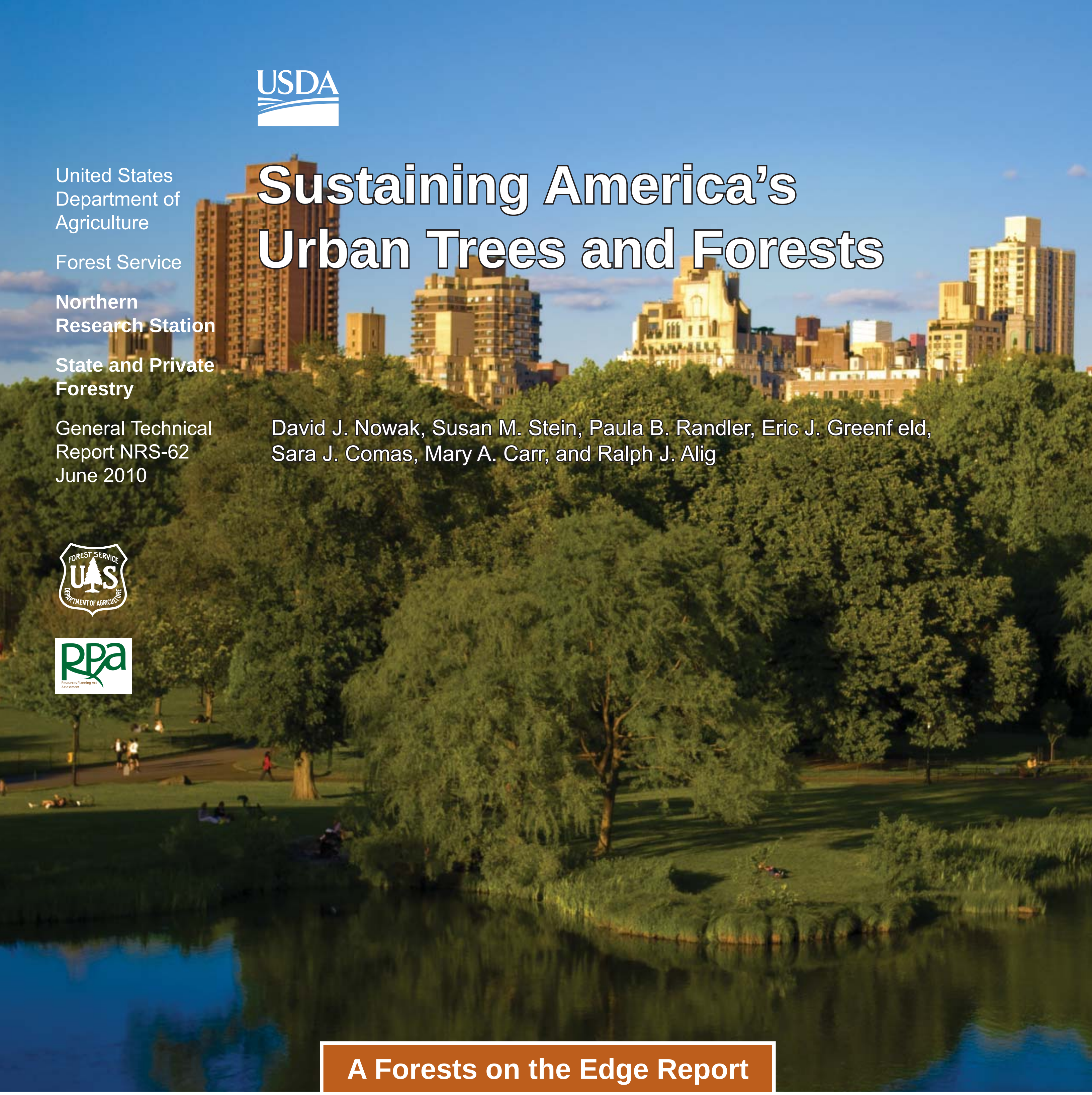

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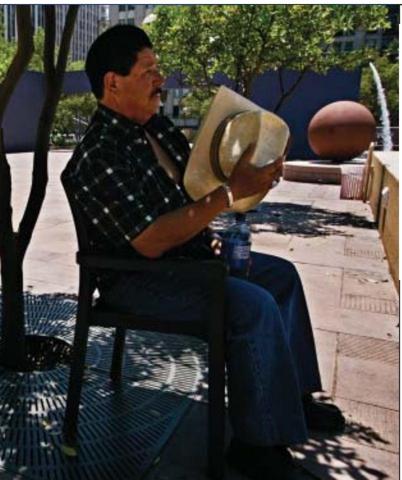
Sustaining America's Urban Trees and Forests

David J. Nowak, Susan M. Stein, Paula B. Randler, Eric J. Greenfield, Sara J. Comas, Mary A. Carr, and Ralph J. Alig

A Forests on the Edge Report



ABSTRACT

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Close to 80 percent of the U.S. population lives in urban areas and depends on the essential ecological, economic, and social benefits provided by urban trees and forests. However, the distribution of urban tree cover and the benefits of urban forests vary across the United States, as do the challenges of sustaining this important resource. As urban areas expand across the country, the importance of the benefits that urban forests provide, as well as the challenges to their conservation and maintenance, will increase. The purpose of this report is to provide an overview of the current status and benefits of America's urban forests, compare differences in urban forest canopy cover among regions, and discuss challenges facing urban forests and their implications for urban forest management.

Key Words: Urban forest, urbanization, land management, ecosystem services

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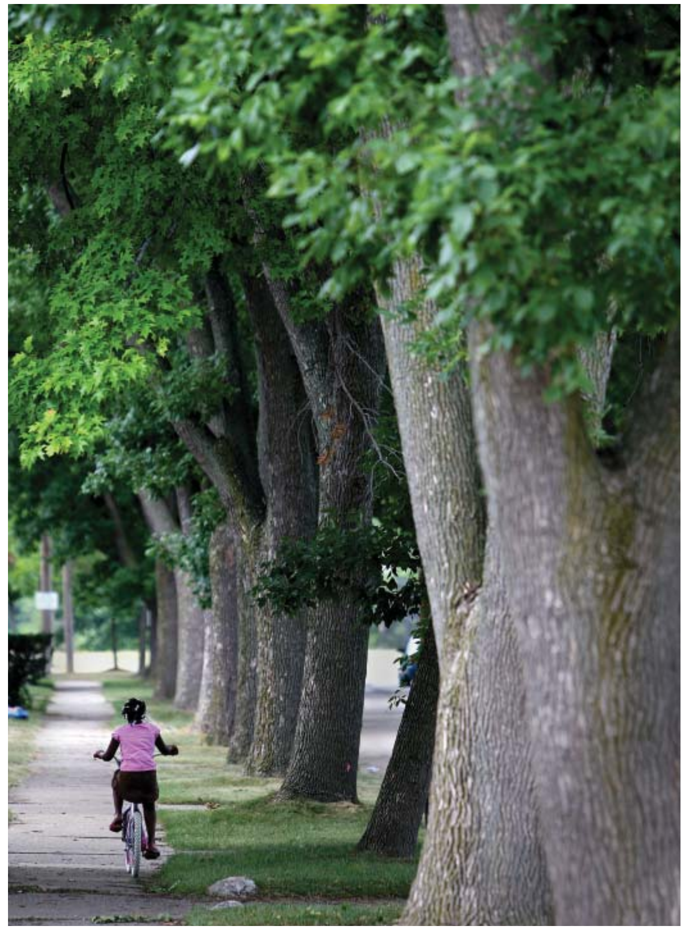

AP Photo: The Plain Dealer, Lisa DeJong

Urban forests offer aesthetic values and critical services.

INTRODUCTION

While the aesthetic values of urban forests might be eye-catching, the many critical services they provide tend to be overlooked. In addition to being attractive, urban forests provide a myriad of essential services to the more than 220 million people who live in urban areas in the United States (U.S. Census Bureau 2001)—including reduced energy use, improved water quality, diverse wildlife habitat, and increased human health and well-being. Urban forests are an essential component of America's "green infrastructure" (see box) and their benefits extend well beyond the cities and towns where they are located.

The care and management of many urban forests can be complicated by natural and social factors including: insects and diseases; wildfire; natural catastrophic events (such as ice storms and wind storms, including hurricanes); invasive plants; climate change; development; air pollution; lack of adequate management; and other social factors. As urban expansion continues, such challenges are likely to increase and new ones might emerge.

This report is one of several produced by the U.S. Department of Agriculture, Forest Service, as part of the Resources Planning Act (RPA) Assessment and Forests on the Edge projects. The report is intended for use by urban forest managers and by organizations that support urban forest management to help increase awareness among the general public of the importance of urban forests, their many benefits, and the various factors that challenge the management of these critical resources. It also presents data used to compare tree cover among counties across the conterminous United States (the lower 48 states). Alaska and Hawaii were not included in the analyses because of incomplete cover data. The report concludes with a list of tools for cost-effective management.

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Urban forests provide green space in the urban landscape.

America's Green Infrastructure

America's forests are sometimes referred to as "green infrastructure" to emphasize the critical public benefits they provide. The term has been defined as "an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations" (Benedict and McMahon 2002). Urban forests are an integral part of this structure, providing a lattice of green in an otherwise artificial landscape. "The value of an urban forest is equal to the net benefits that members of society obtain from it" (McPherson et al. 1997).

Similar to other national assessments, findings may not completely capture specific details at all levels or in specific localities. However, results can help foster an understanding of where, nationwide, vital urban forest contributions are most significant and could be enhanced or lost in the future. Although the results are summarized at the county scale, it is at both the local and regional levels where landowners, communities, and agencies can come together to plan for sustainable growth while conserving the ability of urban and rural forests to provide valuable ecosystem services and economic opportunity far into the future.

About Forests on the Edge

Sponsored by the State and Private Forestry, Cooperative Forestry staff of the U.S. Forest Service, in cooperation with Forest Service Research and Development and other partners, the Forests on the Edge project uses data prepared and analyzed by scientists across the country to increase public understanding of the contributions of and pressures on America's forests, and to create new tools for strategic planning. This publication was also sponsored by the Resources Planning Act (RPA) Assessment staff of the U.S. Forest Service. For details on Forests on the Edge and previous reports, visit the Forest Service Open Space website at http://www.fs.fed.us/openspace/fote.

