	114,468	7,933	-4,793	13,041	5,741	597,130,685
Eastern hophornbeam	1,332,159	12,312	2,494	1,649	10,407	3,030	122,437,539
American basswood	1,248,899	172,688	6,314	-10,840	32,789	4,270	1,003,160,382
Boxelder	1,165,639	83,974	7,106	6,403	8,031	3,277	369,604,161
White ash	1,165,639	8,272	2,373	2,325	7,014	1,778	107,642,633
River birch	1,082,379	6,182	2,074	2,038	3,855	1,333	90,071,957
Shingle oak	1,082,379	133,009	10,692	10,395	22,877	10,071	783,216,221
Black willow	1,082,379	5,368	1,776	1,744	6,951	1,964	24,236,644
Silver maple	749,339	353,558	11,965	50,730	11,911	10,287	1,417,843,560
Eastern cottonwood	749,339	645,203	19,814	3,815	81,186	26,132	1,436,840,862
Northern red oak	749,339	301,263	11,122	5,136	23,200	8,247	1,612,993,642
Mockernut hickory	666,079	4,059	1,293	1,272	2,271	580	34,293,141
Red maple	582,819	57,707	5,035	4,801	15,131	4,546	477,990,184
Sugar maple	582,819	21,879	3,278	3,228	10,143	2,726	184,613,181
Kentucky coffeetree	333,040	29,318	2,459	2,340	5,078	1,694	241,850,918
Apple spp	333,040	27,876	2,902	2,787	11,173	3,726	242,613,732
Callery pear	333,040	19,024	2,248	2,169	3,420	1,141	174,639,592
Pin oak	333,040	174,116	6,821	6,141	22,017	8,888	864,867,673
Common persimmon	249,780	26,088	2,025	1,919	10,168	3,391	174,697,581
American sycamore	249,780	240,722	7,780	6,854	51,298	11,086	795,649,069
Kwanzan cherry	249,780	38,524	3,353	3,132	5,974	2,062	183,888,409
Saucer magnolia	166,520	13,900	1,466	1,409	5,028	1,499	129,576,283
Other species	166,520	48,251	-	-13,267	-	-	-
Peach	166,520	9,795	1,234	1,134	660	228	48,931,218
Swamp white oak	166,520	6,256	850	823	1,330	586	66,049,009
Norway maple	83,260	78,361	2,453	2,152	24,808	5,973	483,022,208
Pawpaw	83,260	55	47	47	411	308	3,671,762
Northern catalpa	83,260	37,344	1,731	1,585	2,058	559	87,438,757
Washington hawthorn	83,260	98	63	63	114	38	3,671,762
Tulip tree	83,260	13,718	1,004	949	13,390	3,521	138,066,232
Cherry plum	83,260	4,971	657	636	896	243	41,495,675

continued

Table 15.—continued

Common Name	Number of Trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)	Net Carbon Seuestration (tons/year)	Leaf Area (ac)	Leaf Biomass (tons)	Structural Value ($US)
White oak	83,260	9,764	959	919	433	141	91,239,196
Black oak	83,260	66,379	2,988	2,730	6,228	1,964	261,532,635
Total	87,089,863	8,413,287	470,541	218,672	1,413,072	478,230	42,498,043,272
Golf-Park-Institutional							
American elm	5,911,453	165,089	11,434	8,557	47,241	15,327	1,076,575,038
Northern hackberry	2,830,836	147,433	8,379	3,042	46,856	10,875	1,295,092,803
Boxelder	2,248,017	219,980	9,735	-5,083	31,289	12,768	998,577,070
Chinkapin oak	2,081,497	14,484	2,512	2,451	6,352	2,796	241,611,887
Osage-orange	1,165,639	213,578	8,619	6,620	21,304	9,553	1,183,137,915
Bitternut hickory	1,082,379	35,789	2,610	2,469	10,601	2,973	226,129,3 64
Black walnut	915,859	145,783	6,810	6,200	35,226	12,593	1,054,738,446
Green ash	832,599	68,566	1,731	1,316	15,996	4,654	1,076,355,876
Pin oak	666,079	73,885	4,394	4,221	11,638	4,698	594,086,667
White mulberry	582,819	27,565	2,010	1,913	6,116	1,996	237,203,011
Honeylocust	499,559	209,936	5,803	5,015	7,430	3,471	1,204,829,532
Eastern red cedar	499,559	29,114	1,336	1,248	12,987	16,093	325,220,498
Other species	333,040	2,141	-	-513	-	-	-
Pecan	249,780	5,784	687	672	1,706	529	51,384,976
Shagbark hickory	249,780	13,036	1,207	1,154	1,299	424	136,469,830
Bur oak	249,780	65,558	2,103	1,954	5,508	2,425	419,597,046
Pawpaw	166,520	181	84	83	612	458	9,179,403
Kentucky coffeetree	166,520	28,660	1,241	1,128	3,785	1,262	263,106,803
Black cherry	166,520	5,580	651	638	333	115	46,495,070
Silver maple	83,260	81	38	37	94	22	2,185,572
American sycamore	83,260	2,025	242	234	152	33	18,872,694
Eastern cottonwood	83,260	5,533	406	384	2,989	962	56,546,236
Cherry plum	83,260	5,154	455	434	487	132	49,998,190
Northern red oak	83,260	124	54	53	310	110	7,077,091
Black willow	83,260	24,836	1,050	993	5,591	1,580	70,764,110
Total	21,397,793	1,509,894	73,592	45,219	275,901	105,850	10,645,235,127

continued

Table 15.—continued

Common Name	Number of Trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)	Net Carbon Seuestration (tons/year)	Leaf Area (ac)	Leaf Biomass (tons)	Structural Value ($US)
Other							
American elm	23,312,773	368,826	26,699	18,156	86,336	28,010	1,893,421,513
Northern hackberry	5,495,154	267,981	16,758	16,540	63,024	14,627	1,989,415,002
Eastern redcedar	4,412,775	20,886	3,524	3,417	18,900	23,419	244,411,985
Honeylocust	3,080,616	112,322	10,481	8,713	9,781	4,569	840,333,875
Pawpaw	2,747,577	4,484	1,895	1,880	7,142	5,344	141,309,779
Bur oak	2,747,577	312,315	10,233	10,000	21,847	9,618	1,734,0 71,605
Boxelder	1,748,458	130,529	6,426	5,964	18,943	7,730	442,735,169
Eastern hophornbeam	1,248,899	10,027	1,664	1,655	6,916	2,014	140,663,685
Osage-orange	1,165,639	123,905	5,807	5,705	13,201	5,920	538,342,819
Bitternut hickory	1,082,379	59,327	4,173	4,129	16,453	4,614	338,345,034
White oak	999,119	104,977	6,441	6,361	9,404	3,051	904,601,103
White mulberry	915,859	92,222	2,994	1,564	4,501	1,469	345,314,913
Black walnut	832,599	125,131	5,422	5,333	20,881	7,465	630,673,527
American sycamore	749,339	235,859	6,897	6,726	34,249	7,402	562,029,765
Black willow	749,339	5,635	654	645	1,877	530	5,665,613
American basswood	749,339	79,483	4,731	4,414	62,316	8,116	937,318,655
Green ash	666,079	26,723	1,003	573	4,833 1,406	192,504,754	
Shagbark hickory	582,819	73,942	4,482	4,387	9,073	2,964	355,435,545
Eastern cottonwood	499,559	259,811	6,592	6,411	35,003	11,267	468,265,237
White ash	416,300	54,741	3,116	2,230	9,772	2,477	328,452,625
Northern red oak	416,300	6,620	693	688	2,714	965	37,727,257
Silver maple	249,780	196,269	3,422	2,911	14,344	3,368	553,932,951
Chinkapin oak	249,780	23,898	1,664	1,602	4,307	1,896	150,768,437
Other species	166,520	57,524	-	-2,876	-	-	-
Black cherry	166,520	4,345	70	-139	216	75	2,497,797
Pin oak	166,520	4,440	465	462	3,521	1,421	40,705,526
Shellbark hickory	83,260	120	51	51	61	14	2,497,797
Black oak	83,260	324	98	98	200	63	4,371,145
Siberian elm	83,260	1,667	140	138	737	224	1, 948,669
Total	55,867,396	2,764,331	136,594	117,738	480,550	160,038	13,827,761,782
Total for Kansas City Region	249,446,667	19,865,210	1,001,132	666,625	3,311,311	1,176,282	93,447,671,317

