

## Urban Forests and Climate Change

For the last 20 years there has been a growing realization that reducing threats to societal stability and welfare from planetary-wide climate disruption will depend to a great degree in making cities more efficient in their consumption of energy and materials. Since cities are our economic engines and places where most of the world's people live, they contribute most of the greenhouse gases derived from fossil fuel emissions.<sup>1</sup> Solutions to the global problem of climate change will ultimately be local and urban, requiring cooperation among different levels of government, businesses, institutions, and individuals. The purpose of the Urban Forestry section is to provide information and recommendations as to how our city's natural areas and managed vegetation, particularly trees, can also contribute to reducing our collective carbon footprint, and in addition, provide a buffer against imminent climate change impacts.

The total cover and distribution of all vegetation in cities and suburbs (synonymous with Urban Forest) are important in making cities more liveable, and play key roles in making urban regions more economically and ecologically sustainable, roles that will become even more important as climate changes.<sup>2,3</sup> If we are to optimize the benefits society derives from its investment in urban forests, then policy makers and the public must more broadly appreciate that urban vegetation functions as a city's "green infrastructure" and, therefore, requires similar attention to its development, maintenance and repair as does our built "gray" infrastructure.

### How the Urban Forest Reduces the Urban Carbon Footprint

#### Direct Carbon Uptake and Sequestration

An urban forest, especially trees, provides the ecosystem service of reducing a city's carbon footprint in two major ways, directly by carbon uptake from the atmosphere and long-term storage in wood, and indirectly by reducing a city's energy use (carbon emission avoidance). All plants take up CO<sub>2</sub> from the atmosphere and convert the carbon into their living tissues. Unlike grasses and other herbaceous plants, however, only shrubs and trees store carbon in woody tissue for decades to centuries, and so keep enough CO<sub>2</sub> out of atmospheric circulation over a sufficient time frame to reduce the rate of climate change.

Urban and suburban housing lots in total typically store and sequester most of a city's tree carbon, particularly if neighborhoods are old and contain mature trees, and also if larger trees were not removed during development. The potential to plant more trees in yards and on streets exists and, if realized, could increase tree density and the multiple ecosystem benefits trees provide for both individual households and the city as a whole.

#### Avoided Carbon Emissions via Reduced Energy Use

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<sup>1</sup> L. R. Brown, *Eco-Economy: Building an Economy for the Earth* (New York: W. W. Norton, 2001).

<sup>2</sup> Margaret M. Carreiro and others, *Ecology, Planning and Management of Urban Forests: International Perspectives* (New York: Springer Science+Business Media, 2008).

<sup>3</sup> Richard Register. *Ecocities: Building Cities in Balance with Nature* (Berkeley, CA: Berkeley Hills Books, 2002).

Vegetation buffers urban climate and therefore reduces energy use particularly in summer by providing shade, serving as windbreaks, and transpiring water into the atmosphere. If sited properly, trees physically reduce the amount of sunlight that reaches buildings, especially buildings less than three stories tall. Shading decreases the energy needed to cool buildings in summer and trees can also reduce building energy demand in winter. While deciduous trees planted along south and west building aspects shade buildings in summer, they admit sunlight in winter, thereby reducing heating costs over the entire year in north temperate climates. Low amounts of vegetation, high coverage by impervious surfaces (buildings, roads) with high thermal absorption properties, and low coverage by unpaved soil, which would otherwise hold cooling moisture between rain events, are the main contributors to the urban heat island effect. Buildings and roads contribute greatly to the heat island, because they are made of materials that absorb a high percentage of incident solar energy and have a high heat storage capacity.

The most important means by which the urban forest reduces the heat island effect is via the ecosystem process of transpiration, the transference of liquid soil water through a plant and into the atmosphere in the form of water vapor. This process cools the air because energy (the latent heat of vaporization) is absorbed from the air to convert liquid water inside leaf pores to gaseous water as the moisture is evaporated into the air. Unlike paved surfaces, exposed moisture-storing soil also cools the city environment as soil water evaporates into the air.

## Quantification and Monetary Valuation of the Ecosystem Services Provided by the Urban Forest and Associated With Reducing Urban Carbon Footprints

### Ecosystem Service Quantification

There have been many studies that have quantified the extent to which vegetation can reduce urban temperatures from the scale of the whole city to that of the residential lot, and that have also estimated resultant energy savings.<sup>4</sup> By reducing the urban heat island effect, increases in urban forest cover can reduce energy use.