AMERICA'S URBAN FORESTS

The term urban forest refers to all publicly and privately owned trees within an urban area—including individual trees along streets and in backyards, as well as stands of remnant forest (Nowak et al. 2001). Urban forests are an integral part of community ecosystems, whose numerous elements (such as people, animals, buildings, infrastructure, water, and air) interact to significantly affect the quality of urban life.

The key to defining urban forests is to define urban land. The term "urban" connotes areas with relatively high amounts of people and artificial surfaces. The U.S. Census Bureau has a specific definition of urban based on population density (urbanized areas and urban clusters); this definition was used in this report to delimit urban areas (Appendix 1). Urban land and population data were derived from U.S. Census data (U.S. Census Bureau 2007).

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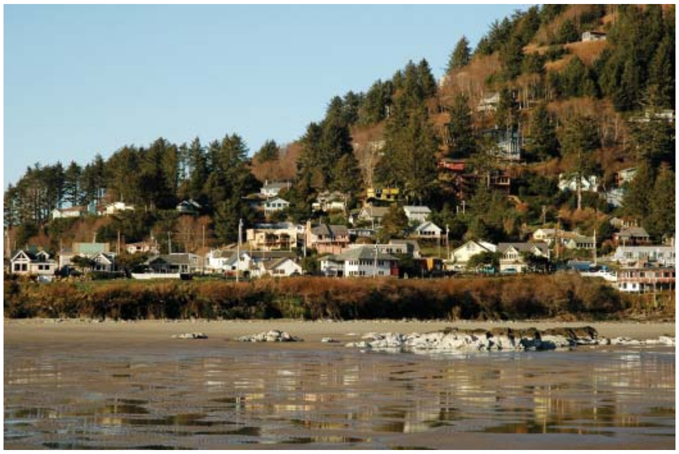
New York City's Central Park, the f rst landscaped park in America, constitutes a huge urban forest containing some 26,000 trees.

Geopolitical boundaries are often used to delimit the boundaries of "places" (such as towns and cities). However, places can encompass significant amounts of rural land (for example, some so-called cities are actually large counties), and places do not always truly delimit urban areas so much as they define community boundaries. State reports document tree and other vegetative cover within both urban and community boundaries at the state, county, sub-county, and place levels (Nowak and Greenfield 2008, USDA Forest Service 2009).

In 2000, 3.1 percent of the conterminous United States was classified as urban (Nowak et al. 2005), yet this small percentage of land supports 79 percent of the population, or more than 220 million people (U.S. Census Bureau 2001). Urban land is expanding at a considerable rate and is projected to increase substantially over the next half-century (Alig et al. 2004, Nowak and Walton 2005) (Appendix 1). The Northeast and Southeast are the most urbanized regions of the country (Alig and Healy 1987, Alig et al. 2004, Nowak et al. 2005) (Fig. 1), and four states in the Northeast are projected to be more than half urban land by 2050: Rhode Island, New Jersey, Massachusetts, and Connecticut (Appendix 1).

Based on photo-interpretation, tree cover in urban areas of the conterminous United States is estimated at 35.1 percent (20.9 million ac) (Appendix 2). As urban areas expand, the amount of urban forest will increase and urban forests will become increasingly critical to sustaining environmental quality and human well-being in urban areas. Careful planning and management will be crucial to maintain and enhance urban forest benefits.



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A coastal Oregon village.

What's Urban Forestry?

Management of urban trees and associated resources to sustain urban forest cover, health, and numerous socioeconomic and ecosystem services is known as urban forestry. Because of land jurisdiction issues, urban foresters typically focus on trees located along streets as well as in public parks and natural areas. However, since one of the main goals of urban forestry is to optimize forest benef ts for society, urban foresters can also help guide the management of trees on private lands, which typically dominate the overall urban forest composition.

Casey Trees

An arborist specializes in the care of trees.

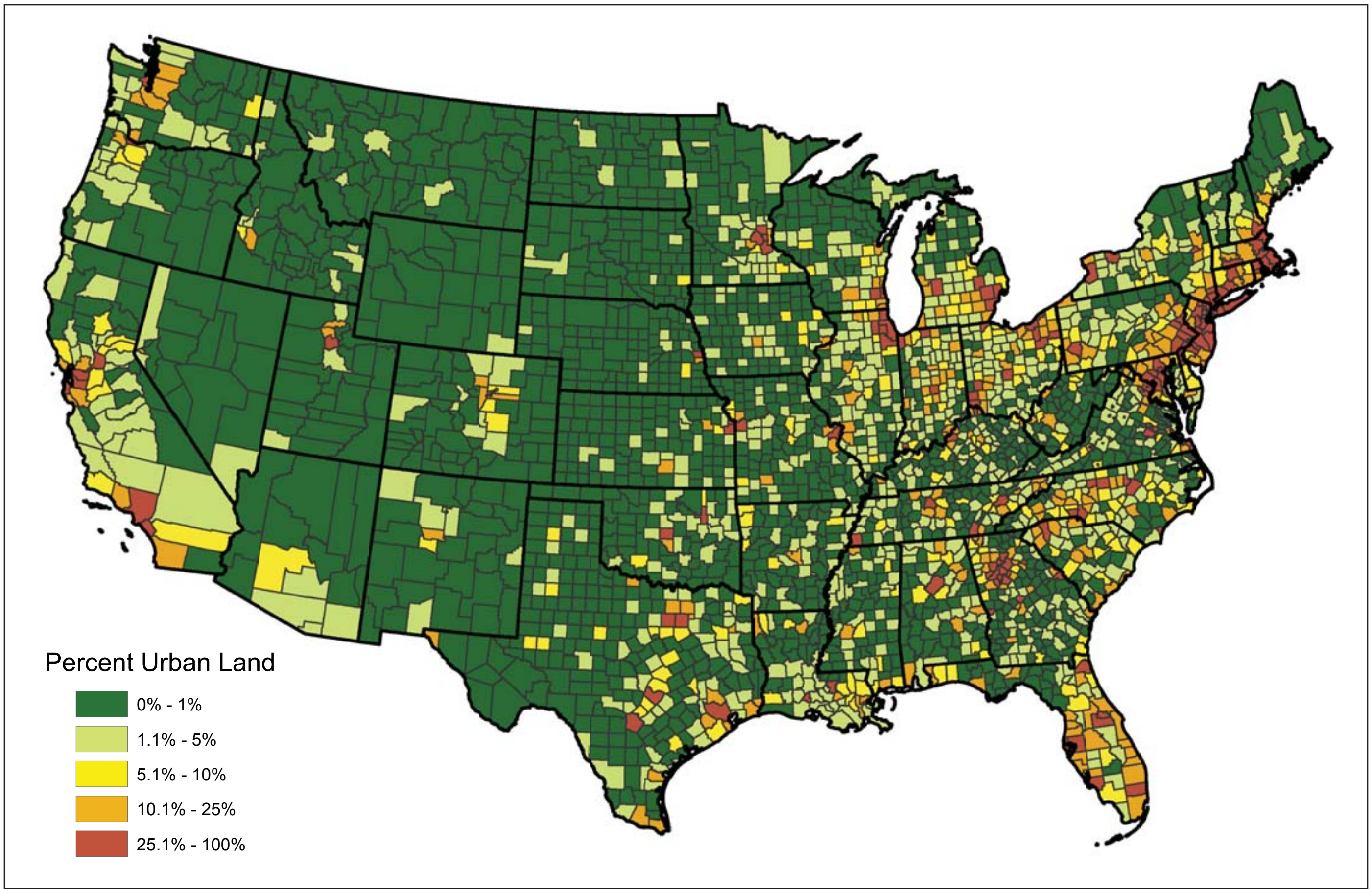

Figure 1—Percentage of the county classified as urban (2000).

URBAN FOREST BENEFITS

Given that close to 80 percent of the population of the conterminous United States lives in an urban area, the benefits provided by urban forests touch most U.S. citizens. Nationally, urban forests in the United States are estimated to contain about 3.8 billion trees, with an estimated structural asset value of $2.4 trillion (Nowak et al. 2002).[1] This dollar value reflects only a portion of the total worth of an urban forest. Urban trees also provide innumerable annual ecosystem services that affect both the local physical environment (such as air and water quality) and the social environment (such as individual and community well-being) that influence urban quality of life (Nowak and Dwyer 2007). Urban forest services and benefits include, but are not limited to:

www.treespayusback.com

Trees are a valuable asset to the urban community.

[1] Structural asset value is based, in part, on extrapolations of estimated replacement costs of trees of the same size, condition, species, and location.

- **Local climate and energy use**—Trees influence thermal comfort, energy use, and air quality by providing shade, transpiring moisture, and reducing wind speeds. The establishment of 100 million mature trees around residences in the United States is said to save about $2 billion annually in reduced energy costs (Akbari et al. 1988, 1992; Donovan and Butry 2009).
- **Air quality**—Trees improve air quality by lowering air temperatures, altering emissions from building energy use and other sources, and removing air pollutants through their leaves. Urban trees in the conterminous United States remove some 784,000 tons of air pollution annually, with a value of $3.8 billion (Nowak et al. 2006).

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The shade of trees keeps people cool.

AP Photo: Dayton Beach News-Journal, Jessica Webb

Trees provide homes for urban wildlife.

- **Climate change**—Urban trees can affect climate change by directly storing carbon within their tissues and by reducing carbon emissions from power plants through lowered building energy use. Urban trees in the conterminous United States currently store 770 million tons of carbon, valued at $14.3 billion (Nowak and Crane 2002).
- **Water flow and quality**—Trees and soils improve water quality and reduce the need for costly storm water treatment (the removal of harmful substances washed off roads, parking lots, and roofs during rain/snow events), by intercepting and retaining or slowing the flow of precipitation reaching the ground. During an intense storm in Dayton, OH, for example, the tree canopy was estimated to reduce potential runoff by 7 percent (Sanders 1986).
- **Noise abatement**—Properly designed plantings of trees and shrubs can significantly reduce noise (Anderson et al. 1984). Wide plantings (around 100 ft) of tall dense trees combined with soft ground surfaces can reduce apparent loudness by 50 percent or more (6 to 10 decibels) (Cook 1978).
- **Wildlife and biodiversity**—Urban forests help create and enhance animal and plant habitats and can act as “reservoirs” for endangered species (Howenstine 1993). Urban forest wildlife offer enjoyment to city dwellers (Shaw et al. 1985) and can serve as indicators of local environmental health (VanDruff et al. 1995).
- **Soil quality**—Trees and other plants help remediate soils at landfills and other contaminated sites by absorbing, transforming, and containing a number of contaminants (Westphal and Isebrands 2001).