Table 16.—Summary of tree structure and functions by land use, Kansas City region, 2010

	Trees		Carbon Storage (tons)		Carbon Seq tons/yr)		Net Carbon Seq (tons/yr)		Leaf Area (ac)		Leaf Biomass (tons)		Tree Value ($US billion)	
LAND USE	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Agriculture & Vacant	81,095,000	32.5	6,927,000	34.9	303,000	30.3	278,000	41.7	1,092,000	33.0	415,000	35.3	25.5	27.3
Comm-Utility-Trans	3,996,000	1.6	251,000	1.3	18,000	1.8	7,000	1.0	50,000	1.5	17,000	1.4	1.0	1.1
Residential	87,090,000	34.9	8,413,000	42.4	471,000	47.1	219,000	32.8	1,413,000	42.7	478,000	40.6	42.5	45.5
Golf-Park-Inst	21,398,000	8.6	1,510,000	7.6	74,000	7.4	45,000	6.7	276,000	8.3	106,000	9.0	10.6	11.3
Other	55,867,000	22.4	2,764,000	13.9	137,000	13.7	118,000	17.7	481,000	14.5	160,000	13.6	13.8	14.8
Total	249,447,000		19,865,000		1,001,000		667,000		3,311,000		1,176,000		93.4	

APPENDIX IV. POPULATION INFORMATION BY STEM DIAMETER CLASS

This appendix details how trees in each diameter class are distributed among land uses (Fig. 35); whether the most common species in the diameter classes less than 3 inches or greater than 18 inches are gaining or losing prominence (Fig. 36); and how trees less than 3 inches in diameter are distributed by land use (Fig. 37).

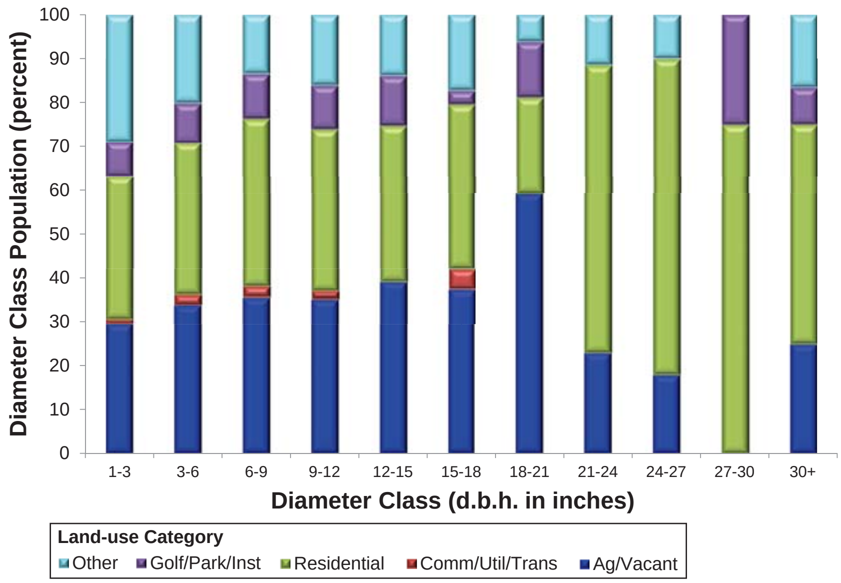


Figure 35.—Percent of diameter class population in each land-use category, Kansas City region, 2010

For example, of the trees that have diameters between 27 and 30 inches, 75 percent are found in residential land uses and 25 percent are found in golf/park/institutional areas.

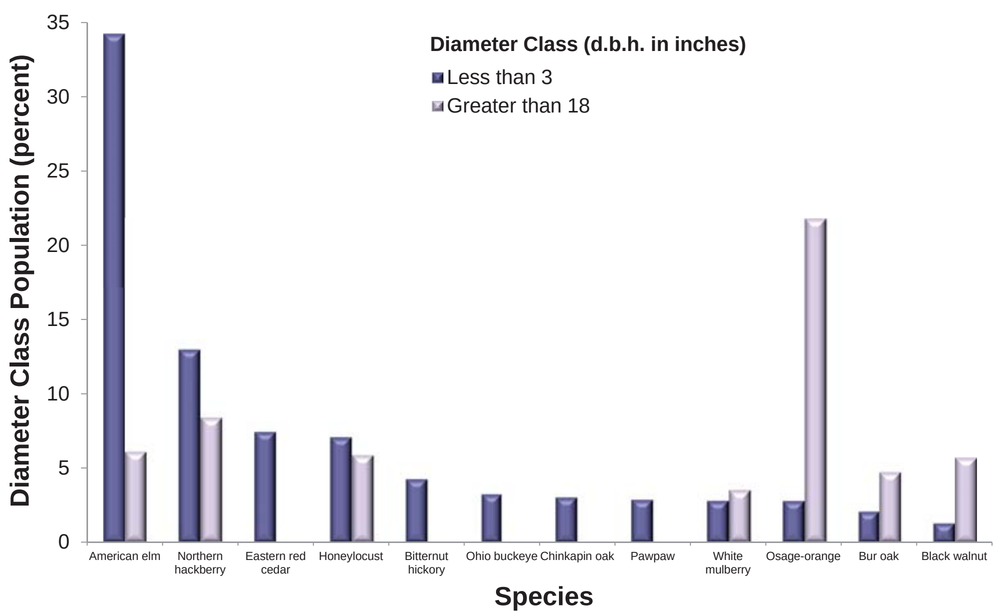


Figure 36.—Percent of diameter class (<3 inches or >18 inches) population occupied by the most common tree species in those classes, Kansas City region, 2010

For example, American elm comprises 34 percent of the trees with diameters less than 3 inches and 6 percent of the trees with diameters greater than 18 inches.

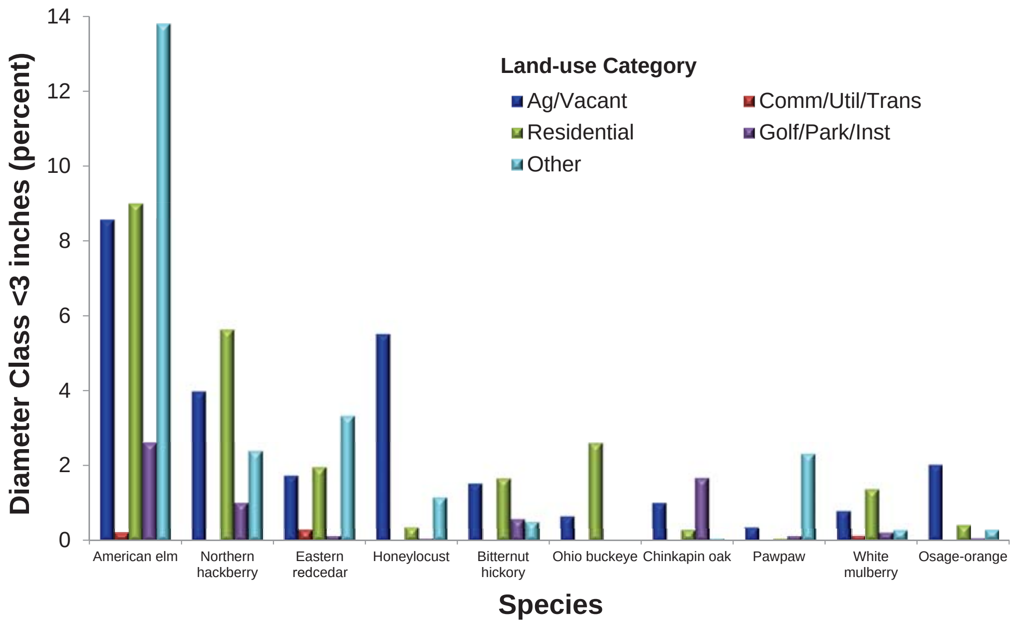


Figure 37.—Percent of diameter class (<3 inches) occupied by the most common species in that diameter class, Kansas City region, 2010

For example, 2.6 percent of the trees less than 3 inches in diameter are Ohio buckeye within residential land uses.

