People & Trees

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Assessing the US Urban Forest Resource

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ABSTRACT

Urban areas in the conterminous United States doubled in size between 1969 and 1994, and currently cover 3.5 percent of the total land area and contain more than 75 percent of the US population. Urban areas contain approximately 3.8 billion trees with an average tree canopy cover of 27 percent. The extent and variation of urban forests across the 48 states are explored to help build a better understanding of this significant national resource. Urbanization and urban forests are likely to be a significant focus of forestry in the 21st century.

Keywords: inventory; urban forestry

Human population is having an ever-increasing impact on the local, regional, and global environments. This impact is particularly significant in urban areas, where concentrations of people fragment and transform natural resources, resulting in large-scale environmental consequences. Urban forests (i.e., all trees and other associated resources within urban areas) are characterized by the integration of natural resources with human developments (Nowak 1994a). In these situations, vegetation often has substantial environmental, social, and economic values.

Urban forests can improve environmental quality, enhance individual and community well-being, provide a wide range of services to individuals and communities, and produce a more healthful and comfortable environment for most Americans. Knowledge of the current and potential significance of urban forests is expanding rapidly as research continues to document the important role urban forests can play in improving the quality of life. Urban residents will look to urban forests and associated management programs for an increasing number of benefits in the years ahead.

Through appropriate planning, de-

Above: **Urban forests are ecosystems composed of interactive anthropogenic and natural systems.**

Figure 1. **Urban areas in the conterminous United States.** ***Source:*** **Dwyer et al. 2000.**

sign, and management, urban forests can mitigate many of the environmental impacts of urban development by moderating climate, reducing building energy use, absorbing ultraviolet radiation and atmospheric carbon dioxide, improving air and water quality, lowering rainfall runoff and flooding, and reducing noise levels (Nowak and Dwyer 2000). In addition to affecting the physical and biological environment, urban forests can enhance the social and economic environment of a city. These important influences can range from altered aesthetic surroundings and increased property values to a stronger sense of community and a greater connection between people and the natural environment (Dwyer et al. 1992). Forests can turn city blocks into special places—places for residents to recreate, to gather with family and friends, and to care about.

The effects of the urban forest on the physical, biological, and social environments range from the inner city to the most remote wilderness. The quality of the air, and both the quality and quantity of the water that leaves urban areas, can affect the quality of exurban areas. The nature of the urban environment also plays an important role in people's perceptions of, interest in, and use of both urban and exurban forests, as well as their participation in natural resource management issues across the country.

The urban forest may be the only forest that some urban residents will ever experience. Thus, urban forests can provide a context for the values that urbanites place on forests in general. Vice-President Gore (1998) articulated the importance of forest resources in urban areas across the United States when he remarked, "Most of us can't afford to travel to Yellowstone or the Grand Canyon when we want to enjoy the rich American landscape; a livable neighborhood lets you and your spouse walk through a natural ecosystem as you simply take an evening stroll down your street."

Urban forests and their management are particularly important components of US forests and forestry because they occur where the vast majority of the human population lives, works, and recreates. Three out of four Americans live in urban areas where they directly affect and are affected by urban forests. The complexity of the urban ecosystem, its wide-ranging uses, and the diversity of its residents create an outstanding laboratory for learning about interactions between people and forests, communicating with most of the country's population, and developing management strategies to meet diverse public needs while sustaining forest ecosystems. Thus, urban and community forestry can become a key component of the overall national effort to involve all citizens in natural resource management, and the urban forest is likely to be the most influential forest of the 21st century.

Many of the functions and benefits ascribed to urban forests are directly related to the urban forest structure (e.g., number of trees, sizes, species composition, tree location). This article discusses some of the findings from the first national assessment of urban forests in the United States (Dwyer et al. 2000). The objective of the national assessment was to provide a solid knowledge base for large-scale planning activities to manage the nation's urban forest resource. The focus of this discussion is the extent and variation in the urban forest resource across the 48 conterminous states.

Urban Areas

The urban forest resource cannot be assessed without delimiting its spatial extent. Urban forests are ecosystems characterized by the presence of trees and other vegetation in association with people and their developments. Although people influence forests across the landscape, urban forests are located where human influences are concentrated (cities, towns, and villages). The fundamental definition of urban is an area with a much higher population density than elsewhere (Mills and Hamilton 1984).