- **Real estate and business**—Landscaping with trees—in yards, in parks and greenways, along streets, and in shopping centers—can increase property values and commercial benefits (Anderson and Cordell 1988; Corrill et al. 1978; Donovan and Butry 2008; Dwyer et al. 1992; Wolf 2003, 2004). One study found that on average, prices for goods purchased in Seattle were 11 percent higher in landscaped areas than in areas with no trees (Wolf 1998).
- **Individual well-being and public health**—The presence of urban trees and forests can make the urban environment a more aesthetic, pleasant, and emotionally satisfying place in which to live, work, and spend leisure time (Dwyer et al. 1991; Taylor et al. 2001a, 2001b; Ulrich 1984). Urban trees also provide numerous health benefits; for example, tree shade reduces ultraviolet radiation and its associated health problems (Heisler et al. 1995), and hospital patients with window views of trees have been shown to recover faster and with fewer complications than patients without such views (Ulrich 1984).
- **Community well-being**—Urban forests make important contributions to the economic vitality and character of a city, neighborhood, or subdivision. Furthermore, a stronger sense of community and empowerment to improve neighborhood conditions in inner cities has been attributed to involvement in urban forestry efforts (Kuo and Sullivan, 2001a, 2001b; Sommer et al. 1994a, 1994b; Westphal 1999, 2003).

AP Photo: Williamsport Sun-Gazette, Mark Nance

Numerous health and recreational benef ts are associated with urban trees.

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The Boston Commons, the nation's oldest public park.

COMPARING OUR URBAN FORESTS

Where in the United States are urban forests providing the greatest relative canopy cover and thereby potentially providing the greatest benefits? Where is there potentially available space to increase tree canopy cover in urban areas? This report takes a coarse look at these questions, using the best available national data and presenting results at the county level. Appendix 2 contains a detailed description of the methods used and limitations of the data and analyses.

Comparing Urban Tree Cover

Tree canopy cover can serve as an indicator of the extent to which trees and forests are providing critical services to local residents. A national assessment of urban tree cover, or the amount of urban land covered by tree canopies, can illustrate how urban tree cover and associated benefits vary across the United States. In addition, these data can be used to compare urban cover estimates among counties.

Variations in Urban Tree Cover

The amount of urban forest canopy cover varies widely in cities across the United States, depending in part on the location and size of the city, population density, development intensity, and surrounding natural vegetative cover. In urban areas, tree cover and density are typically greatest in parks, forests, and residential lands (Nowak et al. 1996). Cities in naturally forested regions average nearly twice the percentage tree cover of cities in grassland regions, and more than three times the percentage tree cover of cities in desert regions (Nowak et al. 2001). This difference is in part due to the capacity for natural regeneration of trees in forested regions and along streams in grassland regions. However, urban tree cover in forested regions is often limited by land use activities (such as buildings or constant mowing and burning) that limit tree regeneration. In addition, tree cover in grassland and desert areas is often limited by insufficient precipitation and local natural seed sources.

The density of trees in a city also varies based on such factors as intensity of development, natural vegetation type, tree management, and tree size distribution. Average tree density in some U.S. cities has been found to range from 14.4 trees per ac in Jersey City, NJ, to 111.6 trees per ac in Atlanta, GA (Nowak et al. 2008).

Tree cover estimates used in the analysis were based on National Land Cover Database (NLCD) estimates derived from Landsat satellite imagery taken around 2001 (Homer et al. 2004, USGS 2008, Yang et al. 2003). Percentage tree cover in urban areas is typically greater in the Eastern United States (Fig. 2). It is estimated that up to 80 percent of urban areas in some counties (such as Fayette County, Tennessee) are covered by tree canopies. However, the canopy cover estimates given in Figure 2 are conservative because the canopy cover map underestimates canopy cover by an average of 9.7 percent (Greenfield et al. 2009) (Appendix 2).

Considering tree cover in relation to population density, tree canopy cover per person (square feet of tree cover per capita) is typically greatest in the Southeast and New England states (Fig. 3), with values exceeding 10,000 ft^2 per person in several counties. Again these estimates are probably conservative considering the typical under-estimation of canopy cover discussed previously.

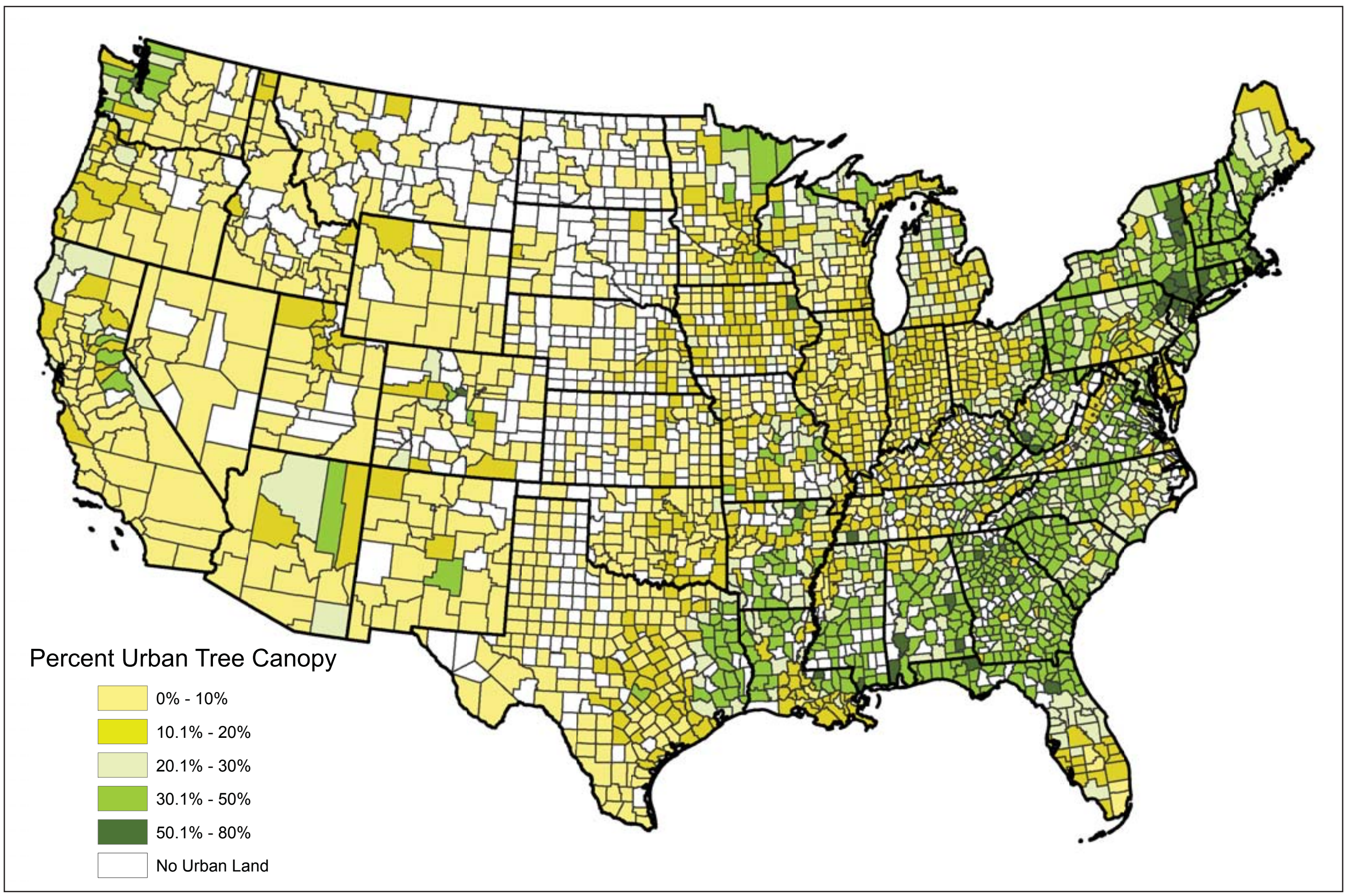

Figure 2—Percentage tree cover in urban areas (2000).