APPENDIX V. GENERAL RECOMMENDATIONS FOR AIR QUALITY IMPROVEMENT

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

Temperature reduction and other microclimatic effects
Removal of air pollutants
Emission of volatile organic compounds (VOC) and tree maintenance emissions
Energy conservation on buildings and consequent power plant emissions

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the overall 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. Local urban forest management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include:

Strategy	Reason
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

APPENDIX VI. RELATIVE TREE EFFECTS

The tree and forest resource in the Kansas City region provides benefits that include carbon storage and sequestration and air pollutant removal. To estimate a relative value of these benefits, tree benefits were compared to estimates of average carbon emissions in the region[31], average passenger automobile emissions[32], and average household emissions.[33]

General tree information:

Average tree stem diameter = 5.2 inches
Median tree stem diameter = 3.4 inches
Number of trees sampled = 2,756
Number of species sampled = 51

Table 17.—Average tree effects by stem diameter class (d.b.h.), Kansas City region, 2010

D.b.h.	Carbon storage			Carbon sequestration			Pollution removal	
(inches)[a]	(lbs)	($)	(miles) [a]	(lbs/yr)	($/yr)	(miles) [b]	(lbs)	($)
1-3	6	0.06	20	1.6	0.02	6	0.05	0.19
3-6	38	0.39	140	5.6	0.06	21	0.2	0.61
6-9	136	1.41	500	10.9	0.11	40	0.3	1.24
9-12	314	3.25	1,150	17.9	0.19	66	0.6	1.97
12-15	557	5.76	2,040	23.5	0.24	86	0.8	2.95
15-18	914	9.46	3,350	32.0	0.33	117	1.1	3.98
18-21	1,336	13.82	4,890	40.5	0.42	148	1.3	4.57
21-24	1,824	18.87	6,680	53.2	0.55	195	1.7	6.09
24-27	2,488	25.73	9,110	59.5	0.62	218	1.8	6.25
27-30	2,826	29.24	10,350	76.1	0.79	279	3.0	10.55
30+	5,806	60.06	21,260	92.6	0.96	339	2.8	9.90

[a] lower limit of the diameter class (d.b.h.) is greater than displayed (e.g., 3-6 is actually 3.01 to 6 inches)
[b] miles = number of automobile miles driven that produces emissions equivalent to tree effect

The trees in the Kansas City region provide:

Carbon storage equivalent to:
Amount of carbon (C) emitted in region in 613 days or
annual carbon emissions from 11,922,000 automobiles or
annual C emissions from 5,986,400 single family houses

Carbon monoxide removal equivalent to:
Annual carbon monoxide emissions from 2,582 automobiles or
annual carbon monoxide emissions from 10,700 family houses

Nitrogen dioxide removal equivalent to:
Annual nitrogen dioxide emissions from 287,200 automobiles or
annual nitrogen dioxide emissions from 191,500 single family houses

Sulfur dioxide removal equivalent to:
Annual sulfur dioxide emissions from 3,342,900 automobiles or
annual sulfur dioxide emissions from 56,000 single family houses

Particulate matter less than 10 micron (PM_{10}) removal equivalent to:
Annual PM_{10} emissions from 63,376,300 automobiles or
annual PM_{10} emissions 6,118,000 single family houses

Annual C sequestration equivalent to:
Amount of C emitted in region in 31 days or
annual C emissions from 600,800 automobiles or
annual C emissions from 301,700 single family homes

APPENDIX VII. TREE PLANTING INDEX MAP

To determine the best locations to plant trees, tree canopy and impervious cover maps from National Land Cover Data[34] were used in conjunction with 2000 U.S. Census data to produce an index of priority planting areas for the Kansas City region. Index values were produced for each census block group; the higher the index value, the higher the priority of the area for tree planting. This index is a type of "environmental equity" index with areas with higher human population density and lower tree cover tending to get the higher index value. The criteria used to make the index were:

- Population density: the greater the population density, the greater the priority for tree planting
- Tree stocking levels: the lower the tree stocking level (the percent of available greenspace [tree, grass, and soil cover areas] that is occupied by tree canopies), the greater the priority for tree planting
- Tree cover per capita: the lower the amount of tree cover per capita (m^2/capita), the greater the priority for tree planting

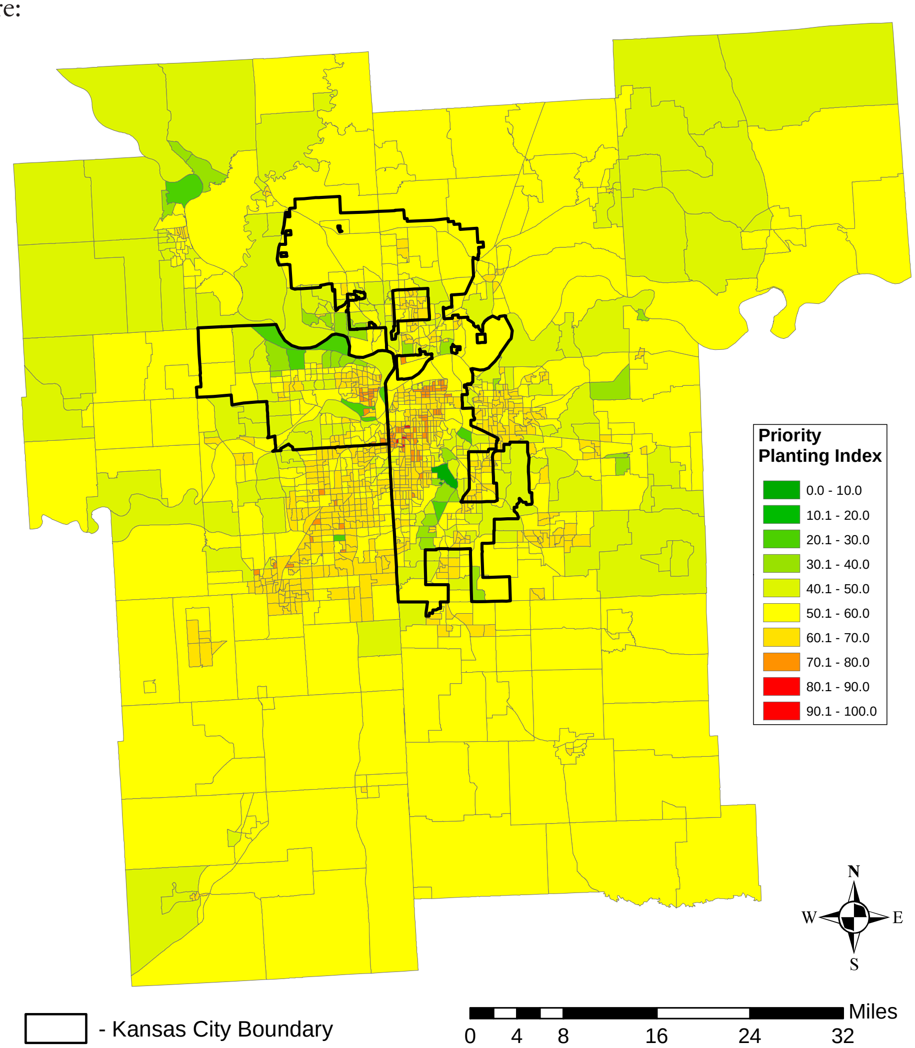


Figure 38.—Priority planting areas, Kansas City region. Higher index scores indicate higher priority areas for planting.

Each criteria was standardized[35] on a scale of 0 to 1 with 1 representing the census block group with the highest value in relation to priority of tree planting (i.e., the census block group with highest population density, lowest stocking density or lowest tree cover per capita were standardized to a rating of 1). Individual scores were combined and standardized based on the following formula to produce an overall priority planting index (PPI) value between 0 and 100:

$$PPI = (PD * 40) + (TS * 30) + (TPC * 30)$$

Where PPI = index value, PD is standardized population density, TS is standardized tree stocking, and TPC is standardized tree cover per capita.