Patches of green space with and without trees can also have a localized cooling effect on their neighborhoods. Forested parks can potentially have a greater cooling effect on built areas immediately surrounding them, particularly at night. The “cool spots” caused by Louisville’s urban parks is evident in an infra-red satellite image of our inner city area (Figure 4-6), which shows the spatial variation in temperature recorded on July 8, 2000.

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<sup>4</sup> W.Y. Chen and C.Y. Yim, “Assessment and Valuation of Ecosystem Services Provided by Urban Forests,” in *Ecology, Planning and Management of Urban Forests: International Perspectives*, eds. Margaret M. Carreiro and others (New York: Springer Science+Business Media, 2008), 53-83.

## URBAN HEAT INDEX

Recorded Temperature<sup>1</sup> on July 8, 2000:

Mean Temperature: 75.6°F  
 Minimum Temperature: 64.0°F  
 Maximum Temperature: 87.1°F

Local Observed Temperature<sup>2</sup>  
(in Degrees Fahrenheit)

54 - 79
80 - 88
89 - 93
94 - 97
98 - 100
110 - 140



1. National Climatic Data Center  
 http://www.cgd.noaa.gov/heatindex.html

2. Radiance data (the amount of electromagnetic radiation heating or cooling an object on a surface) obtained from NOAA and State Data Atlas North America. Data was converted to degree Fahrenheit with GIS conversion tools.

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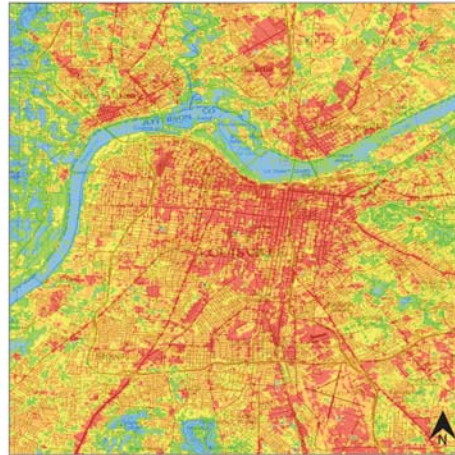


Image taken July 8, 2000

Figure 4-6. Infra-red Satellite Image of the City of Louisville

Increasing tree cover in commercial areas, such as streets and paved parking lots, also reduces local temperatures and decreases the urban heat island effect. In Davis, California as little as 8% tree shading coverage reduced parking lot temperatures by as much as 36° F.<sup>5</sup> Tree shading of parking lots is important to the heat budget of a city, since parking lots comprise about 10% of all impervious surface area in U.S. cities.<sup>6</sup>

### Ecosystem Service Valuation

Translating quantified ecosystem service benefits provided by urban forests (e.g., kWh saved or tons of CO<sub>2</sub> sequestered) into their respective monetary values would improve the likelihood that urban forest preservation and budgetary needs will be incorporated more objectively and frequently into municipal planning and management.

Model simulations of Chicago's urban forest determined that a 10% increase in tree cover would reduce energy use from heating and cooling by 5% to 10%. Various scenarios were also modeled to provide a more detailed assessment of the value of increased tree planting in the city. Street trees provided nearly half of the energy saved and yard trees contributed an additional 37%. The highest benefit-to-cost ratios were found for trees in residential yards and public housing, suggesting the importance of funding urban forestry outreach and education programs that target homeowners and the general public.

<sup>5</sup> E. G. McPherson, "Sacramento's Parking Lot Shading Ordinance: Environmental and Economic Costs of Compliance," *Landscape and Urban Planning* 57 (2001): 105–123.

<sup>6</sup> J. R. Geiger. "Where Are All the Cool Parking Lots?," (Davis, CA: Center for Urban Forest Research, Pacific Southwest Research Station, USDA Forest Service, 2002), 2. [http://www.fs.fed.us/psw/programs/cufr/products/3/cufr\\_151.pdf](http://www.fs.fed.us/psw/programs/cufr/products/3/cufr_151.pdf)

## Additional Ecosystem Services Provided by Urban Forests That Increase Urban Resilience to Anticipated Climate Change Impacts

IPCC climate forecasts, based on mid-range reductions in greenhouse gas emissions, indicate that by 2080 cities in our region can expect a summer (June-August) climate that will be 7° F warmer than the 1980-2000 average.<sup>7</sup> While predicted *average* rainfall during the summer will likely remain within 10% of mean values from 1980-2000, the hotter environment will translate into greater drought risk due to increased evapotranspiration rates from plants and soil. In addition, while average rainfall over the year may not change much, we can expect more intense rainfall per event interspersed with longer intervals between rain events. An intelligently distributed and well-managed urban forest in our parks, riparian areas, streets, yards, parking lots and institutional campuses can contribute to reducing the negative impacts of hotter summer temperatures and flooding/drought cycles on our urban built infrastructure and our citizenry.