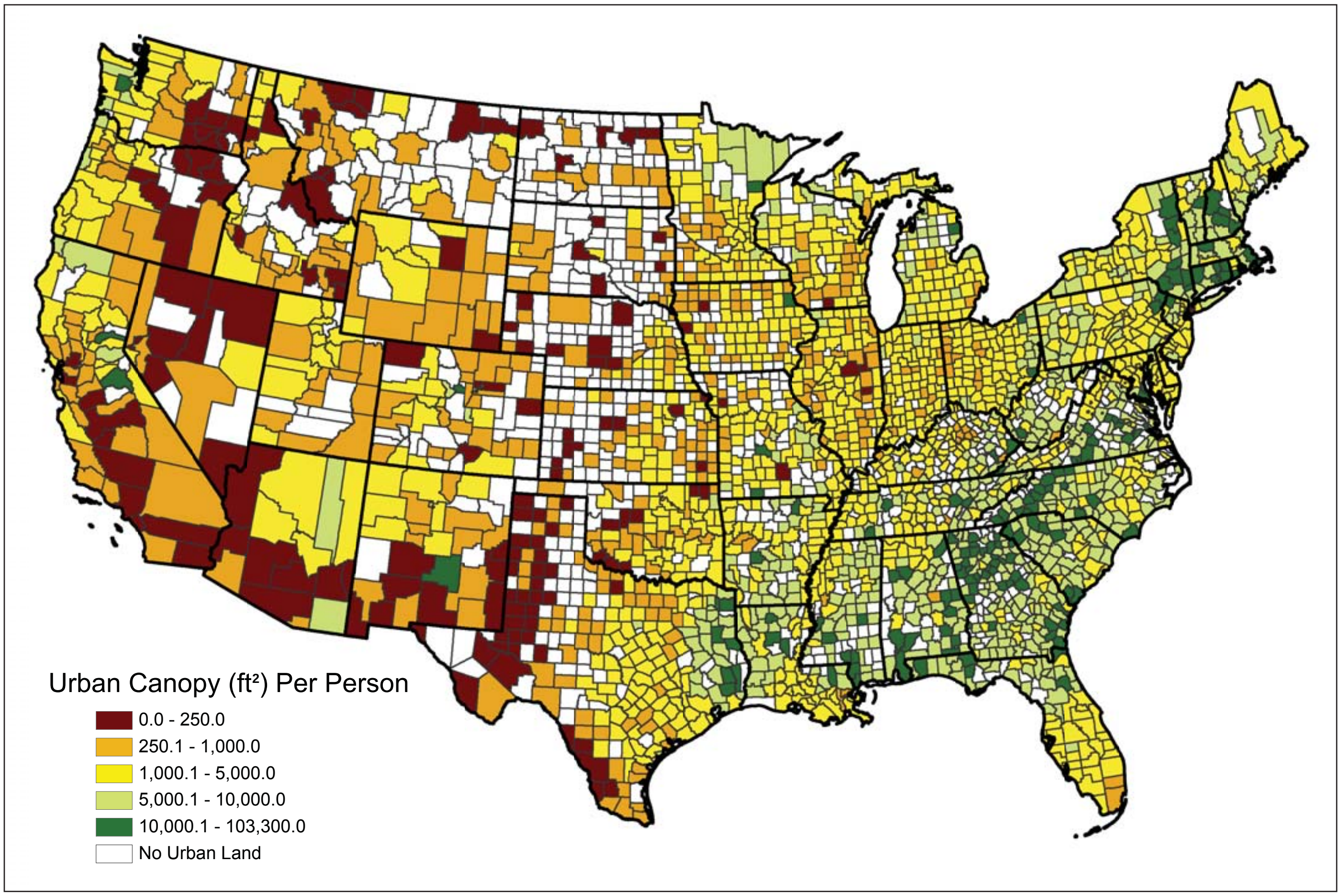

Figure 3—Urban canopy (ft²) per person (urban canopy / urban population).

Comparing Tree Cover Among Counties

Because various regions of the United States have differing degrees of underestimation of tree cover (Greenfield et al. 2009) and because population densities in urban areas vary among counties, county tree cover was compared only with other counties in the same ecological mapping unit (to avoid differences due to cover mapping methods) and having a similar population density (to avoid comparing heavily populated areas with sparsely populated areas) (Appendix 2). To compare tree cover among like counties, tree cover was standardized on a score between 0 (lowest cover in class) and 1 (highest cover in class) (Fig. 4). In the cases where there were not at least two other counties in the same grouping or where there was no urban land, counties did not receive a score.

Counties given the highest index value (highlighted in darkest green in Figure 4) are those that have the greatest relative cover (and benefits) compared to similar counties with similar population density in the region. However, unlike the map illustrating actual tree cover (Fig. 2), indexed counties with high relative tree cover are found in most every state.

Denver has an extensive network of parks.

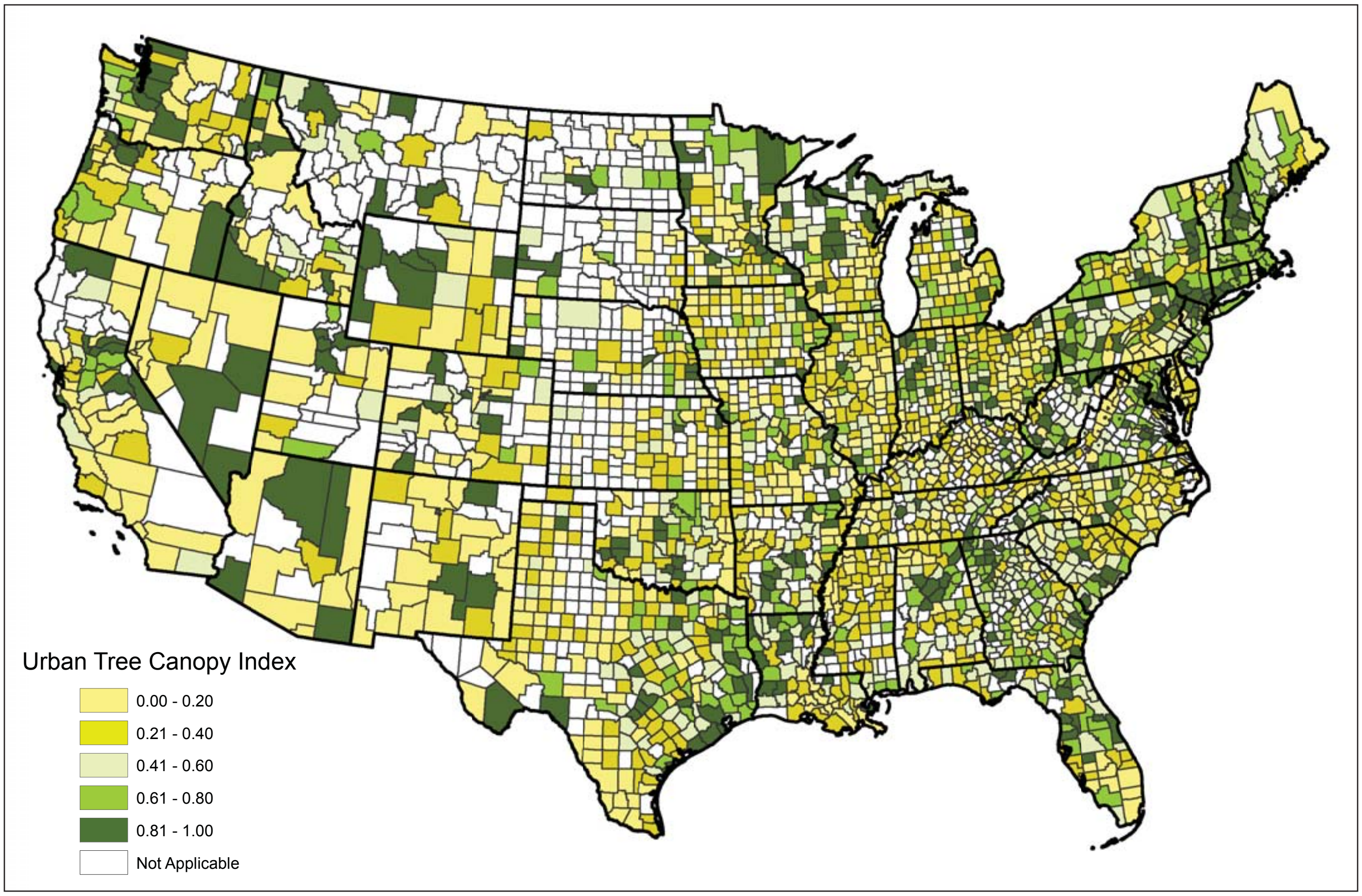

Figure 4—Urban tree canopy index for counties (2000); 0.00 is the lowest rating, 1.00 is the highest.

A low index score for urban tree canopy cover does not necessarily mean that a county is doing a poor job of sustaining urban tree cover, but rather could be an indication of land-use restrictions or other factors. For example, some counties may have a high proportion of agricultural land or other land uses that limit tree cover within urban boundaries. Detailed information on county land cover can be found in state assessments reports (such as Nowak and Greenfield 2008, 2009; USDA Forest Service 2009). Local investigation of the reasons why particular counties scored relatively low compared to their neighbors could potentially help communities develop ways to increase canopy cover if desired.

Potential Opportunities for Expanding Urban Forest Cover

As introduced above, the current urban tree cover pattern exhibited across the United States is the result of numerous physical and social forces that both limit and enhance canopy cover. These forces vary by region, specific location, development, population, and other social and physical factors. Throughout urban areas, particularly areas with low tree cover, there are several opportunities to enhance canopy. However, the questions should be asked: should one increase canopy in specific areas, and if so, by how much? Enhancing urban canopy cover will generally increase the benefits derived from urban forests; however, it can also potentially increase costs and risk (such as fire risk, energy costs, water usage) and it can change wildlife habitat and recreation opportunities. Thus, maximum tree cover may not be optimal tree cover. Optimal canopy cover is based on a mix of costs (ecological, social, and economic); community desires; and services (ecological, social, and economic) provided by tree cover.

Therefore, the context of existing community goals and ecosystem processes is critical when deciding whether to develop plans to enhance canopy and determining the amount of space and locations of these spaces. In some cases, particularly in the arid West, expansion of canopy cover could be limited by local natural resources (such as water). In other areas, particularly forested regions, canopy expansion can be limited by human processes (for example, impervious surfaces or mowing). Careful determination of the desirability of increasing canopy cover with optimal results related to trees


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Increasing urban tree canopy, but at what cost?

species, locations, and canopy health will hinge on full consideration of all the long-term costs associated with canopy cover change along with all the potential benefits and community desires.

Once the decision to increase canopy cover is made, effective long-term management plans for increasing canopy cover also will address optimal locations to plant trees relative to infrastructure, use constraints, and human populations; desired ecosystems from the increased canopy; and tree species best suited to local conditions and desired ecosystem services—such as planting drought-tolerant species in low-rainfall areas. With a focus on sustaining long-term canopy cover and tree health at minimal cost, increasing canopy cover can be accomplished through tree planting and/or management actions that facilitate natural regeneration.

Seeking the Best Fit: Drought-Tolerant Species in Low-Rainfall Areas

Drought-tolerant trees, or drought “avoiders,” are built for survival in drier, less hospitable climates. Their success is due to the presence of various mechanisms that help them to use water eff ciently, such as extensive root systems, thick waxes on leaves and bark, and leaf cells that function well with little water (Coder 1999).

With a yearly average rainfall of less than 10 inches, the city of Scottsdale, AZ, has taken several measures to prepare for stringent water conservation, including the planting of drought-tolerant shrubs and trees in the downtown areas (City of Scottsdale 2007).

To aid Scottsdale and other Arizona communities with such efforts, the Arizona Department of Water Resources has produced a list of native, drought-tolerant, and low-water-use plants, trees, and shrubs (Arizona Municipal Water Users Association 2004). These include the California fan palm (*Washingtonia filifera*), honey mesquite (*Prosopis glandulosa*), sweet acacia (*Acacia smalli*), and evergreen elm (*Ulmus parvifolia*).


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Drought-tolerant acacia trees can help conserve water.