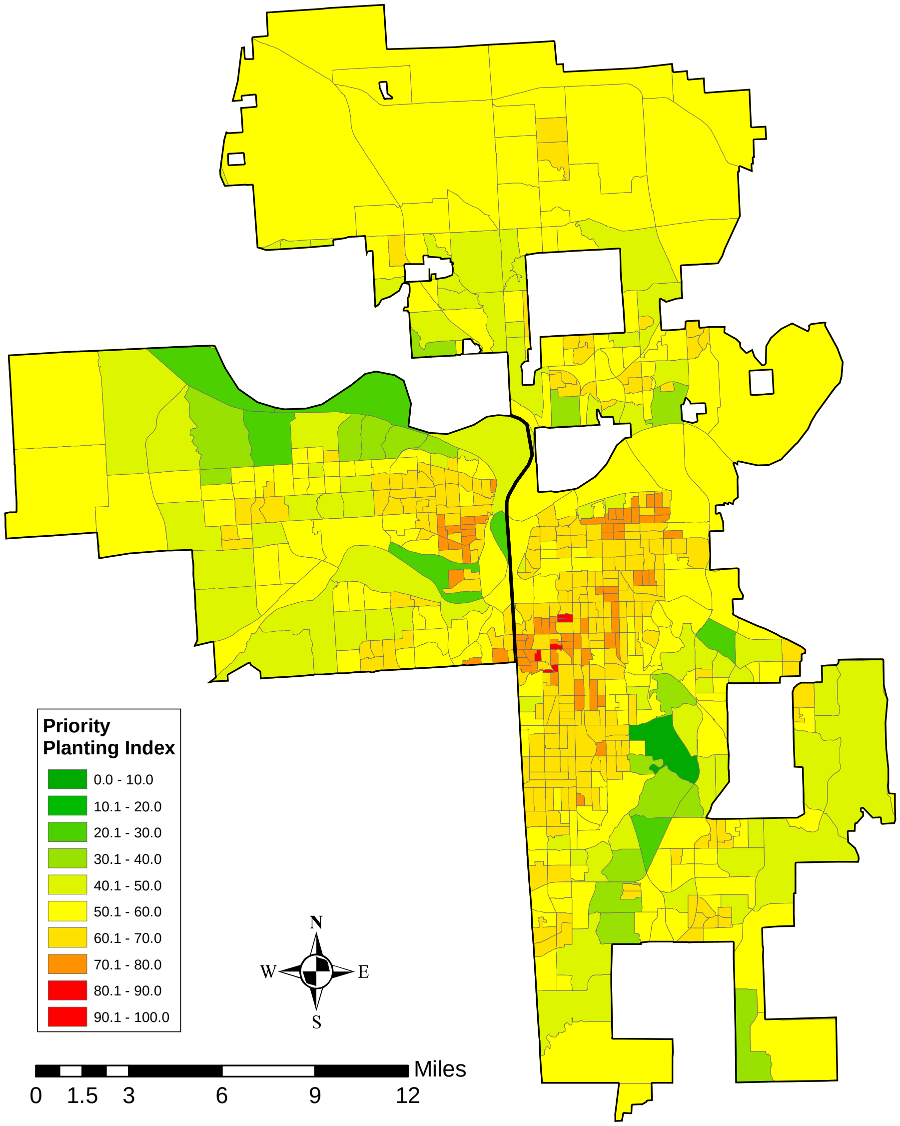


Figure 39.—Priority planting areas, Kansas City.
Higher index scores indicate higher priority areas for planting.

APPENDIX VIII. i-TREE FORECAST PROTOTYPE MODEL METHODS AND RESULTS

The i-Tree Forecast Prototype Model was built to simulate future forest structure (e.g., number of trees and sizes) and various ecosystem services based on annual projections of the current forest structure data. There are three main components of the model:

1) Tree growth—simulates tree growth to annually project tree diameter, crown size, and leaf area for each tree
2) Tree mortality—annually removes trees from the projections based on user defined mortality rates
3) Tree establishment—annually adds new trees to the projection. These inputs can be used to illustrate the effect of the new trees or determine how many new trees need to be added annually to sustain a certain level of tree cover or benefits.

Tree Growth

Annual tree diameter growth is estimated for the region based on: 1) the length of growing season; 2) species average growth rates; 3) tree competition; 4) tree condition; and 5) current tree height relative to maximum tree height.

To determine a base growth rate based on length of growing season, urban street tree, park tree, and forest growth measurements were standardized to growth rates for 153 frost-free days based on: Standardized growth = measured growth × (number of frost-free days of measurement/153).[3] Growth rates of trees of the same species or genera were also compared to determine the average difference between standardized street tree growth and standardized park tree and forest tree growth rates. Park growth averaged 1.78 times less than street trees, and forest growth averaged 2.26 times less than street tree growth.

For this study, average standardized growth rates for open-grown trees was input as 0.26 in/yr for slow growing species, 0.39 in/yr for moderate growing species and 0.52 in/yr for fast growing species. There are limited measured data on urban tree growth for slow, moderate or fast-growing tree species, so the growth rates used here are estimates. These growth rates by species growth-rate class were estimated such that the entire population average growth rate was comparable to the measured growth rates for trees standardized to the number of frost free days.

Crown light exposure (CLE) measurements of 0-1 were used to represent forest growth conditions; 2-3 for park conditions; and 4-5 for open-grown conditions. Thus, for: CLE 0-1: Base growth = Standardized growth (SG) / 2.26; CLE 2-3: Base growth = SG / 1.78; and CLE 4-5: Base growth = SG. However, as the percent canopy cover increased or decreased, the CLE correction factors were adjusted proportionally to the amount of available greenspace (i.e., as tree cover decreased and available greenspace increased—the CLE adjustment factor decreased; as tree cover increased and available greenspace decreaseed—the CLE adjustment factor increased).

Base growth rates are also adjusted based on tree condition. These adjustments factors are based on percent crown dieback and the assumption that less than 25 percent crown dieback had a limited effect on diameter growth rates. For trees in fair to excellent condition (less than 25 percent dieback), base growth rates are multiplied by 1 (no adjustment), trees in poor condition (crown dieback of 26-50 percent) by 0.76, critical trees (crown dieback of 51-75 percent) by 0.42, dying trees (crown dieback of 76-99 percent) by 0.15, and dead trees (crown dieback of 100 percent) by 0.

As trees approach their estimated maximum height, growth rates are reduced. Thus the species growth rates as described above were adjusted based on the ratio between the current height of the tree and the average height at maturity for the species. When a tree's height is over 80 percent of its average height at maturity, the annual diameter growth is proportionally reduced from full growth at 80 percent of height to one-half growth rate at height at maturity. The growth rate is maintained at one-half growth until the tree is 125 percent past maximum height, when the growth rate is then reduced to 0.

Tree height, crown width, crown height, and leaf area were then estimated based on tree diameter each year. Height, crown height, and crown width are calculated using species, genus, order, and family specific equations that were derived from measurements from urban tree data (unpublished equations). If there is no equation for a particular species, then the genus equation is used, followed by the family and order equations, if necessary. If no order equation is available, one average equation for all trees is used to estimate these parameters. Leaf area was calculated from the crown height, tree height, and crown width estimates based on i-Tree methods.[3]

Total canopy cover was calculated by summing the two-dimensional crown area of each tree in the population. This calculated estimate of crown area was adjusted to attain the actual tree cover of the study area based on photo-interpretation. Trees often have overlapping crowns, so the sum of the crown areas will often over estimate total tree cover as determined by aerial estimates. Thus the crown overlap can be determined by comparing the two estimates:

