What Is a Tree Worth?

Trees brighten city streets and delight nature-starved urbanites. Now scientists are discovering that they also play a crucial role in the green infrastructure of America's cities.

BY JILL JONNES

ON APRIL 8, 1905, PRESIDENT THEODORE Roosevelt, attired in a dark suit and top hat, could be found in Fort Worth, Texas, where youngsters looked on from a nearby window as he shoveled soil over the roots of a sapling. It was Arbor Day, which schools across the nation had recently begun commemorating, and the ever vigorous president was demonstrating his hands-on love of trees. For Roosevelt, Arbor Day was no publicity stunt. In an address to America's schoolchildren a couple of years later, he celebrated "the importance of trees to us as a Nation, of what they yield in adornment, comfort, and useful products." He saw trees as vital to the country's well-being: "A people without children would face a hopeless future; a country without trees is almost as hopeless."

For centuries, tree lovers mighty and humble have planted and nurtured trees—elms, oaks, ginkgoes, magnolias, apples, and spruces (to name but a handful of America's 600-some species). "I never before knew the full value of trees," wrote Thomas Jefferson in 1793. "Under them I breakfast, dine, write, read, and receive my company. What would I not give that the trees planted nearest the house at Monticello were full grown." But trees were often taken for granted in a new nation that seemed to have a limitless supply.

Then along came Julius Sterling Morton, a nature lover who moved to Nebraska in the 1850s, briefly edited the state's first newspaper, and soon entered politics. He conceived of an annual day of tree planting, inaugurating a tradition that was rapidly adopted around the country and then the world. (Today, Arbor Day is observed nationwide on the last Friday in April, though individual states mark it on other days.) In 1874, when Nebraska proclaimed Arbor Day an official holiday, *The Nebraska City News* rhapsodized about trees: "The birds will sing to you from their branches, and their thick foliage will protect you from the dust [and] heat."

But tree lovers quickly learn that many practical-minded Americans—especially politicians—see little value in trees, except perhaps as board timber. Roosevelt was an exception. An ardent birder and conservationist, he reveled in his power to create or enlarge 150 national forests, mainly by presidential fiat. In 1905, he appointed his partner in boxing and bush-whacking, forester Gifford Pinchot, to run the newly created U.S. Forest Service and ensure the wise conservation and use of these public lands.

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President Theodore Roosevelt, a passionate nature lover, took the recently established Arbor Day very much to heart during his years in the White House. On a brief visit to Fort Worth, Texas, in 1905 he stopped long enough to plant an elm on the grounds of the Carnegie Library.

Roosevelt's national forests were the grand gesture, but they were supplemented by the more modest efforts of a number of arborists who saw a need for trees in the nation's cities and towns. The Progressive Era witnessed a great burst of urban tree planting, with Chicago's municipal forester declaring in 1911 that "trees planted in front of every home in the city cost but a mere trifle, and the benefits derived therefrom are inestimable." In the years after World War II, city forestry departments planted new trees and maintained maturing ones, while the U.S. Forest Service became known for Smokey Bear and efforts to fight forest fires that raged out west during the dry season.

By the 1970s, most Americans lived in cities and

suburbs, and the tree lovers among them watched sadly as graceful old elms, big oaks, and verdant small woodlands disappeared, victims of Dutch elm disease, development, and shrinking municipal budgets. This urban deforestation was one more blow to declining cities. City streets stripped of trees lost much of their character and beauty. "Elm trees were part of my life," one

> ## CHICAGO MAYOR RICHARD Daley Jr., a self-proclaimed tree hugger, wanted to know: Do more trees mean cleaner air?

Chicago woman ruefully told a forester in the 1980s. She cherished the deep shade and cathedral-like canopy of these majestic giants. "As each one died in my neighborhood . . . the place began to look old, worn, and crowded." Soon thereafter, she moved to another neighborhood that still had trees.