AP Photo: Evan Vucci

AP Photo: Reed Saxon

Richard Old, XID Services, Inc., Bugwood.org

AP Photo: Mel Evans

Urban forests face a number of challenges including wind, wildlf res, invasive plants, and insect pests.

URBAN FOREST CHALLENGES

Throughout the country, urban forests face a myriad of management challenges. Like forests in rural and ex-urban settings, urban forests are exposed to a broad range of human-caused and natural challenges, all of which can be compounded by climate change. However, the proximity of urban forests to relatively high numbers of people and associated development can considerably increase the level and complexity of management challenges. These challenges include:

- **Insects and diseases**—Urban forests across the country are severely affected by numerous insects and diseases, many of them introduced from other places, that have caused or have the potential to cause significant damage. Some invasive species—such as the gypsy moth, emerald ash borer, and the fungi that cause Dutch elm disease and chestnut blight—have caused catastrophic tree mortality that has virtually eliminated dominant tree species in some places (Dozier 2000, Liebhold et al. 1995). Endemic pests such as mountain pine beetle have also caused severe damage to urban forests (Ellig 2008).
- **Wildfire**—Uncontrolled fires, or wildfires, can cause substantial damage to urban forests and dramatically alter the urban landscape, especially in urban areas adjacent to wildlands (often referred to as the wildland-urban interface) (Spyratos et al. 2007). High population growth and urban expansion in California, for example, have led to a substantial increase in fire ignitions in wildland-urban interface areas (Syphard et al. 2007).
- **Natural catastrophic events**—Urban forests can be greatly affected by natural catastrophic events such as ice storms, snow, and severe wind, which can result in broken branches or uprooted trees among other impacts (Greenberg and McNab 1998,

Irland 2000, Proulx and Greene 2001, Valinger and Fridman 1997). Such events can cause damage to people and property.

- **Invasive plants**—Kudzu (*Pueraria lobata*), English ivy (*Hederal helix*), European buckthorn (*Rhamnus cathartica*), and, in some areas, Norway maple (*Acer plantanoides*), are among the invasive plants that can degrade or modify urban forests in part by removing and replacing native plants and altering ecosystem structure. English ivy and kudzu have been known to cover acres of canopy trees (Dozier 2000, Webb et al. 2001).
- **Additional development**—Development within and around urban areas in forested regions can lead to decreases in forest area and fragmentation of forest stands, which can significantly affect plant and wildlife populations, forest biodiversity and health (Nowak et al. 2005), and parcelization of forested areas (where stands remains intact but have multiple landowners), which can affect the available timber supply and forest management (Zhang et al. 2005).
- **Air pollution**—Forest ecosystems can be substantially affected by air pollution, especially from regional deposition of ozone, nitrogen, sulfur, and hydrogen (Stolte 1996). Ozone has been documented to reduce tree growth (Pye 1988), reduce resistance to bark beetle, and increase susceptibility to drought (Stolte 1996). Beckett et al. (1998) reviewed several reports and surmised that pollutant particles can have a wide variety of effects on trees and that heavy metals and other toxic particles can accumulate in urban soils, causing damage and death in some species.
- **Climate change**—In the United States, climate change is expected to produce warmer air temperatures, altered precipitation patterns, and more extreme temperature and precipitation events (EPA 2009, IPCC 2007), all of which can cause changes in urban forests (Iverson and Prasad 2001, Johnston 2004). Climate change also has the potential to exacerbate all of the other urban forest threats discussed above.
- **Other changes over time**—Urban forests also are constantly changing through time as a result of land development, ownership changes, tree growth and mortality, natural regeneration, tree planting, and tree maintenance and management activities. These changes present additional challenges for maintaining urban forest cover, health, and benefits.

URBAN FOREST MANAGEMENT ISSUES

The management of urban forests typically involves a variety of activities such as inventorying tree populations; enacting tree and land use planning ordinances and policies; developing and implementing long-term management and maintenance plans, annual work plans, and budgets; and promoting community education and participation (Dwyer et al. 1992, Elmendorf et al. 2003). Effective urban forest management nationwide has often been hampered by challenges such as inconsistent management approaches, lack of funding, weak linkages with other resource management programs, and inadequate planning that fails to consider the surrounding ecosystem, the community, and the regional context.

As understanding of the ecological and economic values of trees increases, so does recognition of the importance of urban forest management. Close to 1,000 communities in the United States have signed a climate protection agreement that includes tree planting and urban forest maintenance as forms of reducing global warming. In recognition of the importance of urban forestry, the U.S. Conference of Mayors recently conducted an urban forestry survey of 135 U.S. cities with populations of 30,000 or more. Their final report (City Policy Associates 2008) recognizes "the invaluable role of urban forests in the protection of public health and the reduction of harmful greenhouse gases." According to the results, 95 percent of the cities surveyed have adopted tree management ordinances; 47 percent have enlarging tree canopy as a goal; and 70 percent maintain tree inventories (55 percent of which are up to date).

Larry Korhnak

Planning is an important part of urban forest management.

Challenges to Comprehensive Management

Despite such widespread recognition for the importance of comprehensive management, the level of resources allocated to the management of urban forests varies greatly from one urban area to another. The diversity of forest cover types, land uses, population densities, and land ownerships across many urban areas calls for complex, long-term urban forest management plans (Dwyer et al. 2000). However, because of a lack of funding, volunteer time, and information on appropriate management, many urban areas are unable to initiate, complete, or implement even the most basic of urban forest management plans (Dwyer et al. 1992, Elmendorf et al. 2003). Some communities have no urban forestry department; many that do tend to focus on planting and managing trees in public places, particularly along streets and in parks, which account for only a small portion of the overall urban forest canopy.

Comprehensive urban forest management considers all trees and associated elements across the entire jurisdiction to adequately address a heterogeneous landscape held by numerous land owners. A first step in developing a proper management plan is to assess the current composition and distribution of a community's trees and their associated ecosystem services. This basic urban forest information, combined with community desires related to forests and ecosystem services, can provide a strong foundation for developing long-term management plans.

However, such long-term management and planning can be complicated at the regional scale where urban forests cross multiple community, county, or other government jurisdictions. In these cases, a coordinated multi-jurisdictional effort can help to sustain optimal urban forest benefits across a region.

Urbanization of Rural and Exurban Forests

Rural and exurban forests in the vicinity of urban lands will be considerably affected by population growth and associated urban expansion. As these surrounding forests become urbanized, management and policy decisions become more complex—with more stakeholders and more at stake than ever before (Bradley 1984; Stein et al. 2005, 2007). Issues such as timber harvesting, fire protection, ecological functions, recreational uses, scenic views, wildlife, invasive species, and forest fragmentation become more contentious and difficult to handle as urbanization increases (Bradley 1984; Hammer et al. 2004; Mehmood and Zhang 2001; Riitters et al. 2002; Stein et al. 2007, 2009).

Effective attention to such challenges becomes crucial as urbanization results in the conversion of large rural and exurban forests to smaller urban forests. Projections indicate that, between 2000 and 2050, urbanization will subsume a total of 29.2 million ac of forest land—an area about the size of Pennsylvania (Nowak and Walton 2005) (Fig. 5). These emerging urban forests, which will consist of remnant forest stands along with scattered

Community Accomplishments Reported

More than 7,000 communities nationwide, serving 177 million residents, have already made a serious commitment to urban forest management, according to the Community Accomplishment Reporting System (CARS). Managed by the U.S. Forest Service, CARS is a database that tracks the capacity of communities to manage their forest resources. The digital dataset contains information on the number of communities in each state that have adopted practices to protect and manage their forests, whether by staff ng, laws, plans, advocacy groups, or inventories. The dataset also serves as a measure of sustainability, because if communities are doing such activities, their forests are more likely to be sustained.

Casey Trees

Community involvement, like this planting party, will help sustain urban forests and parks for years to come.

trees affected by numerous land uses and ownerships, will need to be managed effectively to ensure healthy trees and forests that can sustain environmental quality and human well-being. With increasing urbanization, urban forest management will likely take on a relatively higher regional and national importance because as rural and exurban forest areas decline, the services of the remaining urban and non-urban forests will become even more critical to the regional and national population.

Larry Korhnak

Urban expansion complicates forest management.