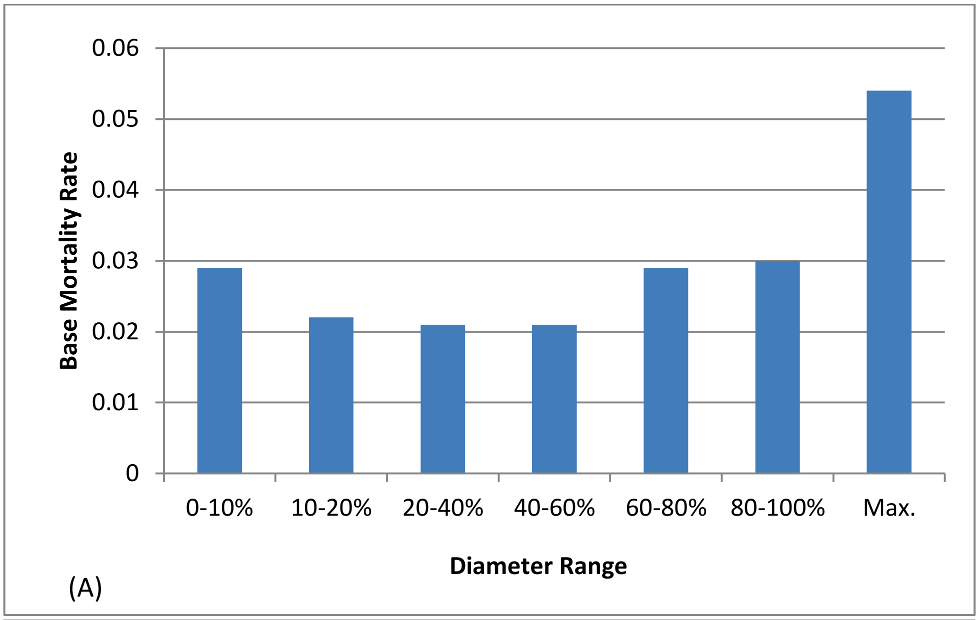
% crown overlap = (sum of crown area – actual tree cover area)/sum of crown area

When future projections predicted an increase in percent tree cover, the percent crown overlap was held constant However, when 100 percent tree cover was attained all new canopy added was considered as overlapping canopy. When there was a projected decrease in percent tree cover, the percent crown overlap decreased in proportion to the increase in the amount of available greenspace (i.e., as tree cover dropped and available greenspace increased – the crown overlap decreased).

Tree Mortality Rate

Canopy dieback is the first determinant for tree mortality. Trees with 50-75 percent crown dieback having an annual mortality rate of 13.1 percent; trees with 76-99 percent dieback have a 50 percent annual mortality rate, and trees with 100% dieback have a 100 percent annual mortality rate.[36] Trees with less than 50 percent dieback have a user defined mortality rate that is adjusted based on the tree size class and diameter.

Trees are assigned to species size classes: small trees have an average height at maturity of less than or equal to 40 ft (maximum diameter class = 20+ inches); medium trees have mature tree height of 41- 60 ft (maximum diameter = 30+ inches); large trees have a mature height of greater than 60 ft (maximum diameter = 40+ inches). Each size class has a unique set of seven diameter ranges to which base mortality rates area assigned based on measured tree mortality by diameter class (Fig. 40).[36] The same distribution



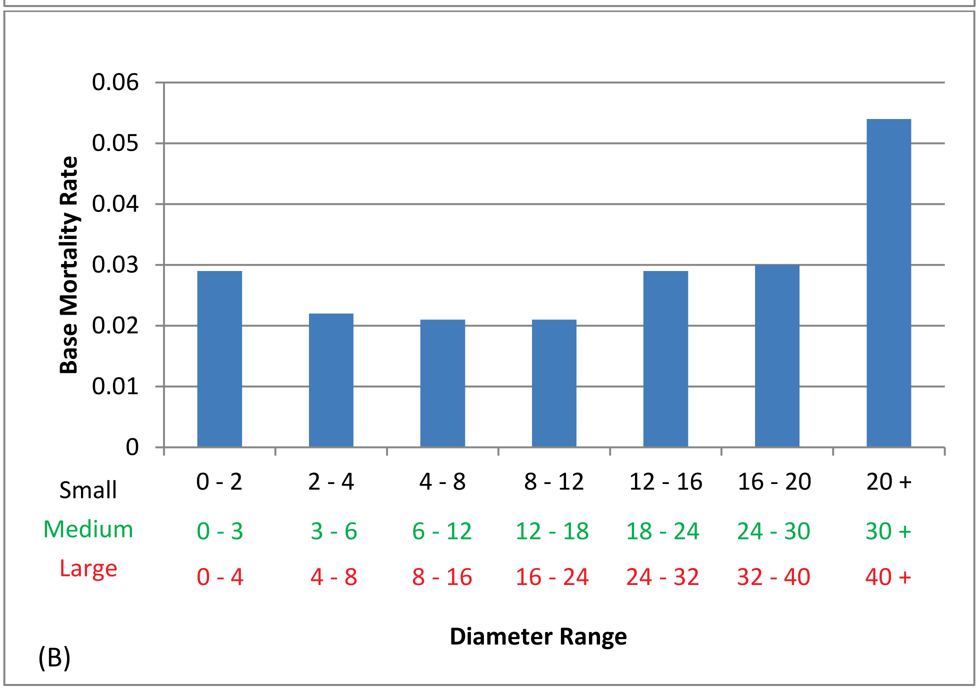


Figure 40.—A) Mortality rate distribution by diameter class (d.b.h.) with d.b.h. range classified by maximum d.b.h. for the species, and B) for actual d.b.h. classes for small, medium, and large tree species.

of mortality by diameter class was used for all tree size classes, but the diameter range of the classes differed by size class. The actual mortality rate for each diameter class was adjusted so that the overall average mortality rate for the base population equaled the mortality rates assigned by user. That is, the relative curve of mortality stayed the same among diameter classes, but the actual values would change based on the user-defined overall average rate.

Tree Establishment

Based on the desired tree cover level and the number of years desired to reach that canopy goal, the program calculates the number of trees needing to be established annually to reach that goal given the model growth and mortality rate. In adding new trees to the model each year, the species composition of new trees was assumed to be proportional to the current species composition. Crown light exposure of newly established trees was also assumed to be proportional to the current growth structure of the canopy. Newly established trees were input with a starting stem diameter of 1 inch.

Model Scenarios

Numerous model scenarios were run for the Kansas City region. All scenarios were run with 2, 3, 4, or 5 percent average annual mortality rates for projections 10, 25 and 50 years in the future. All model scenarios were run by land use class.

For cases of maintaining current tree cover, two additional scenarios were run:

1) Ash mortality: the entire ash population dies in 10 years. The mortality rate is 10 percent of the initial population per year.
2) Black walnut mortality: the entire black walnut population dies in 10 years. The mortality rate is 10 percent of the initial population per year.

<u>Land Use—Agriculture & Vacant</u>

Area: 1,615,263 ac
Current Canopy Cover: 11.8%
Tree-size Classes (height)
Small Trees – 14.7%
Medium Trees – 8.2%
Large Trees – 77.1%

Agriculture & Vacant Land Use Scenarios:

The following tables illustrate the number of trees that must be established annually to attain the desired canopy cover goal within the 10-, 25- and 50-year periods.

Maintain existing agriculture & vacant canopy cover of 11.8 percent

	Trees								
	No Additional Mortality			Ash Kill in 10 Years			Black Walnut Kill in 10		
Mortality (%)	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs
2	0	0	0	0	0	0	0	0	0
3	0	0	74,000	0	0	160,000	0	0	260,000
4	0	40,000	960,000	0	100,000	1,100,000	450,000	300,000	1,200,000
5	0	1,200,000	2,100,000	130,000	1,500,000	2,300,000	600,000	1,700,000	2,400,000

Increase agriculture & vacant canopy cover by 5 to 16.8 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	760,000
4	1,900,000	1,400,000	1,800,000
5	3,650,000	2,900,000	2,900,000

Increase agriculture & vacant canopy cover by 10 to 21.8 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	1,200,000	0	0
3	3,400,000	1,400,000	1,200,000
4	5,500,000	2,500,000	2,500,000
5	7,500,000	4,200,000	4,000,000

Increase agriculture & vacant canopy cover by 20 to 31.8 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	8,800,000	1,800,000	900,000
3	11,000,000	3,300,000	2,440,000
4	13,000,000	5,400,000	4,200,000
5	16,000,000	7,300,000	6,400,000

Land Use – Commercial, Utilities & Transportation

Area: 166,523 ac

Current Canopy Cover: 9.6%

Tree Size Classes (height)

- Small Trees – 0.0%
- Medium Trees – 18.2%
- Large Trees – 81.8%

Commercial, Utilities & Transportation Land Use Scenarios:

The following tables illustrate the number of trees that must be established annually to attain the desired canopy cover goal within the 10, 25 and 50 year periods.