Chicago mayor Richard Daley Jr., a self-proclaimed tree-hugger born on Arbor Day, was equally heart sore. Upon taking office in 1989, he vowed to plant a half-million trees as part of his effort to revive his decaying Rust Belt city. "What's really important? . . . A tree, a child, flowers," the mayor said in a *Chicago Wilderness Magazine* interview. "Taking care of nature is part of life. If you don't take care of your tree and don't take care of your child, they won't thrive." Knowing that his city's air was among the most polluted in the nation, he asked, "Don't trees clean the air?"

Lumberjacks had long known how to calculate the board feet value of a single lodgepole pine or a vast forest, farmers the price of fruit-tree crops. And yet, in the late 20th century, city trees collectively created an urban forest about which we knew almost nothing. The truth was that no one could provide an answer to Daley's question that was grounded in science.

In fact, no one had concrete answers to a host of fundamental questions. What was the character of

an American urban forest? How many poplars, ashes, or lindens were there? How old were they and what size? How healthy? How did trees interact with the ecosystem? Did they really affect air quality? Anyone whose family home was shaded by large oaks or maples knew the delicious cool of those trees on a hot summer day, but how much did they reduce the need for air conditioning?

When thunderstorms lashed down, how many gallons of rainwater did the leaves of a Norway maple absorb and keep out of the stressed sewerage system? And what effect did tree-lined streets and tree-rich landscaping have on commerce? Or crime? Or human well-being? Finally, how could you quantify the benefits so as to persuade city officials that trees were valuable green infrastructure and not mere ornamentation—or, worse yet, a leafy liability?

Daley hired a young arborist named Edith Makra to be his "Tree Lady." She was to get lots of trees planted, but the mayor still wanted to know if more trees meant cleaner air. To get an answer, he prevailed on a fellow tree lover in Congress, 20-term representative Sidney R. Yates (D-Ill.), to earmark some serious federal research dollars. Makra was soon on the phone to the man she believed could answer the mayor's question, and many others about city trees: Rowan Rowntree, a 55-year-old visionary U.S. Forest Service scientist and the grandson of the famous California wildflower botanist and author Lester Rowntree.

"I told him the mayor would be getting us $900,000 and could he help us," Makra recalls. The timing was perfect. While studying urban forests in Oakland, Tucson, and Menlo Park, New Jersey, Rowntree and his colleagues had figured out how to establish a science of urban trees, but they lacked critical funding, staff, and data. Now, not only was Makra offering significant financing, but Rowntree had trained two young scientists, Gregory McPherson and David Nowak, who were ideally suited to work on the ambitious project.

McPherson had grown up in a small, elm-shaded town in southern Michigan, then discovered a love for

City dwellers have always delighted in the pleasures of shaded oases like this vest-pocket hideaway in downtown Chicago. Now that scientists can attach a dollar value to the environmental benefits of trees, however, planners are beginning to regard America's urban forests as valuable infrastructure.

New York (SUNY), Syracuse, before taking a tenured position at the University of Arizona in Tucson. That's where he was when Rowntree lured him to Chicago.

Rowntree had met Nowak in the early 1980s when the younger man was a SUNY undergraduate, and was so impressed that he suggested Nowak do a master's in urban forestry with him. In 1987, when Rowntree returned home to Berkeley to help run a U.S. Forest Service research project there, Nowak came out with him to work on his Ph.D. at the University of California. Chicago would be Nowak's first post-doctoral job.

In 1994, after three years of work that encompassed Chicago as well as surrounding Cook and Du Page counties, Rowntree and his protégés issued their study, the "Chicago Urban Forest Climate Project." They could at last report the size of the Chicago metro area's urban forest: It consisted of roughly 51 million trees, two-thirds of which were in "good or excellent condition." The report was replete with

the American West while studying in Utah for a master's degree in landscape architecture. Design was not his strong point, but marshaling data was. He became Rowan's doctoral student at the College of Environmental Science and Forestry at the State University of charts and graphs and included detailed information about commercial and residential distribution, tree canopy density, and other attributes of Chicago's woodlands. In Chicago, street trees made up only a tenth of the urban forest, but they provided a quar-

ter of the tree canopy—what a bird flying overhead would see of the leafy tree crowns and foliage that provide shade and cover. And the canopy shaded only 11 percent of the city, less than half of the proportion city officials believed was ideal.