In this article, urban areas are defined as the area occupied by the union of three census-defined urban designations (US Department of Commerce 1994): (1) urbanized areas (population of 50,000 or more and a minimum population density of 384 people per square kilometer); (2) places (concentrations of people in incorporated or census-designated areas that have a name, are locally recognized, and are not part of any other place) that contain some urbanized areas within their boundaries; and (3) urban places (places with at least 2,500 people and located outside of urbanized areas). Areas totally surrounded by urbanized areas but not within an urbanized area or place boundary were also considered to be an urban area (Dwyer et al. 2000). This urban area definition in-

cludes geographic areas where populations and urban influences are most concentrated and encompasses the cities, towns, and villages that comprise the area considered by many to be the urban and community forest *(fig. 1)*.

Courtesy of Emerge

The urban forest is a significant resource that varies across the city landscape.

Urban Tree Cover Analysis

Land area, water area, and population statistics for urban areas were obtained from the Bureau of the Census (US Department of Commerce 1992). Data on percentage of tree cover across the United States were derived through geographic information system (GIS) analysis of forest-cover maps and maps of census-designated entities. The forest-cover maps were generated by the USDA Forest Service, Southern Research Station, Forest Inventory and Analysis research unit, by applying statistical regression analysis to multitemporal 1-kilometer resolution advanced very high resolution radiometer (AVHRR) data and Landsat thematic mapper™ data (Zhu 1994). These tree-cover data were subsequently combined with the boundaries of states, counties, and urban areas in a GIS to estimate tree cover within each of these designations across the United States. Within each urban geographic boundary, tree cover was calculated by using an average of forest density estimates for individual pixels.

Urban Forest Population Assessment

To assess the total urban forest resource in the United States, the percentage of tree cover for every urban area was estimated from the AVHRR data and multiplied by its associated land and water area (US Department of Commerce 1992) to estimate the total area of tree canopy cover (in hectares).

The average number of trees (>2.54 cm dbh) per hectare of tree cover in urban areas was calculated from urban forest field measurements from selected cities *(table 1)*. The average tree-cover density (i.e., number of trees per hectare of tree cover) for urban areas in the United States was 504 trees per hectare of tree cover. The maximum density for a city was 751 trees per hectare of tree cover in Atlanta, and the minimum density was 312 trees per hectare of tree cover in New York. The average tree-cover density was multiplied by the total hectares of tree cover in urban areas to estimate the total number of urban trees in the United States, and by state.

Table 1. Estimated number of trees, tree density (trees per hectare), percent tree cover, and tree-cover density (trees per hectare of tree cover) for selected US cities.

City	Number of trees (thousands)		Tree density		Tree cover (percent)[1]		Tree-cover density[2]
	Total	Standard error	Mean	Standard error	Mean	Standard error	Mean
Atlanta	9,420	749	276	22	36.7	2.0	751
New York	5,220	719	65	9	20.9	2.0	312
Chicago	4,130	634	68	10	11.0	0.2	618
Baltimore	2,600	406	109	17	21.5	2.5	508
Philadelphia	2,110	211	62	6	15.7	1.3	394
Oakland	1,590	51	120	4	21.0	0.2	570
Boston	1,180	109	83	8	22.3	1.8	372

NOTE: Data are based on field sampling of all land uses within the city. Unpublished tree cover data are on file with USDA Forest Service, Northeastern Research Station. City data are from Nowak and Crane (2000), except for Chicago (Nowak 1994b), and Oakland (Nowak 1991).
[1]Tree cover estimated from 0.04-hectare field plots, except for Chicago and Oakland where data are based on aerial photo sampling of tree cover.
[2]Average tree-cover density = 504 trees per hectare of tree cover.

Urban Forests of the United States

Urban areas occupy 3.5 percent, or 281,000 square kilometers, of the conterminous United States. An earlier estimate of the extent of urban area, based on land-use data from 1969, was 279,000 square kilometers (Grey and Deneke 1986). This previous estimate of urban area was excessive, as it included nonurban transportation lands (i.e., railways and interstate highway systems). Excluding nonurban transportation land, the estimated urban area in the United States in 1969 would be adjusted to 139,000 square kilometers, or about 1.7 percent of the United States (Frey 1973). Thus, urban land in the United States doubled between 1969 and 1994.

Urban areas tend to be concentrated in the Northeast and Pacific Coast regions. Of the 10 most urbanized states, nine are in the Northeast. States with the highest proportion of their land in urban areas are New Jersey, Connecticut, and Massachusetts *(table 2, p. 40)*. States with the lowest proportion of their land in urban areas are in the West and include North Dakota, Wyoming, and South Dakota *(table 2)*.