Maintain existing commercial, utilities, transportation canopy cover of 9.6 percent (Note - there were no ash or walnut trees in this land use category)

	Trees No Additional Mortality		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	0
4	0	0	18,000
5	0	0	75,000

Increase commercial, utilities, transportation canopy cover by 5 to 14.6 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	30,000	0	15,000
4	130,000	40,000	75,000
5	250,000	120,000	140,000

Increase commercial, utilities, transportation canopy cover by 10 to 19.6 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	300,000	0	0
3	450,000	80,000	60,000
4	600,000	160,000	138,000
5	750,000	260,000	230,000

Increase commercial, utilities, transportation canopy cover by 20 to 29.6 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	1,050,000	190,000	65,000
3	1,250,000	285,000	155,000
4	1,450,000	435,000	265,000
5	1,600,000	580,000	400,000

Land Use—Golf, Park & Institutional

Area: 158,196 ac

Current Canopy Cover: 34.3%

Tree Size Classes (height)

- Small Trees – 6.5%
- Medium Trees – 5.6%
- Large Trees – 87.9%

Golf, Park & Institutional Land Use Scenarios:

The following tables illustrate the number of trees that must be established annually to attain the desired canopy cover goal within the 10, 25 and 50 year periods.

Maintain existing golf, park & institutional canopy cover of 34.3 percent

	Trees								
	No Additional Mortality			Ash Kill in 10 Years			Black Walnut Kill in 10		
Mortality (%)	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs
2	0	0	0	0	0	0	0	0	0
3	0	0	50,000	0	0	54,000	0	0	80,000
4	0	28,000	350,000	0	110,000	355,000	80,000	170,000	370,000
5	50,000	400,000	630,000	400,000	490,000	635,000	570,000	550,000	650,000

Increase golf, park & institutional canopy cover by 5 to 39.3 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	95,000
4	0	180,000	400,000
5	500,000	600,000	750,000

Increase golf, park & institutional canopy cover by 10 to 44.3 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	130,000
4	200,000	280,000	460,000
5	800,000	750,000	800,000

Increase golf, park & institutional canopy cover by 20 to 54.3 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	200,000	270,000	230,000
4	760,000	480,000	610,000
5	1,250,000	950,000	1,000,000

Land Use—Residential

Area: 716,029 ac

Current Canopy Cover: 31.4%

Tree Size Classes (height)

- Small Trees – 5.3%
- Medium Trees – 12.4%
- Large Trees – 82.3%

Residential Land Use Scenarios:

The following tables illustrate the number of trees that must be established annually to attain the desired canopy cover goal within the 10, 25 and 50 year periods.

Maintain existing residential canopy cover of 31.4 percent

	Trees								
	No Additional Mortality			Ash Kill in 10 Years			Black Walnut Kill in 10		
Mortality (%)	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs
2	0	0	0	0	0	0	0	0	0
3	0	0	165,000	0	0	320,000	0	0	450,000
4	0	43,000	1,250,000	0	340,000	1,500,000	450,000	900,000	1,650,000
5	72,000	1,700,000	2,500,000	800,000	1,800,000	2,750,000	2,500,000	240,000	2,900,000

Increase residential canopy cover by 5 to 36.4 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	570,000
4	400,000	900,000	1,800,000
5	2,000,000	2,600,000	3,100,000

Increase residential canopy cover by 10 to 41.4 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	39,000	0	830,000
4	2,200,000	1,650,000	2,200,000
5	4,400,000	3,350,000	3,700,000

Increase residential canopy cover by 20 to 51.4 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	1,200,000	0	0
3	3,700,000	1,200,000	1,500,000
4	6,400,000	3,300,000	3,100,000
5	8,900,000	5,400,000	5,000,000

Land Use—Water & Other

Area: 174,848 ac

Current Canopy Cover: 49.2%

Tree Size Classes (height)

- Small Trees – 7.7%
- Medium Trees – 12.6%
- Large Trees – 79.7%

Water & Other Land Use Scenarios:

The following tables illustrate the number of trees that must be established annually the desired canopy cover goal within the 10, 25 and 50 year periods.

Maintain existing water & other canopy cover of 49.2 percent

	Number of Trees								
	No Additional Mortality			Ash Kill in 10 Years			Black Walnut Kill in 10		
Mortality (%)	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs	10 yrs	25 yrs	50 yrs
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	350,000	0	0	410,000	0	0	420,000
5	0	190,000	950,000	0	300,000	1,000,000	0	350,000	1,010,000

Increase water & other canopy cover by 5 to 54.2 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	0
4	0	0	480,000
5	0	610,000	1,180,000

Increase water & other canopy cover by 10 to 59.2 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	0
4	0	0	640,000
5	380,000	880,000	1,400,000

Increase water & other canopy cover by 20 to 69.2 percent

	Number of Trees		
Mortality (%)	10 Years	25 Years	50 Years
2	0	0	0
3	0	0	106,000
4	480,000	470,000	1,000,000
5	1,700,000	1,500,000	2,000,000

The results illustrate that at low mortality rates, the projected tree growth more than compensates for the loss of tree cover due to mortality. This result may be an artifact of mortality rates that are too low relative to actual mortality rates, or that growth rates are too high. However, even though tree cover can be sustained without new trees, the total tree population will decline through time and eventually the tree cover of the area will decline rapidly. With very low mortality rates, which are unreasonable (e.g., 0%), no new trees would ever need to be established and tree cover would increase to 100% as no trees would die and existing trees would continue to grow.

Thus, these population projections are estimates that are based on the assumptions that drive canopy cover and tree population estimates (i.e., tree growth and mortality rates). Some information is known on urban tree and forest growth rates, but very little is known on actual tree mortality rates. Long-term urban forest monitoring studies are needed to help determine actual urban tree mortality rates and factors that influence these rates.

APPENDIX IX. I-TREE HYDRO MODEL METHODS AND CALIBRATION GRAPHS

Data and Model Calibration

The hourly weather data were derived from a local weather station at the Charles B. Wheeler Airport in Kansas City (USAF: 724463, WBAN: 99999). Tree and impervious cover parameters (Table 18) were derived for the watershed from photo-interpretation of Google Earth imagery (image date circa May 2010) using 800 randomly located points.

Table 18.—Cover estimates for the Blue River watershed, 2010

	Percent Cover			
Area	Impervious	Tree	Grass/shrub	Bare Soil
Blue River Watershed	31.5%	34.6%	37.6%	1.3%

The model was calibrated using hourly stream flow data collected at the "Blue River at 12th Street in Kansas City, MO" gauging station (USGS 06893590) from 04/15/2000 – 10/31/2000. Model results were calibrated against measured stream flow to yield the best fit between model and measured stream flow results. Calibration coefficients (0-1 with 1.0 = perfect fit) were calculated for peak flow, base flow, and balance flow (peak and base) (Table 19). Differences between measured and estimated flow can be substantially different, particularly for peak flows, due to mismatching of steam flow and weather data as the weather stations are often outside of the watershed area. For example, it may be raining at the weather station and not in the watershed or vice versa. Tree canopy leaf area index (LAI) was estimated at 5 based on various field studies and the amount of percent of impervious cover connected to the stream was estimated at 65 percent.

Table 19.—Calibration coefficients for model estimates and gauging station data

	Calibration Coefficients		
Watershed	Peak Flow	Base Flow	Balanced Flow
Blue River	0.62	0.53	0.68

Model calibration procedures adjust several model parameters (mostly related to soils) to find the best fit between the observed flow and the model flow on an hourly basis. However, there are often mismatches between the precipitation data, which are often collected outside of the watershed, and the actual precipitation that occurs in the watershed. Even if the precipitation measurements are within the watershed, local variations in precipitation intensity can lead to differing amounts of precipitation than observed at the measurement station. These differences in precipitation can lead to poorer fits between the observed and predicted estimates of flow as the precipitation is a main driver of the stream flow. As can be seen in Figure 41, the observed and simulated results can diverge, which is often an artifact of the precipitation data. For example, observed flow will rise sharply, but predicted flow does not, which is an indication of rain in the watershed, but not at the precipitation measurement station. Conversely, the simulated flow may rise, but the observed flow does not, which is an indication of rain at the precipitation station, but not in the watershed.