So how *did* all these trees benefit the city? Certainly the trees of Chicago had long sweetened the air and sheltered homes and streets from hot summers and freezing winters, but now here were actual data to show it. "In 1991, trees in Chicago removed an estimated 17 tons of carbon monoxide, 93 tons of sulfur dioxide, 98 tons of nitrogen dioxide, 210 tons of ozone, and 234 tons of particulate matter," Rowntree and his colleagues said in the conclusion to their report. In neighborhoods where trees were large and lush, they could improve air quality by as much as 15 percent during the hottest hours of midday. More trees and bigger trees meant cleaner air.

Trees in the Chicago metro area sequestered about 155,000 tons of carbon a year. This sounded like a large amount, but, the report noted, that annual intake equaled the amount of carbon emitted by transportation vehicles in the Chicago area in just one week. However, over time the urban forest could sequester as much as eight times more carbon if the city planted greater numbers of large, long-lived species such as oaks or London planes and actively nurtured existing trees to full maturity. A big tree that lives for decades or even a century or two can sequester a thousand times more carbon than, say, a crab apple with a life span of 10 or 20 years.

Everyone "knew" that trees cooled down buildings. McPherson measured the *actual* energy savings from Chicago's trees. The shade from a large street tree growing to the west of a typical brick residence, he found, could reduce annual air-conditioning energy use by two to seven percent. By planting more trees to cool down built-up city neighborhoods whose higher temperatures made them urban "heat islands," and promoting utility-sponsored residential tree plantings, the city government could further curtail energy use.

All of this information about an urban forest, never fully documented before, meant that Rowntree and his colleagues could calculate that forest's monetary value. The benefits that each tree planted among Chicago's streets, yards, and businesses provided over its life span came to $402—more than twice its cost.

Oddly, Daley, who was remaking Chicago as a glamorous green city, never embraced the implications of the report. He pushed tree planting, but not in the scaled-up, strategic way Rowntree and his team had hoped for. In the byzantine world of Chicago politics, no one ever discovered exactly why. Still, Daley's patronage had made possible groundbreaking tree science.

The Chicago study introduced a radically new way to think about city trees, even for those who had been thinking about urban forests for years. Ray Tretheway, longtime head of the Sacramento Tree Foundation, a nonprofit tree-planting organization, vividly remembers hearing McPherson speak at an urban forestry conference in 1991. "He just blew me away," Tretheway recalls. "These tree benefits, I'd never heard of this before." After meeting with McPherson and Rowntree, Tretheway persuaded the U.S. Forest Service to open a new research station in Davis, not far from Sacramento. With the Chicago study concluded, McPherson headed to California to become head of the station's Center for Urban Forest Research. The University of California, Davis, provided a source of graduate students to carry out the research.

Tretheway acquired a wealth of studies and new data from McPherson and other tree scientists, who in the late 1990s worked up a detailed portrait of Sacramento's five million trees and their numerous benefits. McPherson's graduate student Qingfu Xiao did pioneering research on the impact of trees on stormwater dispersal—an expensive problem for the many cities faced with federal mandates to upgrade their sewerage and water systems—by measuring how much rainfall trees of various species and sizes intercepted.

When McPherson had come west, he found under way in Sacramento a real-life study of how trees save energy. In 1989, the Sacramento Municipal Utility District had been forced by outraged voters to close its dysfunctional Rancho Seco nuclear plant. To

reduce its peak load, the electric utility's new, tree-loving CEO, S. David Freeman, had partnered with Tretheway's foundation to plant half a million young trees for free in the yards of residential customers over the course of a decade.