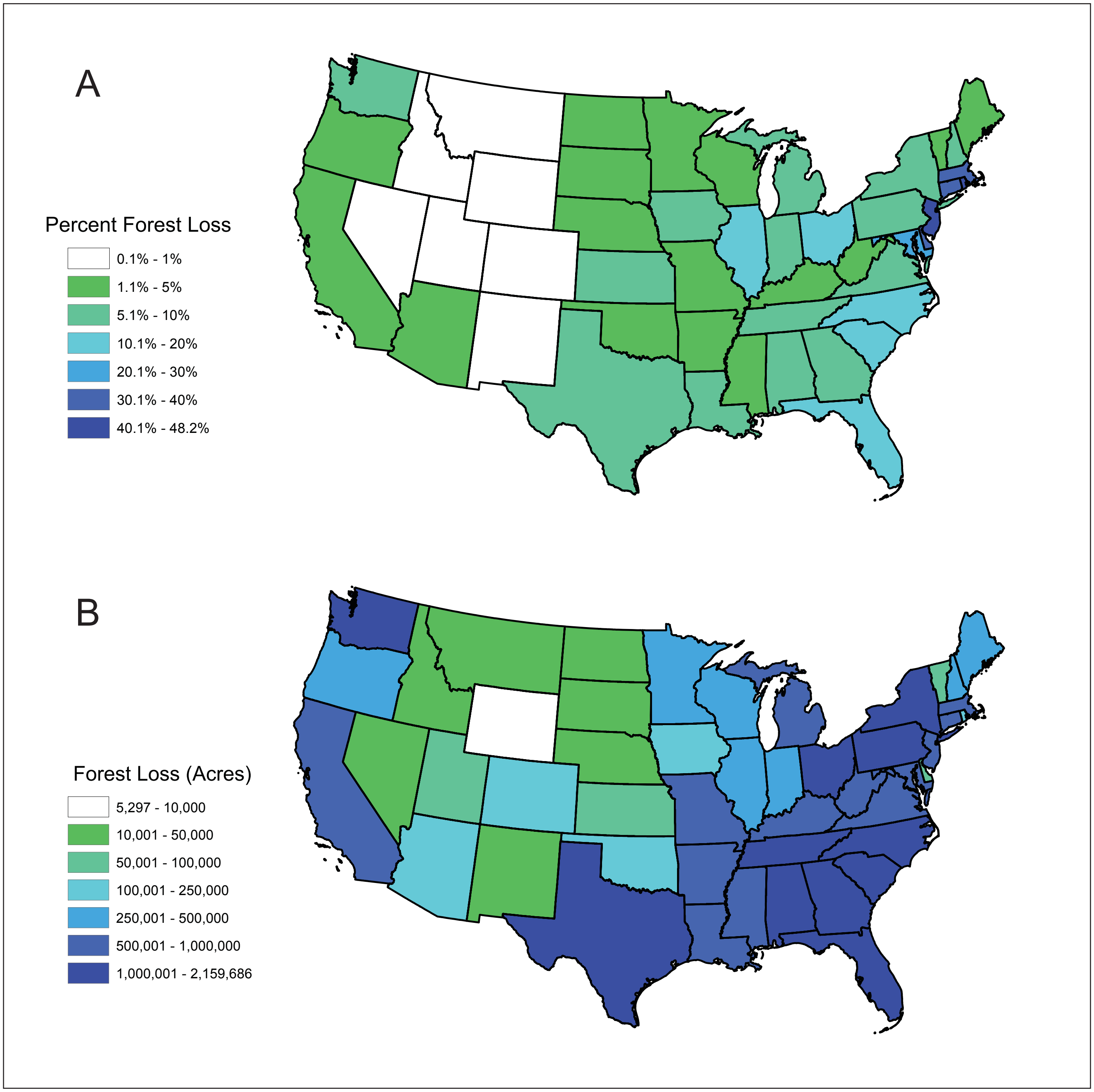

Figure 5—Percentage (A) and acreage (B) of non-urban forest subsumed by projected urban growth (2000-2050), by state. From Nowak and Walton (2005).

Tools for Cost-Effective Management

The costs to maintain and manage urban forests are substantial. A statewide survey of 18 California cities revealed an annual expenditure of close to $80 million. Most of these funds were spent on addressing problems related to the growth of street tree roots, which are severely impeded by sidewalks, curbs, gutters, and street pavement (McPherson 2000). However, most urban forests do not require such intensive management, and the overall benefits of urban forests likely outweigh their planning and management costs. With proper planning and management, costs can be reduced and benefits enhanced.

Innovative tools[2] are currently available or under development that may help to minimize the costs and boost the effectiveness of future urban forest management. These include:

- **i-Tree**—A state-of-the-art, peer-reviewed, and easy-to-use suite of urban forestry analysis tools for collecting and analyzing information on urban forests. i-Tree uses local data to statistically assess urban forest composition and its effects and values related to air pollution removal; carbon storage and sequestration; building energy use; and urban runoff, stream flow, and water quality. Software, training, and technical support are free. Visit: http://www.itreetools.org/.
- **Report pests: i-Ped (Inventory Pest Evaluation, Detection, and Reporting)**—A specialized i-Tree tool for establishing a long-term, large-scale urban pest detection and reporting system. Visit the i-Tree Web site above for this and other tools, or simply report observations and concerns to state foresters (find yours at: http://www.stateforesters.org) or state cooperative extension service (visit: http:/www.csrees.usda.gov/Extension/).
- **Urban Forest Project Reporting Protocol**—Helps communities measure, monitor, verify, and reduce greenhouse gas emissions through planned tree planting and maintenance activities that increase the storage of carbon in trees. Visit: http://www.fs.fed.us/psw/programs/cufr/ and http://www.climateregistry.org/about.html.
- **TreeLink**—A networking Website for citizens, cities, and sponsors that provides up-to-date technological information and grassroots organizing tools such as email listserves, publications, and links to local urban forestry resources. Visit: http://www.treelink.org/.
- **CITYgreen**—A software program used to calculate the monetary values of the economic and ecological benefits (including stormwater run-off, air pollution removal, and carbon storage) provided by the trees and other green spaces in specific locations areas. Visit: http://www.americanforests.org/productsandpubs/citygreen/.
- **Urban Forestry South**—Contains state and nonprofit contacts in the southern states as well as an extensive online library and Web links on a wide range of topics. Visit: http://www.urbanforestrysouth.org/.
- **SelecTree and Tree Browser**—California-based resource that can help find the name of a tree or choose a tree with desired attributes; also provides research, community, and technical resources for learning about the importance of protecting healthy urban forests and incorporating urban wood into the marketplace. Visit: http://www.ufei.org/. The state of Utah also has a similar site, Tree Browser, at: http://treebrowser.org.
- **Forest Service Web sites**—Numerous Forest Service Web sites provide information on urban forest management, including the Northern Research Station (http://www.nrs.fs.fed.us/units/urban); the Urban Natural Resources Institute (http://www.UNRI.org); the Center for Urban Forest Research (http://www.fs.fed.us/psw/programs/cufr/); and Interface South (http://www.interfacesouth.org/). For other helpful links, visit: http://www.fs.fed.us/ucf.

[2] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such does not constitute an official endorsement or approval by the United States Department of Agriculture or Forest Service of any product or service to the exclusion of others that may be suitable.

Casey Trees

i-Tree data collection tool.

Inventorying urban forests.

- **State forestry agencies**—State forestry agencies can also be an important source of urban forestry information. To find a contact for your state, visit: http://www.stateforesters.org/about_nasf#.
- **Additional resources**—In addition to the tools listed above, there are many other sources of urban forest management expertise including: consulting foresters and private tree care firms, the Cooperative Extension Service (http://www.csrees.usda.gov/Extension/), land grant universities, urban forestry centers, and numerous nonprofit groups such as Climate Action Registry (http://www.climateregistry.org/), the National Urban and Community Forestry Council (http://www.treelink.org/nucfac/), the International Society of Arboriculture (http://www.isa.org), the Society of Municipal Arborists (http://www.urban-forestry.com), American Forests (http://www.americanforests.org), and the National Arbor Day Foundation (http://www.arborday.org/), which sponsors numerous programs such as National Arbor Day and Tree City USA awards.

CONCLUSIONS

Management decisions of today will influence the amount and types of benefits derived from the urban forest for future generations. Knowledge of urban forest ecology and how to conserve these essential resources will be critical to developing appropriate management strategies to enhance optimal urban forest cover and to sustain urban forest health and benefits into the future. Management plans to sustain or enhance healthy urban tree cover will be most successful when they incorporate local tree data and consider relevant local social and ecological factors and costs, including community desires relative to canopy cover and associated ecosystem services.

Lack of urban forest management could lead to the loss of urban tree canopy cover and health, and to shifts or loss of species that would diminish the quality of the urban environment and numerous ecosystem services derived from trees and forests. These potential changes could increase environmental management and human health costs, as well as decrease the quality of life of urban residents.

By understanding threats to urban forests (including invasive species, fire, air pollution, lack of management capability, and development pressures), as well as the continued urbanization of rural and exurban forests, management efforts can be directed to help reduce various threats and sustain important urban forest resources. Regional urban forest plans can help improve long-term resource and environmental sustainability by integrating vegetation management issues across a region. Long-term planning and management can reduce the risks associated with various urban forest threats and ensure ecosystem services that will continue to improve urban environmental quality and enhance human quality of life and well-being.

Together, local and regional landowners, communities, and agencies can plan for sustainable growth while conserving the beauty and benefits of America's treasured urban forests.

AP Photo: Nature Consortium, Ron Wurzer

Promoting urban forests for future generations to enjoy.

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Metrics Table

When you know:	Multiply by:	To find:
Feet (ft)	0.305	Meters (m)
Acres (ac)	0.405	Hectares (ha)
Miles (mi)	1.609	Kilometers (km)
Square feet (ft^2)	.0929	Square meters (m^2)
Square miles (mi^2)	2.59	Square kilometers (km^2)
U.S. tons (ton)	0.91	Metric tons (tonne)

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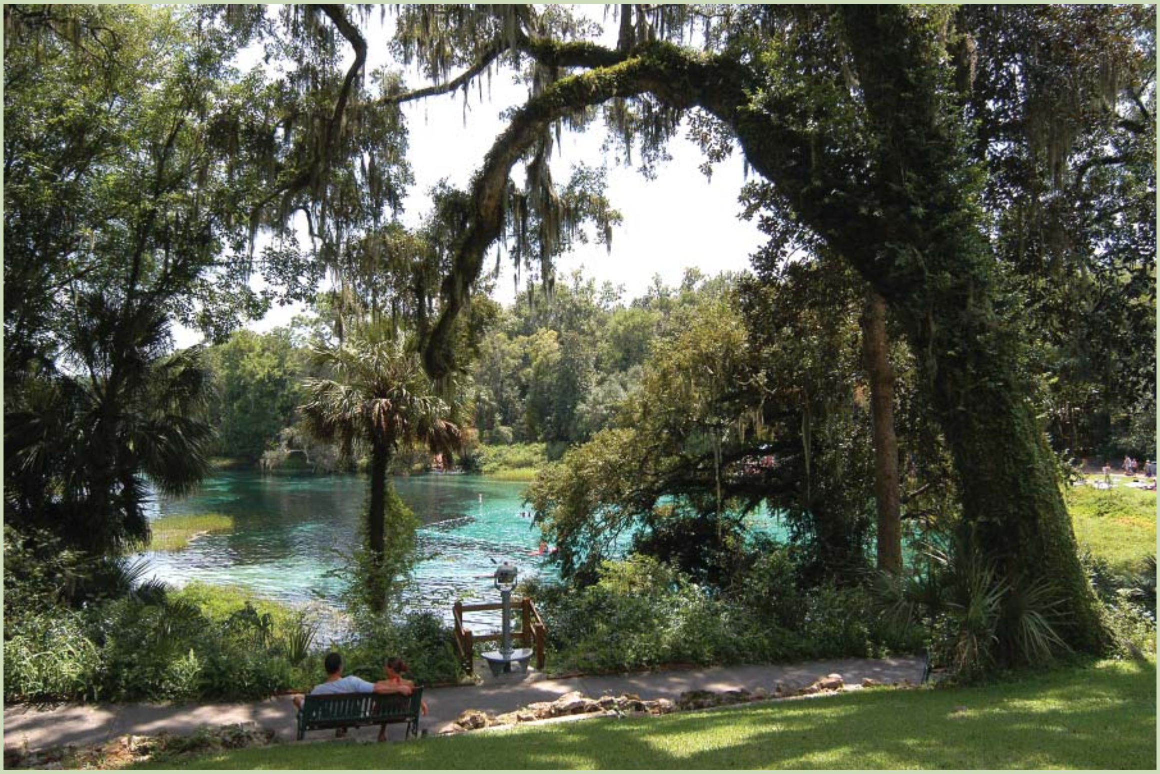
Larry Korhnak

APPENDIX 1—AMERICA'S URBAN LANDS

Defining Urban Land

Urban land has various definitions and levels of significance (Alig and Healy 1987). Urban lands typically have relatively high numbers of people and extensive artificial surfaces. This report uses the U.S. Census Bureau's (2007) definition of urban land, based on population density—with urban land generally being areas with a population density of at least 500 people per square mile. To be classified as urban, an area of land must meet one of the following definitions:

- One or more block groups or census blocks with a population density of 1,000 people/mi².
- Surrounding block groups and census blocks with a population density of 500 people/mi².
- Less densely settled blocks that form enclaves or indentations, or are used to connect discontinuous areas.