As the model simulations are comparisons between the base simulation flows and another simulated flow where surface cover is changed (e.g., increase or decrease in tree cover), both model runs are using the same simulation parameters. What this means is that the effects of changes in cover types

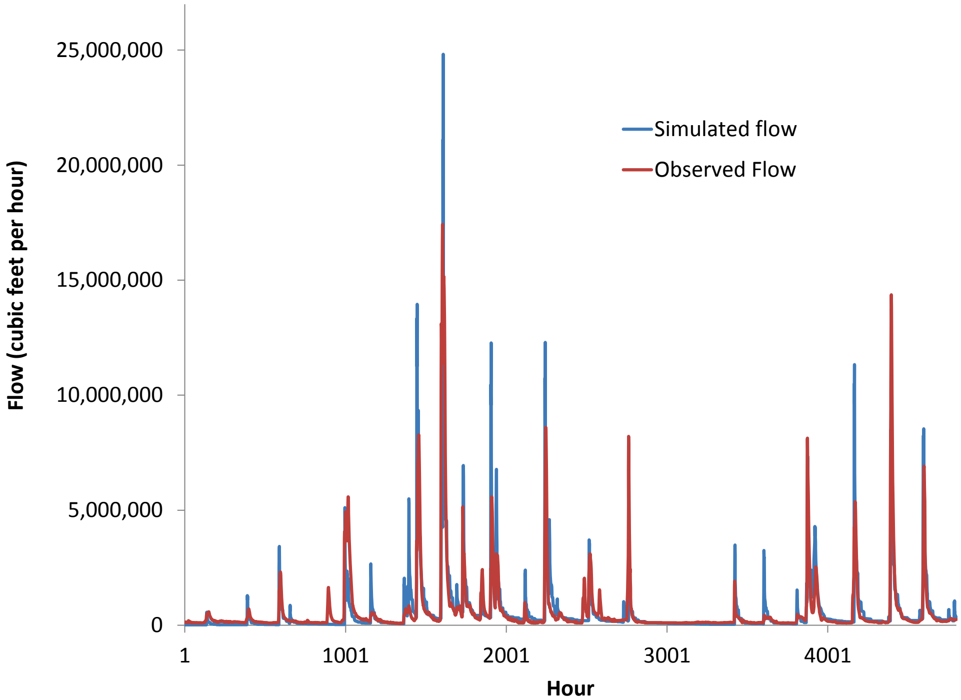


Figure 41.—Comparison of simulated model flow vs. observed flow in Blue River watershed.

are comparable, but may not exactly match the flow of the stream. That is the estimates of the changes in flow are reasonable (e.g., the relative amount of increase or decrease in flow is sound as both are using the same model parameters and precipitation data), but the absolute estimate of flow may be incorrect. Thus the model results can be used to assess the relative differences in flow due to changes in cover parameters, but should not be used to predict the actual effects on stream flow due to precipitation and calibration imperfections. The model can be used to compare the changes in flow (e.g., increased tree cover leads to an x percent change in stream flow), but will likely not exactly match the flow observed in the stream. The model is more diagnostic of cover change effects than predictive of actual stream flow due to imperfections of models and input data used in the model.

The model tends to underestimate observed peak flows, particularly flows over about 8 million cubic feet per hour in Blue River (Fig. 42), which did not occur too often during the simulation period.

Model Scenarios

After calibration, the model was used under various conditions to determine stream flow response given varying tree and impervious cover values for the watershed area. For tree cover simulations, impervious cover was held constant at the original value with tree cover varying between 0 and 100 percent. Increasing tree cover was assumed to fill bare soil spaces first, followed by grass and shrub covered areas, and then finally impervious covered land. At 100 percent tree cover, all impervious land is covered by trees. This assumption is unreasonable as all buildings, roads, and parking lots would be covered by trees, but the results illustrate the potential impact. Tree cover reductions assumed that trees were replaced with grass and shrub cover.

For impervious cover simulations, tree cover was held constant at the original value with impervious cover varying between 0 and 100 percent. Increasing impervious cover was assumed to fill bare soil spaces first, then grass and shrub covered areas, and then finally under tree canopies. The assumption

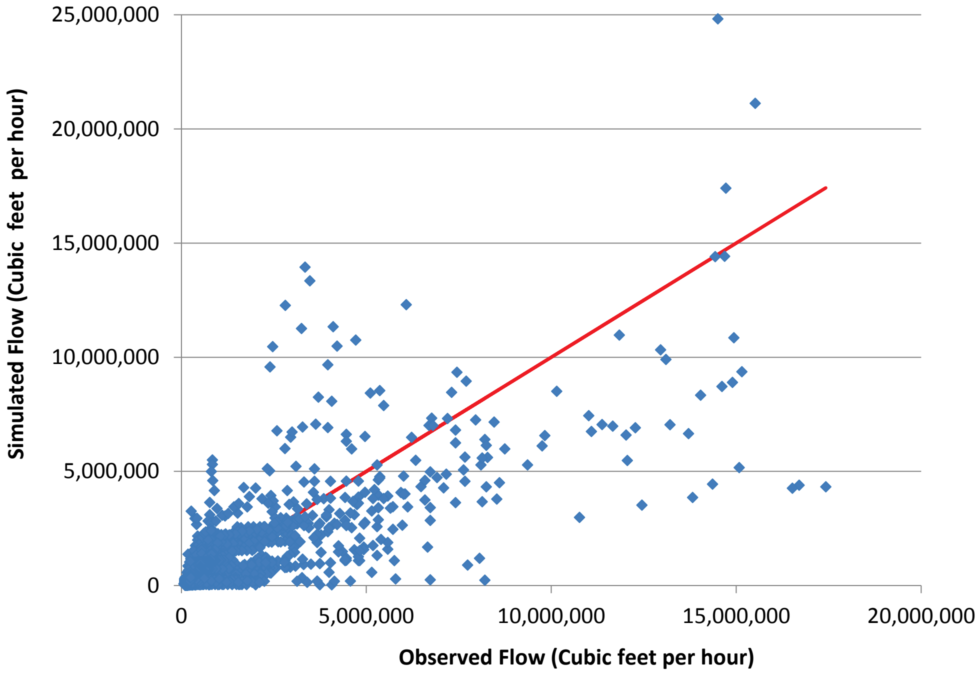


Figure 42.—Comparison observed vs. simulated flow, Blue River watershed.

of 100 percent impervious cover is unreasonable, but the results illustrate the potential impact. In addition, as impervious increased from the current conditions, so did the percent of the impervious cover connected to the stream such that at 100% impervious cover, all (100%) impervious cover is connected to the stream. Reductions in impervious cover were assumed to be filled with grass and shrub cover.

Water Quality Effects—Event Mean Concentration to Calculate Pollution Load

Event mean concentration (EMC) data is used for estimating pollutant loading into watersheds. EMC is a statistical parameter representing the flow-proportional average concentration of a given parameter during a storm event and is defined as the total constituent mass divided by the total runoff volume. EMC estimates are usually obtained from a flow-weighted composite of concentration samples taken during a storm. Mathematically[37,38]:

$$EMC = \overline{C} = \frac{M}{V} = \frac{\int C(t)\,Q(t)dt}{\int Q(t)dt} \approx \frac{\sum C(t)\,Q(t)\Delta t}{\sum Q(t)\Delta t} \qquad (1)$$

where $C(t)$ and $Q(t)$ are the time-variable concentration and flow measured during the runoff event, and M and V are pollutant mass and runoff volume as defined in Equation 1. It is clear that the EMC results from a flow-weighted average, not simply a time average of the concentration. EMCs are reported as a mass of pollutant per unit volume of water (usually mg/L).