By 1993, more than 111,000 trees had been planted, and the utility wanted to assess whether they were starting to reduce energy use. It gathered information from 326 homes on tree mortality, location, species, and size, as well as all the relevant specs on each house. McPherson's number crunching revealed that a tree planted to the west of a house saved about three times more energy ($120 versus $39) in a year than the same kind of tree planted to the south. The shade program underwent "a paradigm shift," according to economist Misha Sarkovich, whom the utility had assigned to monitor the program's impact. Today Sarkovich runs the program, and he evaluates performance not by how many trees are planted but according to the "present value benefit" of each tree, expressed in a dollar amount.

About half of the nearly 500,000 trees the utility has planted in the last 20 years are still alive, and their overhanging boughs have done much to improve customers' quality of life. Some of that improvement can be measured. The trees' shade collectively saves the utility from having to supply $1.2 million worth of electricity annually. Running the shade program costs the utility $1.5 million a year. As more trees are planted and the new canopy becomes lusher, the energy savings will continue to grow. When and if it can begin selling carbon credits, the utility will start to make a profit on its shade tree program.

In the post-Chicago years, McPherson and Nowak developed their science and models, engaging in ever more ambitious studies. McPherson began systematically studying a reference city in each of 16 climate zones to expand his database. As this new research became known, city foresters and nonprofit arbor groups increasingly drew on it to advocate for trees.
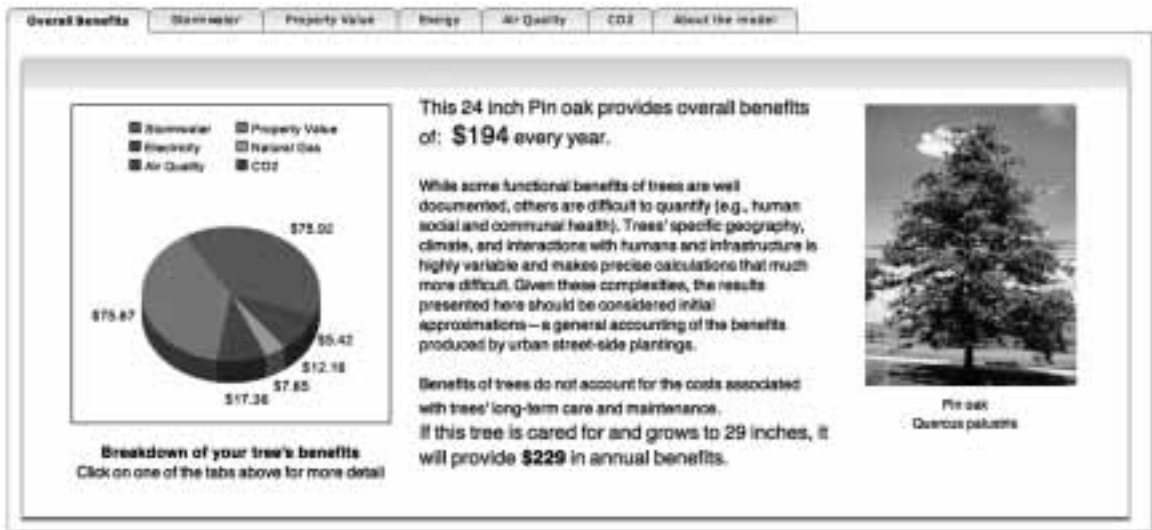
In 2006, McPherson and his colleagues were adding Queens as a reference city when the New York Parks Department asked them to value *all* of New York City's 592,000 street trees. With the advances made over the preceding dozen years, McPherson could deliver a far more sophisticated report than he had for Chicago. Energy savings: New York City's trees annually saved roughly $28 million,

A STUDY IN NEW YORK CITY found an impressive net annual benefit from trees of $100 million.

or $47.63 per tree. Air pollution: Each street tree removed an average of 1.73 pounds of air pollutants per year (a benefit of $9.02 per tree), for a total of more than $5 million. The report also calculated that street trees reduced stormwater runoff by nearly 900 million gallons each year, saving the city $35.6 million it would have had to spend to improve its stormwater systems. The average street tree intercepted 1,432 gallons, a service worth $61, a figure large enough to impress cost-conscious city managers.