More specifically, urbanized areas are places with 50,000 or more people. Urban clusters, a concept new to the 2000 census, are territories with 2,500 to 50,000 people, encompassing many places typically considered suburban (U.S. Census Bureau 2007).

Highest Percentages and Amounts of Urban Lands

In 2000, 3.1 percent of the conterminous United States was classified as urban, with percentage urban land varying from 0.2 percent in Wyoming, Montana, North Dakota, and South Dakota, to 36.2 percent in New Jersey (Table 1). In terms of area, states with the highest amounts of urban land were California (5.1 million ac), Texas (4.6 million ac), and Florida (4.0 million ac). The regions with highest percentage urban land were the Northeast (9.7 percent) and Southeast (7.5 percent); regions with highest amounts of urban land were the Northeast (12.7 million ac) and North Central (12.2 million ac).

Table 1—Urban land growth in the United States (1990-2000)

State	Urban Land 1990 (ac)	Urban Land 1990 (%)	Urban Land 2000 (ac)	Urban Land 2000 (%)	Growth 1990-2000 (ac)	Growth 1990-2000 (%)
KS	463,600	0.9	554,000	1.1	90,400	0.2
ND	80,300	0.2	93,200	0.2	13,100	0.0
NE	251,300	0.5	292,600	0.6	41,300	0.1
SD	94,900	0.2	107,700	0.2	12,800	0.0
Great Plains	890,100	0.5	1,047,500	0.5	157,400	0.1
IA	467,800	1.3	523,100	1.5	55,400	0.0
IL	1,938,800	5.4	2,304,300	6.4	365,500	1.0
IN	1,136,400	4.9	1,423,600	6.1	287,100	1.2
MI	1,797,000	4.8	2,178,700	5.8	382,000	1.0
MN	859,200	1.6	1,009,900	1.9	150,700	0.3
MO	1,005,500	2.3	1,168,300	2.6	162,800	0.4
OH	2,204,900	8.3	2,568,400	9.7	363,500	1.4
WI	874,500	2.4	1,060,800	3.0	186,300	0.5
North Central	10,283,800	3.5	12,237,400	4.2	1,953,400	0.7
CT	975,300	30.6	1,134,500	35.5	158,900	5.0
DE	141,300	10.9	194,500	15.0	53,100	4.1
MA	1,536,500	29.2	1,797,200	34.2	260,700	5.0
MD	957,000	14.3	1,156,500	17.3	199,400	3.0
ME	202,100	1.0	227,800	1.1	25,700	0.1
NH	259,000	4.4	362,000	6.1	103,000	1.7
NJ	1,551,800	31.2	1,804,900	36.2	253,000	5.1
NY	2,265,700	7.2	2,539,500	8.1	273,800	0.9
PA	2,175,300	7.5	2,730,000	9.4	554,800	1.9
RI	213,000	30.2	253,500	35.9	40,500	5.7
VT	80,800	1.3	94,900	1.5	13,800	0.2
WV	291,600	1.9	361,300	2.3	69,900	0.5
Northeast	10,649,300	8.1	12,655,700	9.7	2,006,500	1.5
CA	4,349,100	4.3	5,086,400	5.0	737,400	0.7
OR	539,200	0.9	658,300	1.1	119,100	0.2
WA	1,091,700	2.5	1,367,500	3.1	275,800	0.6
Pacif c Coast	5,980,200	2.9	7,112,200	3.4	1,132,200	0.5
AZ	765,800	1.0	1,074,200	1.5	308,100	0.4
CO	649,900	1.0	815,000	1.2	165,100	0.2
ID	201,900	0.4	260,700	0.5	58,800	0.1
MT	141,800	0.2	166,800	0.2	24,700	0.0
NM	352,100	0.5	481,600	0.6	129,500	0.2
NV	215,700	0.3	348,200	0.5	132,200	0.2
UT	351,900	0.6	442,100	0.8	90,200	0.2
WY	96,100	0.2	108,200	0.2	11,900	0.0
Rocky Mountains	2,775,500	0.5	3,696,400	0.7	921,000	0.2
AL	910,100	2.8	1,140,900	3.4	230,800	0.7
AR	468,800	1.4	582,400	1.7	113,700	0.3
KY	643,500	2.5	778,600	3.0	135,200	0.5
LA	901,900	3.0	1,066,300	3.5	164,300	0.5
MS	490,800	1.6	599,500	2.0	108,700	0.4
OK	647,700	1.4	743,300	1.7	95,600	0.2
TN	1,198,000	4.4	1,557,800	5.8	359,800	1.3
TX	3,704,400	2.2	4,575,200	2.7	870,800	0.5
South Central	8,965,200	2.3	11,044,100	2.8	2,078,700	0.5
FL	3,093,300	8.3	4,017,900	10.8	924,700	2.5
GA	1,702,100	4.5	2,396,900	6.4	694,900	1.8
NC	1,624,200	5.0	2,278,100	7.1	653,600	2.0
SC	907,400	4.6	1,194,000	6.0	286,600	1.4
VA	1,252,600	4.8	1,522,200	5.9	269,600	1.0
Southeast	8,579,700	5.6	11,408,900	7.5	2,829,400	1.8
Total[a]	48,162,800	2.5	59,241,500	3.1	11,078,500	0.6

[a] Summary for lower 48 states including Washington, DC.
Source: Nowak et al. 2005.

Table 1 also shows that urban land in the conterminous United States increased from 2.5 percent of land being urban in 1990 to 3.1 percent in 2000, an increase in area about the size of Vermont and New Hampshire combined. States with the greatest increase in percentage of urban land between 1990 and 2000 were Rhode Island (5.7 percent), New Jersey (5.1 percent), Connecticut (5.0 percent), and Massachusetts (5.0 percent). States with the greatest increase in area of urban land were Florida (925,000 ac), Texas (871,000 ac), and California (737,000 ac). Seven of the 10 states with the greatest increase in percentage urban land between 1990 and 2000 were in the Northeast; the remainder were in the Southeast.

In aggregate, the Southeast had the greatest increase in percentage urban land between 1990 and 2000 (1.8 percent of the land area), followed by the Northeast (1.5 percent). Regions with greatest area of urban growth were the Southeast (2.8 million ac) and the South Central (2.1 million ac).

Between 1990 and 2000, most of the urban expansion across the United States occurred in forested (averaging 33.4 percent of the expansion nationwide) or agricultural (32.7 percent) land. Within each state, urban areas expanded into various cover types in differing proportions. States with the highest proportion of development occurring in forests were Rhode Island (64.8 percent), Connecticut (64.1 percent), and Georgia (64.0 percent) (Table 2). States with most area of forest land converted to urban were Georgia (444,000 ac), North Carolina (366,000 ac), and Pennsylvania (237,000 ac) (Table 3).

Projections: Urbanization and Forests, 2000-2050

Given the urban growth patterns of the 1990s, urban land is projected to rise substantially in the future—from 3.1 percent of conterminous United States in 2000 to 8.1 percent in 2050, an increase in area greater than the size of Montana. It is estimated that the amount of built environment in the United States by 2025 will be double the amount that existed in 2000 (Alig et al. 2004, Nelson 2006). The changing landscape due to urbanization will have significant impacts on land management and efforts to sustain environmental quality in urban and urbanizing areas.

Projected future growth patterns may be affected by demographic shifts (such as population growth) and economic conditions (for example, growth in personal

Table 2—States with the highest percentage of urban land expansion within various land cover types, 1990-2000

State	**% of expansion**
Forest areas	
Rhode Island	64.8
Connecticut 64.1	
Georgia	64.0
Massachusetts 62.9	
West Virginia	62.2
Agricultural lands	
Nebraska	68.9
Indiana	66.8
Illinois	64.8
Wisconsin	62.0
Idaho 54.6	
Woody wetland areas	
Florida	14.4
New Jersey	8.6
Rhode Island	7.9
Massachusetts 6.1	
Michigan 6.1	
Herbaceous wetland areas	
Minnesota 7.4	
Maine	6.3
Florida 6.1	
Massachusetts 4.2	
Delaware 4.0	

Table 3—States with the highest amount of urban land expansion within various land cover types, 1990-2000

	Urban land expansion
State acres	
Forest areas	
Georgia 444,410	
North Carolina	365,510
Pennsylvania 236,570	
Texas 184,390	
Florida 174,250	
Agricultural lands	
Texas 365,520	
Pennsylvania 252,360	
Illinois 236,720	
Indiana 191,820	
Ohio 184,580	
Woody wetland areas	
Florida 133,190	
North Carolina	32,670
Georgia 27,600	
Michigan 23,330	
New Jersey	21,870
Herbaceous wetland areas	
Florida 56,660	
Minnesota 1	1,190
Massachusetts 1	1,000
Georgia 9,240	
Texas 7,960	

income) (Alig et al. 2004), but most urban growth is projected to occur around the more heavily urbanized areas, with significant expansion in the East and along the west coast. By 2050, four states are projected to be more than half urban land:

- Rhode Island (70.5 percent urban),
- New Jersey (63.6 percent),
- Massachusetts (61.0 percent), and
- Connecticut (60.9 percent) (Nowak and Walton 2005).