Nationally, urban areas have an average tree cover of 27 percent *(table 2)*. This percentage of tree cover is not far below the national average for all lands (33 percent) (Dwyer et al. 2000). States with the highest average percent tree cover in urban areas are Georgia,

Table 2. Estimated number of urban trees, urban trees per capita, percent of tree cover in urban areas, proportion of total state tree cover in urban areas, amount of urban land, and proportion of total state area occupied by urban land, by state, in the conterminous United States.

State	Urban trees (thousands)	Urban trees per capita	Urban tree cover	Proportion of state tree cover	Urban area[a] (km^2)	Urban proportion of state
Georgia	232,906	49	55.3%	4.7%	8,338	5.4%
Alabama	205,847	69	48.2	4.7	8,487	6.3
Ohio	191,113	22	38.3	7.0	9,923	8.5
Florida	169,587	13	18.4	5.5	18,407	10.8
Tennessee	163,783	49	43.9	5.1	7,382	6.8
Virginia	156,545	27	35.3	4.9	8,869	8.0
Illinois	155,544	14	33.7	5.5	9,165	6.1
California	148,612	5	10.9	2.2	27,348	6.4
New Jersey	143,869	20	41.4	22.3	6,916	30.6
Texas	140,709	8	10.5	3.6	26,573	3.8
Pennsylvania	139,020	16	34.4	4.2	8,363	7.0
North Carolina	138,606	36	42.9	3.4	6,419	4.6
New York	132,466	8	26.3	3.5	10,127	7.2
Minnesota	127,767	33	37.4	2.2	6,775	3.0
Michigan	110,858	17	29.7	1.6	7,494	3.0
Montana	108,550	251	49.4	2.2	4,365	1.1
Washington	93,272	23	33.6	2.0	5,679	3.1
Maryland	89,434	21	40.1	11.1	4,525	14.1
Missouri	87,148	21	30.6	2.3	5,655	3.1
Massachusetts	86,829	17	25.3	14.4	6,893	25.2
South Carolina	86,696	44	39.8	3.6	4,380	5.3
Indiana	78,498	21	31.2	4.2	5,000	5.3
Maine	68,550	110	47.7	2.2	2,887	3.1
Louisiana	68,510	19	25.3	2.4	5,374	4.0
Mississippi	65,520	48	38.6	1.8	3,365	2.7
Wisconsin	59,344	18	25.8	1.5	4,565	2.7
Oklahoma	58,204	16	14.5	3.6	7,940	4.4
Kentucky	56,681	23	33.4	1.9	3,374	3.2
Arizona	53,950	9	11.4	2.4	9,218	3.1
Iowa	52,474	29	33.1	1.9	3,148	2.2
Connecticut	44,800	14	21.8	14.0	4,085	28.5
Arkansas	43,412	32	25.0	1.5	3,435	2.5
New Hampshire	41,455	60	49.1	4.6	1,678	6.9
Oregon	34,583	17	30.4	.6	2,280	.9
Colorado	28,149	7	13.0	.8	4,345	1.6
Kansas	26,677	17	20.5	2.9	2,575	1.2
West Virginia	22,871	33	42.2	.9	1,086	1.7
Utah	18,330	9	14.0	1.0	2,577	1.2
Nevada	15,834	9	9.9	.8	3,195	1.1
Delaware	13,257	27	46.3	9.0	566	8.8
Idaho	12,494	18	25.6	.3	966	.4
Nebraska	11,243	10	21.1	.9	1,061	.5
Vermont	7,558	42	36.0	.8	416	1.7
South Dakota	6,007	15	19.2	.5	617	.3
New Mexico	5,682	4	4.8	.3	2,316	.7
Rhode Island	4,155	5	8.9	6.0	926	23.2
North Dakota	1,774	5	7.8	.2	457	.2
Wyoming	1,392	3	3.6	.1	797	.3
US total[b]	3,820,491	17	27.1	2.8	281,000[c]	3.5

[a] *Includes land and water.*
[b] *US total includes the District of Columbia but not Alaska and Hawaii.*
[c] *Includes 492 square kilometers that crossed state borders and could not be assigned to an individual state.*

Montana, and New Hampshire; states with the lowest average urban tree cover are Wyoming, New Mexico, and North Dakota. States with the highest proportion of their total tree cover across the state occurring in urban areas include New Jersey, Massachusetts, and Connecticut.