McPherson and his colleagues were also able to tally various benefits associated with aesthetics, increased property values and economic activity, reduced human stress, and improved public health, which were estimated at $52.5 million, or $90 a tree. These drew on straight-up economic studies of real estate prices as well as social science research, which showed, for example, that hospital patients who could see a tree out the window of their room were discharged a day earlier than those without such a view. Other studies showed that shopping destinations with trees had more customers than those that didn't, and leafy public-housing projects experienced less violence than barren ones.

All these data led to the finding that each year New York City's street trees delivered $122 million in benefits, or about $209 a tree. As New York City's

| Overall Benefits | Stormwater | Property Value | Energy | Air Quality | CO2 | About the model |

This 24 inch Pin oak provides overall benefits of: **$194** every year.

While some functional benefits of trees are well documented, others are difficult to quantify (e.g., human social and communal health). Trees' specific geography, climate, and interactions with humans and infrastructure is highly variable and makes precise calculations that much more difficult. Given these complexities, the results presented here should be considered initial approximations — a general accounting of the benefits produced by urban street-side plantings.

Benefits of trees do not account for the costs associated with trees' long-term care and maintenance. If this tree is cared for and grows to 29 inches, it will provide **$229** in annual benefits.

Pin oak
Quercus palustris

Breakdown of your tree's benefits
Click on one of the tabs above for more detail

The software program i-Tree can calculate the benefits of any urban tree in America. Here are the results for the pin oak in the author's backyard.

parks and forestry officials well knew, they received $8 million a year to plant and tend street trees, and spent another $6.3 million to pay personnel. The net benefit they were getting for all these trees was an impressive $100 million.

For the first time, urban forestry science had a dramatic effect on public policy: In 2008, Mayor Michael Bloomberg quadrupled the city's forestry budget, from $8 million to $31 million (down last year to $27 million), when he launched Million Trees NYC, a partnership with entertainer Bette Midler's nonprofit New York Restoration Project. McPherson was thrilled to see science elevate urban forestry above the level of "a kumbaya idea." The million trees (350,000 are in the ground so far) planted by 2018 will transform the Big Apple, and those lush, tree-lined streets and shaded parks may well become Bloomberg's most visible legacy.

In Los Angeles, meanwhile, another tree-hugging mayor, Antonio Villaraigosa, had already launched his own Million Trees initiative back in 2006. McPherson and his team, who had worked with the city's schools a few years earlier to determine how trees could cool and shade school property, were called in again. Their mission for Million Trees LA was to gauge the size of the existing canopy, figure out if there was room for another million trees in the 500-square-mile city, and, if there was, determine the best places to plant them.

City officials directed McPherson to create a map showing the canopy cover in each of the 15 councilmanic districts. While Los Angeles's overall tree canopy covered a respectable 21 percent of the city, the map revealed that the districts with the fewest trees were also the poorest. "When we went around with this map," notes one official, "people who didn't care about trees started to care. Council members in east and south L.A. wanted to know why they didn't have the same level of trees as wealthier neighborhoods."

In the wake of the report, the emphasis of Million Trees LA shifted. "We all knew there were places with fewer trees, but with the map you can really *see* it," says executive director Lisa Sarno. "It's become a matter of social and environmental justice." In poor residential neighborhoods where tree-planting efforts have been stepped up, the demand is for lemon, lime, and orange trees, which produce fruit that is expensive to buy at grocery stores. At long last, this radical new way of thinking about city trees had begun to influence politicians, planners, and city managers.