The pollution load () calculation from the EMC method is

$$L = EMC * Q = EMC * d_r * A \qquad (2)$$

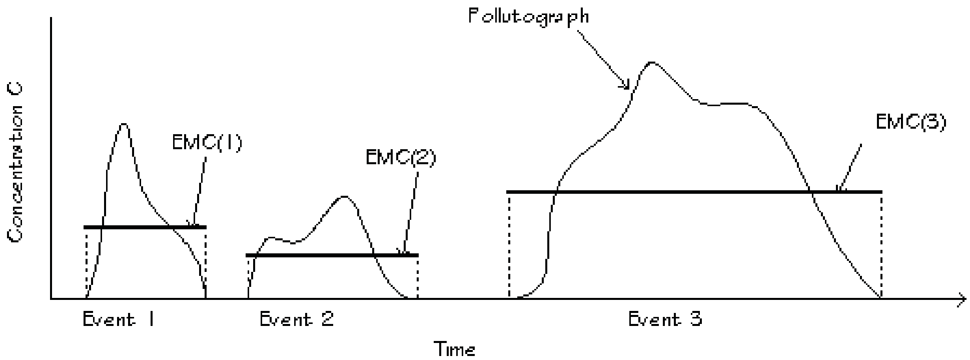


Figure 43.—Inter-storm variation of pollutographs and event mean concentrations (EMC).

Where EMC is event mean concentration (mg/l, mg/m^3, lbs/ft^3,…), Q is runoff of a time period associated with EMC (l/h, m^3 /day, ft^3/day, …), d_r is runoff depth of unit area (mm/h, in/h, …), A is the land area (m^2, ft^2…) which is catchment area in i-Tree Hydro.

Thus, when the EMC is multiplied by the runoff volume, an estimate of the loading to the receiving water is provided. The instantaneous concentration during a storm can be higher or lower than the EMC, but the use of the EMC as an event characterization replaces the actual time variation of C versus *t* in a storm with a pulse of constant concentration having equal mass and duration as the actual event. This process ensures that mass loadings from storms will be correctly represented. EMCs represent the concentration of a specific pollutant contained in stormwater runoff coming from a particular land use type or from the whole watershed. Under most circumstances, the EMC provides the most useful means for quantifying the level of pollution resulting from a runoff event.[39] Figure 43 illustrates the inter-storm variation of pollutographs and EMC.

Since collecting the data necessary for calculating site-specific EMCs can be cost-prohibitive, researchers or regulators will often use values that are already available in the literature. If site-specific numbers are not available, regional or national averages can be used, although the accuracy of using these numbers is questionable. Due to the specific climatological and physiographic characteristics of individual watersheds, agricultural and urban land uses can exhibit a wide range of variability in nutrient export.[40]

To understand and control urban runoff pollution, the U.S. Congress included the establishment of the Nationwide Urban Runoff Program (NURP) in the 1977 amendments to the Clean Water Act (PL 95-217). The U.S. Environmental Protection Agency developed the NURP to expand the state knowledge of urban runoff pollution by applying research projects and instituting data collection in selected urban areas throughout the country.

In 1983, the U.S. Environmental Protection Agency[41] published the results of the NURP, which nationally characterizes urban runoff for 10 standard water quality pollutants, based on data from 2,300 station-storms at 81 urban sites in 28 metropolitan areas.

Subsequently, the USGS created another urban stormwater runoff base[42], based on data measured through mid-1980s for more than 1,100 stations at 97 urban sites located in 21 metropolitan areas. Additionally, many major cities in the United States collected urban runoff quality data as part of the application requirements for stormwater discharge permits under the National Pollutant Discharge

Elimination System (NPDES). The NPDES data are from over 30 cities and more than 800 station-storms for over 150 paramaters.[43]

The data from the three sources (NURP, USGS, and NPDES) were used to compute new estimates of EMC population means and medians for the 10 pollutants with many more degrees of freedom than were available to the NURP investigators.[43] A "pooled" mean was calculated representing the mean of the total population of sample data. The NURP and pooled mean EMCs for the 10 pollutants or constituents are listed in the Table 20.[43] NURP or pooled mean EMCs were selected because they are based on field data collected from thousands of storm events. These estimates are based on nationwide data, however, so they do not account for regional variation in soil types, climate, and other factors.

Table 20.—National pooled EMCs and NURP EMCs

		EMCs (mg/l)		
Pollutant/Constituent (Abbrevation)	Data Source	Mean	Median	No. of Events
Total Suspended Solids (TSS)	Pooled	78.4	54.5	3047
	NURP	17.4	113	2000
Biochemical Oxygen Demand (BOD5)	Pooled	14.1	11.5	1035
	NURP	10.4	8.39	474
Chemical Oxygen Demand (COD)	Pooled	52.8	44.7	2639
	NURP	66.1	55	1538
Total phosphorus (TP)	Pooled	0.315	0.259	3094
	NURP	0.337	0.266	1902
Soluble phosphorus (Soluble P)	Pooled	0.129	0.103	1091
	NURP	0.1	0.078	767
Total Kjeldhal nitrogen (TKN)	Pooled	1.73	1.47	2693
	NURP	1.67	1.41	1601
Nitrite and Nitrate (NO2 and NO3)	Pooled	0.658	0.533	2016
	NURP	0.837	0.666	1234
Copper (Cu)	Pooled	13.5	11.1	1657
	NURP	66.6	54.8	849
Lead (Pb)	Pooled	67.5	50.7	2713
	NURP	175	131	1579
Zinc (Zn)	Pooled	162	129	2234
	NURP	176	140	1281

Note: (1) Polled data sources include: NURP, USGS, NPDES
(2) No BOD5 data available in the USGS dataset - polled includes NURP+NPDES
(3) NO TSP data available in NPDES dataset - polled includes NURP+USGS

For i-Tree Hydro, the pooled median and mean EMC value for each pollutant were applied to the runoff regenerated from pervious and impervious surface flow, not the base flow values, to estimate effects on pollutant load across the entire modeling period. All rain events are treated equally using the EMC value, which mean some events may be overestimated and others underestimated. In addition, local management actions (e.g., street sweeping) can affect these values. However, across the entire season, if the EMC value is representative of the watershed, the estimate of cumulative effects on water quality should be relatively accurate. Accuracy of pollution estimates will be increased by using locally derived coefficients. It is not known how well the national EMC values represent local conditions.

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blocks (maximum value – minimum value). Standardized value for tree stocking was calculated as TS = [1 – (t/(t+g)], where TS is the value (0-1), t is percent tree cover, and g is percent grass cover. Standardized value for tree cover per capita was calculated as TPC = 1 – [(n – m)/r], where TPC is the value (0-1), n is the value for the census block (m^2/capita), m is the minimum value for all census blocks, and r is the range of values among all census blocks (maximum value – minimum value).

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Brush Creek, Kansas City MO.

Photo by Mid-America Regional Council, used with permission.

Nowak, David J.; Bodine, Allison R.; Hoehn, Robert E. III; Crane, Daniel E.; Ellis, Alexis; Endreny, Theodore A.; Yang, Yang; Jacobs, Tom; Shelton, Kassie. 2013. **Assessing urban forest effects and values: the greater Kansas City region.** Resour. Bull. NRS-75. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 72 p.

An analysis of trees in the greater Kansas City region of Missouri and Kansas reveals that this area has about 249,450,000 trees with tree and shrub canopy that covers 28.3 percent of the region. The most common tree species are American elm, northern hackberry, Osage-orange, honeylocust, and eastern redcedar. Trees in the greater Kansas City region currently store about 19.9 million tons of carbon (72.8 million tons CO_2) valued at $411 million. In addition, these trees remove about 1.0 million tons of carbon per year (3.7 million tons CO_2 per year valued at $20.7 million per year) and about 26,000 tons of air pollution per year ($198.3 million per year). The greater Kansas City region's trees are estimated to reduce annual residential energy costs by $14.0 million per year. The compensatory value of the trees is estimated at $93.4 billion. Loss of the current tree cover in the Blue River watershed of the greater Kansas City region would increase total flow over a 6.5-month period by an average of 2.3 percent (63.4 million ft^3). Information on the structure and functions of the urban forest can be used to inform urban forest management programs and to integrate urban forests within plans to improve environmental quality in the greater Kansas City region.

KEY WORDS: urban forestry, ecosystem services, air pollution removal, carbon sequestration, tree value

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