Three factors help to explain variation in percentage of tree cover among urban areas across the United States: ecoregion type, population density, and land use. Based on an analysis of all urban areas in the conterminous United States, urban tree cover tends to be highest in urban areas that developed in forested ecoregions (34.4 percent), followed by grasslands (17.8 percent), and deserts (9.3 percent). These results are consistent with previous estimates of urban tree cover by ecoregion types (based on aerial photo interpretation of 58 US cities), where tree cover averaged 31.1 percent in forest cities, 18.9 percent in grassland cities, and 9.9 percent in desert cities (Nowak et al. 1996).

Percentage of tree cover in urban areas tends to decrease as population density increases in all ecoregion types (forest: $r = -0.37$; grassland: $r = -0.25$; desert: $r = -0.18$). This pattern is consistent with results from an earlier analysis of 58 US cities, which showed that the percentage of total green space (bare soil and vegetation cover) in cities tends to decrease with population density, regardless of ecoregion type ($r = -0.64$) (Nowak et al. 1996).

Percentage of tree cover in urban areas tends to increase with increasing city area in forest and grassland areas, but tends to decrease with city area in desert areas. This pattern is likely a reflection of the distribution of land uses in cities, which is a significant determinant of the amount of local tree cover (Nowak et al. 1996). As city area increases, the amount of vacant land is likely to increase. In forest and some grassland areas, vacant lands tend to fill with trees through natural regeneration. As vacant land in desert regions generally does not support natural tree regeneration, increased vacant land tends to decrease the overall percentage of tree cover in large desert cities.

The number of trees within urban areas of the United States is estimated to be 3.8 billion (ranging between 2.4 and 5.7 billion based on minimum and maximum city tree-cover density estimates). This estimate is much higher than an earlier estimate of 660 million urban trees, which was based on the conservative assumption that 10 nonstreet trees exist for every street tree in cities (Kielbaso 1990). With an estimated 60 million US street trees in urban areas (Kielbaso 1990), results from this assessment suggest that an average of about 62 nonstreet trees exist for every street tree in urban areas across the country. This national ratio is similar to that found in Oakland (57 nonstreet urban trees per street tree) (Nowak 1991); but is higher than the ratio found in Chicago (9) and Cook and DuPage Counties, Illinois (34) (Nowak 1994b).

States with the highest estimated total tree population in urban areas include Georgia, Alabama, and Ohio *(table 2)*. States with the lowest urban area tree populations are Wyoming, North Dakota, and Rhode Island. Differences in state urban tree population totals are a function of the amount of urban land in the state and average percent tree cover within urban areas of the state. To obtain better estimates of state urban forest population totals, field data are needed to determine actual urban tree population density within the state. Current state estimates are based on a national average from limited field samples.

Individual City Population Estimates

Superimposed on broad regional variations in urban forest structure are significant local variations among and within cities. Although limited data exist on urban forest structure in particular cities *(table 1),* this type of local data is essential for understanding local-scale variations and structure, and fundamental to improving urban forest management. Current estimates of individual city tree populations range from 1.2 million trees in Boston to 9.4 million trees in Atlanta *(table 1)*. Within cities, tree population characteristics vary by land-use type (Nowak 1994a, 1994b).

To assist foresters and others who plan or manage the urban forest, the Urban Forest Effects (UFORE) model has been developed to quantify urban forest structure and selected functions (e.g., carbon storage and sequestration, air pollution removal) based on field sampling of tree parameters (Nowak and Crane 2000). More research is needed on the structure of forests in individual cities, how urban forest structure and health change over time, and how structure is linked to important forest benefits.

Influences on Natural Resources

As urban development continues to expand over the landscape, the interrelations among urban growth, urban influence, and natural resource systems will become increasingly important. Many cities, particularly in the Southeast, are surrounded by forestland. The expansion of these cities is likely to have a significant impact on the extent, use, and management of adjacent forest resources. For example, increased population density has been found to reduce the availability of timber from forestlands (Barlow et al. 1998; Wear et al. 1999). Residential developments around cities also can limit access to public and private lands for outdoor recreation (Ewert et al. 1993). As urbanization spreads into less-developed rural areas, a growing percentage of the nation's natural resources will become part of urban forest ecosystems, and increasing amounts of forestland outside these systems also will be subject to urban influences.

The expansion of urban areas has particularly important implications for the use and management of public holdings, including national forests, national parks, and state- and locally administered natural resources. As urban residents frequently travel to exurban areas for outdoor recreation, the demands placed on forest ecosystems in close proximity to growing urban centers pose difficult challenges for natural resource managers. Heightened resource use, increased mobility or ignition of potential hazards (for example, insects and disease, fire, invasive species), conflicts regarding recreational opportunities, and seasonal and permanent home development can

greatly complicate the issues that must be addressed in protecting the health and sustainability of these valuable areas. Thus, urbanization is likely to be one of the most significant forest influences of the 21st century.