Once they had the science, urban forestry champions became frustrated by the puzzle of how to disseminate what they had learned. David Nowak, who has long worked out of the U.S. Forest Service's Northeastern Research Station in Syracuse, New York, had begun collaborating with the Davey Tree Expert Company, a nationwide tree care company, to create free computer software that could help others to replicate

his work on the structure and benefits of urban forests. At the University of California, Davis, graduate student Scott Maco was creating similar software for McPherson just for urban street trees, the major concern of most foresters wanting to impress city hall with trees' benefits.

In early 2003, Mark Buscaino, the new head of urban forestry at the U.S. Forest Service, proposed pulling together Nowak and McPherson's work into a free software suite—christened i-Tree—aimed at city foresters, landscape architects, urban planners, and nonprofit tree groups. Gregory Ina, general manager of the Davey Institute at the Davey Tree Expert Company, loved the idea and brought Maco on board in 2005 to run the effort. (Of course, in the long run, more trees will be good for Davey Tree's business.) In tandem with the U.S. Forest Service and other partners, Maco and Davey Tree have worked to make the i-Tree software more sophisticated and easier to customize, and they provide customer support to the municipalities, scholars, foresters, consultants, and nonprofit and citizen groups that use it.

Davey estimates that last year 2,000 i-Tree projects were under way, mostly in the United States. A software package called i-Tree Hydro, which models stormwater hydrology, will be released this winter. One spin-off, developed in partnership with the Washington, D.C., nonprofit organization Casey Trees, is the Tree Benefit Calculator, which tells homeowners the value of their trees. It recently informed me that my 25-year-old backyard pin oak last year provided the following benefits: It intercepted and absorbed 7,669 gallons of rainwater ($75.92), raised my property value ($75.67), saved 229 kilowatts of electricity ($17.36), and improved air quality and stored carbon ($17.58). Of course, my family also enjoys the pin oak's beauty, the squirrels frolicking about its branches and feasting on acorns, and the many cardinals and other birds it attracts. It buffers us from a nearby busy street, abates noise, and once held a rope swing for my daughter.

Most of us take trees for granted, but when we do think of them, generally we appreciate how they beautify and soften our world and connect us to nature. (We also sometimes curse them for clogging our gutters with fallen leaves or damaging our property when they fall down.) Trees are the largest and longest-lived structures on our planet. At the White House, one bedroom is still shaded by a magnolia planted by President Andrew Jackson in memory of his wife. But such benefits don't always have traction with public planners and politicians. Money does much of the talking. "The monetizing is a necessary evil," Nowak says. "We know trees have great value, but they're intrinsically underrated. You have to talk the language of people who make decisions."

As we humans wrestle with how to repair the damage we have wrought on nature, and how to slow climate change, urban trees offer an obvious low-tech solution. Every city, McPherson says, should have a "maximally functional" canopy. "We should shoot for a performance standard, like how many megawatt hours of air conditioning we can save, or how many pounds of nitrogen dioxide we can absorb, reducing ozone and smog." Trees can play a role in cooling cities while making them more beautiful, healthier, and friendlier to humans. And at a time when everyone seems to want to go "green," urban forestry science offers meaningful ways to think about how to do that. Business sage Warren Buffett, who knows something about the value of thinking long term, has said, "Someone's sitting in the shade today because someone planted a tree a long time ago."

It is easy to imagine that Theodore Roosevelt, who believed that trees added "immeasurably to the wholesome beauty of life," would have been delighted but not surprised to learn of the many practical roles played by the very trees most familiar to Americans—those that surround them in their daily life in cities and suburbs. While science and technology are transforming and expanding the way we think about trees, Rowntree, now a scientist emeritus with the U.S. Forest Service, estimates, "We are only 50 percent of the way to knowing what trees really do for us." What we *have* learned only proves the old proverb truer than ever: "The best time to plant a tree was 20 years ago, the next best time is today." ∎