Nationwide, by 2050, about 5.3 percent of forest land remaining outside of urban areas is projected to be subsumed by urban growth. This amount can be substantially higher at the individual state level, with Rhode Island (48.2 percent), New Jersey (40.4 percent), Massachusetts (37.0 percent), Connecticut (35.8 percent), and Delaware (32.5 percent) projected to have the greatest percentage of their current non-urban forest land transformed by urban growth.

While northeastern states tended to have the highest percentage of forest land that is projected to be taken over by urbanization by 2050, southern states tend to be highest in total amount of forest land to be transformed (Fig. 5). Between 2000 and 2050, North Carolina is projected to have 2.16 million ac of forest land changed by urbanization, followed by Georgia with 1.92 million ac, New York with 1.68 million ac, Pennsylvania with 1.57 million ac, and Texas with 1.54 million ac. The total projected amount of U.S. forest land projected to be subsumed by urbanization between 2000 and 2050 is about 29.2 million ac, an area approximately the size of Pennsylvania.

APPENDIX 2—METHODS AND DATA CONSTRAINTS

Methods

Most of the data presented in this report were derived from two sources: (1) the multi-resolution land characteristics consortium's National Land Cover Database (NLCD) (Homer et al. 2004, USGS 2008, Yang et al. 2003); and (2) the U.S. Census Bureau (U.S. Census Bureau 2007). The NLCD, released in early 2007, was used to develop estimates related to tree cover. NLCD is processed from 2001 Landsat satellite imagery and provides estimates of percentage tree canopy and impervious surface cover within 30-m (approximately 98-ft) pixels or cells across the state. The tree canopy percentages in this report are calculated using the land area (not including water) of the geopolitical units derived from the U.S. Census cartographic boundary data and NLCD. In addition to percentage tree cover, tree canopy cover per capita was calculated as tree canopy cover (m^2) divided by the number of people (derived from U.S. Census data) within the area of analysis. Data analyses were based on urban lands only (Appendix 1) and summarized on the county basis. In addition to illustrating variations in urban tree cover and tree cover per capita, an urban canopy index was developed.

The urban canopy index, displayed in Figure 3, is a standardized score that allows for comparison of canopy cover among counties within the same mapping zone and same population density class.

For this comparison, the following three urban population density classes were established:

- Density class 1—0 to 1,499.9 people/mi^2
- Density class 2—1,500 to 1,999.9 people/mi^2
- Density class 3—2,000 or more people/mi^2

Mapping zones were delimited within the NLCD to increase classification accuracy and efficiency (Fig. 6). The mapping units represent relatively homogeneous ecological conditions (Homer and Gallant 2001). To assign counties within a mapping zone, centroid (geometric center) points of the county were used. For three or more counties in the same mapping zone and population density class, a standardized tree canopy score based on the range of values within that zone and class was assigned to each county. The standardized score is calculated as:

> **Standardized score** = (tree canopy percentage within urban lands in county – minimum tree canopy percentage in group) / range of tree canopy percentage in group.

Counties were assigned a standardized score between 0.00 (lowest rating) and 1.00 (highest rating) for each mapping zone and population grouping. Counties did not receive a score if there were not at least two other counties in the same grouping.

Data Accuracy and Application

Scale Issues

The data presented in this report yield the most comprehensive and up-to-date assessment of urban forests in the conterminous United States. The data allow for relative comparisons among counties. The U.S. Census generalized cartographic boundary data are simplified and smoothed extracts of the Topologically Integrated Geographic Encoding and Referencing (TIGER) database, with a target scale range of 1:5,000,000 (U.S. Census Bureau 2007). Because of this scale and generalization, border simplification has an impact on the attribute measurements that are derived from the boundary data, especially for small areas and at the local scale. The 2001 NLCD also has local-scale data and application limitations, and users of the data are cautioned that the NLCD was not designed for local application (Homer et al. 2004).

Tree Canopy Cover Estimates

A recent analysis of 127 census places and 20 counties sampled throughout the conterminous United States compared NLCD tree canopy and impervious surface cover estimates with high-resolution (1 m [3 ft] or less resolution) aerial photo-interpreted estimates (Greenfield et al. 2009). This analysis revealed that NLCD underestimates tree canopy, on average, by about 9.7 percent compared to photo-interpreted values. Thus, the absolute estimates of urban tree cover (Fig. 2) and tree cover per capita (Fig. 3) based on the NLCD maps are likely conservative. For more refined and locally appropriate data, local field- or high-resolution (3 ft or less) image analyses are recommended (such as i-Tree [http://www.itreetools.org] and Urban Tree Canopy Assessments (UTC) [www.nrs.fs.fed.us/urban/utc]).

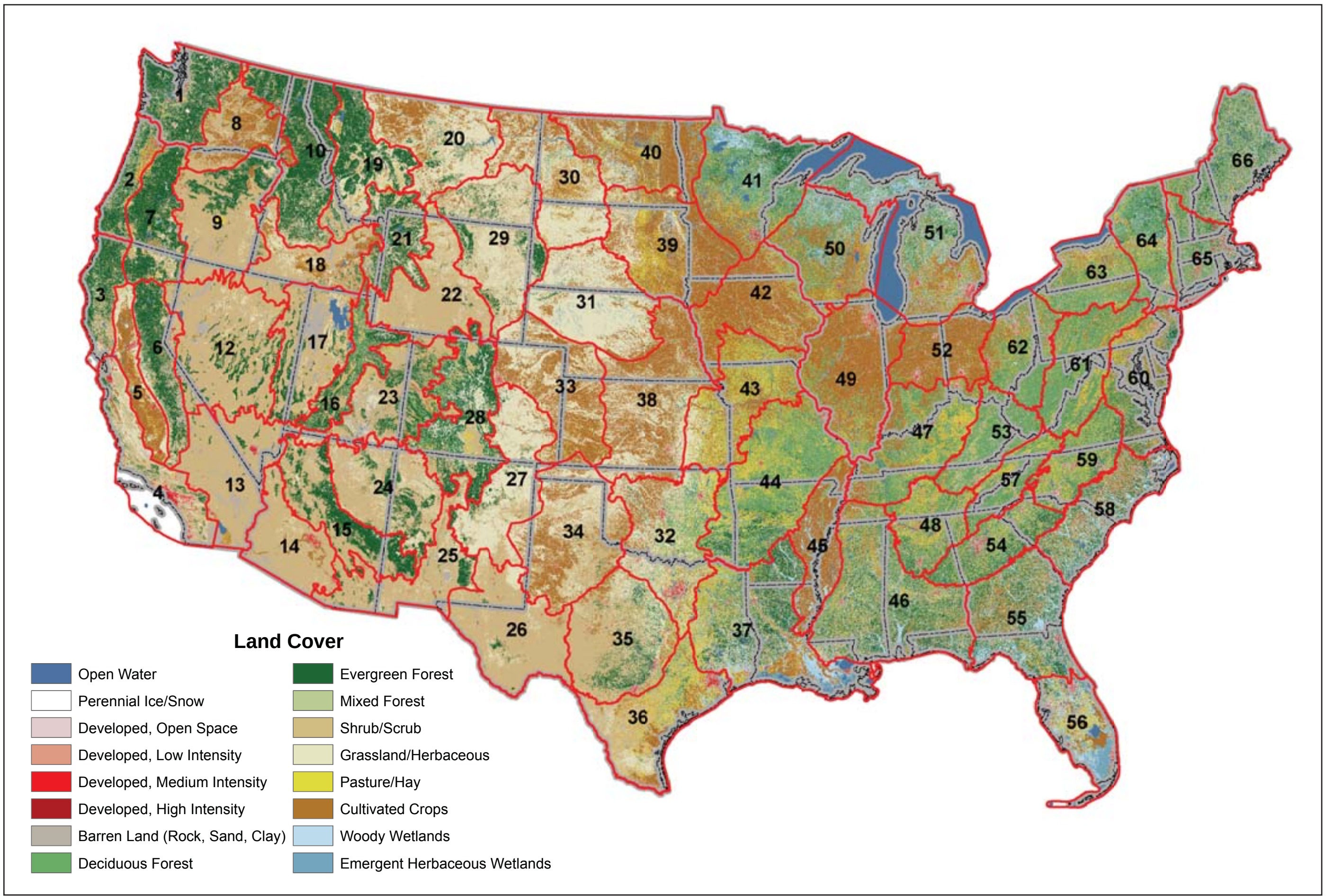

Figure 6—Mapping zones of the conterminous United States relative to states and land cover (NLCD 2001).

Despite the potential underestimates in tree canopy cover values, relative comparisons of tree cover among counties (Fig. 4) in this report are reasonable because the under-prediction of tree cover is likely fairly consistent within each mapping zone. Higher resolution cover data will probably provide more accurate results at the local scale, but the NLCD cover maps provide a cost-effective way to consistently assess and compare the relative differences of urban cover types regionally.

National Urban Tree Cover Estimate

Because NLCD tends to underestimate tree cover, we photo-interpreted tree cover in urban areas using imagery from Google Earth. Images were taken on various dates but were typically from the mid to late 2000s. Within urban and community areas of the lower 48 states, 15,000 randomly located points were photo-interpreted in relation to tree cover. Community areas were defined as areas within U.S. Census place boundaries. From this sample, 8,594 points fell within urban areas. If a state did not have at least 100 urban points, the sample was increased in these states to reach a minimum of 100 randomly sampled points. The total number of urban points interpreted was 9,436. Tree cover was calculated as the percent of total points in the urban areas that fell upon tree canopies. Urban tree cover within each state was weighted by total urban land in the state to calculate national urban tree cover in the conterminous United States.

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FORESTS ON THE EDGE

Forests on the Edge is a project of the U.S. Department of Agriculture, Forest Service, State and Private Forestry, Cooperative Forestry staff, in conjunction with Forest Service Research and Development and other partners. The project aims to increase public understanding of the contributions of and pressures on America's forests, and to create new tools for strategic planning. The f rst report (Stein et al. 2005) identif ed private forested watersheds in the conterminous United States most likely to experience housing development. Subsequent reports have provided more in-depth discussion and data on the location and impacts of future house development in rural areas. This report presents an overview of the current status of and benef ts from America's urban forests across the Nation, the pressures that challenge them, and the implications for urban forest management.

Future Forests on the Edge work will include assessments of additional contributions and risks, and construction of an Internet-based system that permits users to view, combine, and depict results for selected contribution and threat layers.

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