Conclusion

The urban forest resource is complex, expanding in extent, and increasing in national and local significance. The resource and its management has a substantial impact on the health and well-being of urban residents who live, work, and spend most of their leisure time in urban areas. The urban forest also influences how urban residents experience, perceive, and relate to natural resources across the urban-to-wilderness spectrum.

The information presented in this article is the beginning of an effort to assess the urban forest at a national scale as part of the USDA Forest Service's strategic planning efforts. Additional information is needed on the structure and function of the urban forest at the national, regional, and local scales, as well as on the interrelationships among structure, functions, and benefits provided to individuals and communities. This information is critical given the increasing importance of urban forests as a component of our nation's natural resources.

Literature Cited

BARLOW, S.A., I.A. MUNN, D.A. CLEAVES, and D.L. EVANS. 1998. The effect of urban sprawl on timber harvesting. *Journal of Forestry* 96(12):10–14.

DWYER, J.F., E.G. MCPHERSON, H.W. SCHROEDER, and R.A. ROWNTREE. 1992. Assessing the benefits and costs of the urban forest. *Journal of Arboriculture* 18(5):227–34.

DWYER, J.F., D.J. NOWAK, M.H. NOBLE, and S.M. SISINNI. 2000. *Assessing our nation's urban forests: Connecting people with ecosystems in the 21st century*. General Technical Report PNW-490. Portland, OR: USDA Forest Service.

EWERT, A.W., D. CHAVEZ, and A.W. MAGILL, eds. 1993. *Culture, conflict, and communication in the wildland-urban interface*. Boulder, CO: Westview Press.

FREY, H.T. 1973. *Major uses of land in the United States, summary for 1969*. Agricultural Economic Report 247. Washington, DC: US Department of Agriculture, Economic Research Service.

GORE, A. 1998. Speech given before the Brookings Institution, September 2, Washington, DC.

GREY, G.W., and F.J. DENEKE. 1986. *Urban forestry.* New York: John Wiley & Sons.

KIELBASO, J.J. 1990. Trends and issues in city forests. *Journal of Arboriculture* 16(3):69–76.

MILLS, E.S., and B.W. HAMILTON. 1984. *Urban economics*. Glenview, IL: Scott, Foresman and Company.

NOWAK, D.J. 1991. Urban forest development and structure: Analysis of Oakland, California. PhD dissertation, University of California, Berkeley.

———. 1994a. Understanding the structure of urban forests. *Journal of Forestry* 92(10):42–46.

———. 1994b. Urban forest structure: The state of Chicago's urban forest. In *Chicago's urban forest ecosystem: Results of the Chicago urban forest climate project,* eds. E.G. McPherson, D.J. Nowak, and R.A. Rowntree, 3–18. General Technical Report NE-186. Radnor, PA: USDA Forest Service.

NOWAK, D.J., and D.E. CRANE. 2000. The urban forest effects (UFORE) model: Quantifying urban forest structure and functions. In *Integrated tools for natural resources inventories in the 21st century,* eds. M. Hansen and T. Burk, 714–20. General Technical Report NC- 212. St. Paul, MN: USDA Forest Service.

NOWAK, D.J., and J.F. DWYER. 2000. Understanding the benefits and costs of urban forest ecosystems. In *Urban and community forestry in the Northeast,* ed. J. Kuser, 11–25. New York: Plenum Press.

NOWAK, D.J., R.A. ROWNTREE, E.G. MCPHERSON, S.M. SISINNI, E. KERKMANN, and J.C. STEVENS. 1996. Measuring and analyzing urban tree cover. *Landscape and Urban Planning* 36:49–57.

US DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS. 1992. *Census of population and housing, 1990: Summary tape file 3 on CD-ROM* [machine-readable data files]. Washington, DC.

———. 1994. *Geographic areas reference manual*. Washington, DC: Economics and Statistics Administration, Bureau of the Census.

WEAR, D.N., R. LIU, J.M. FOREMAN, and R.M. SHEFFIELD. 1999. The effects of population growth on timber management and inventories in Virginia. *Forest Ecology and Management* 118:107–15.

ZHU, Z. 1994. *Forest density mapping in the lower 48 states: A regression procedure*. Research Paper SO-280. New Orleans, LA: USDA Forest Service.

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