### Air Quality Benefits.

Unless fossil fuels are rapidly reduced as an energy source for home cooling and transportation, hotter summer temperatures will increase both primary pollutant emissions (e.g., particulates, nitrogen oxide gases (NO<sub>x</sub>), and sulfur dioxide gas (SO<sub>2</sub>)) and secondary pollutant (e.g., ozone (O<sub>3</sub>), peroxyacetyl nitrates (PANs), aldehydes) formation in the atmosphere. For every 2° F rise in temperature above 78° F, smog increases by 7% to 18%.<sup>8</sup> By intercepting particulates and taking up many gaseous pollutants, urban tree canopies cleanse the air of pollutants that adversely affect human cardio-pulmonary health and that damage materials. In 1991, urban forests in the Chicago metropolitan area were estimated to remove a total of 6,145 tons of air pollutants valued at \$9.2 million dollars per year.<sup>9</sup> Pollutant removal by trees (at 11% tree cover levels) in the inner city of Chicago was valued at \$1 million, with large healthy trees removing between 60 to 70 times more pollutants than smaller trees. In Sacramento, shaded parking lots reduced asphalt temperatures by 36° F, vehicle temperatures by 47° F and fuel tank temperatures by 7° F over unshaded lots. That results in fewer organics volatilized from vehicle materials (hoses, fabrics) and gas tanks to contribute to O<sub>3</sub> formation. By increasing parking lot area shaded by trees from their current 8.1% to the 50% shade coverage stipulated in Sacramento's city ordinance, annual benefits from all ecosystem services (including storm water management, improved air quality, reduced heat island and others) would also increase from \$700,000 to approximately \$4 million per year.<sup>10</sup>

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<sup>7</sup> J. H. Christensen and others, "Regional Climate Projections," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. S. Solomon and others (U.K.: Cambridge University Press, 2007). <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf>

<sup>8</sup> Melvin Pomerantz and others, "Physics and Public Policy for Urban Heat Island Mitigation: Summary of a presentation to the American Physical Society, Atlanta, GA, March 1999." Heat Island Group, 2000, <http://eetd.lbl.gov/HeatIsland/PUBS/APS-PressRelease/>

<sup>9</sup> D.J. Nowak, "Air Pollution Removal by Chicago's Urban Forest," in *Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project*, ed. E.G. McPherson (Randnor, PA: United States Department of Agriculture, Forest Service, Northeastern Forest Experimental Station, 1994), 63–81.

<sup>10</sup> E. G. McPherson, "Sacramento's Parking Lot Shading Ordinance: Environmental and Economic Costs of Compliance," *Landscape and Urban Planning* 57 (2001): 105–123.

## Stormwater Management Benefits.

Since cities have a large percentage of impervious surfaces (up to 95% in downtown areas), less ground water is recharged, and more local neighborhoods become prone to flooding. In addition, stormwater runoff, particularly that running through combined sewer outlets, has also caused great damage to local streams and riparian areas through stream bank undercutting and erosion. Cities have had to make large investments in the construction of stormwater management systems to replace the flood prevention services formerly supplied by our green infrastructure (i.e., permeable soils and vegetation). The urban forest can also mitigate the severity of this urban flooding syndrome by intercepting and storing rainwater in tree canopies and by collecting and directing more water flow down the trunk to the soil at the tree base instead of paved surfaces. Increasing urban tree cover should be considered a viable strategy for alleviating the costs of storing and discharging stormwater. The costs of flood damage could also be included in the ecosystem service valuation of an urban forest. Investments in greater tree planting and management will be needed soon, if we are to buffer cities like Louisville from the negative impacts of more intense rain events and hotter weather that climate change will likely bring.

## Biodiversity Support and Other Benefits

There are many other recognized ecological services provided by green space in parks, streets, yards and institutional campuses. Parks and other natural areas within urban and suburban communities provide important habitat for local biodiversity, and places for recreation and spiritual rejuvenation for stressed city dwellers.<sup>11</sup> Even though some of these services have been quantified in a few locations, their dollar values are in need of improved estimation.<sup>12</sup> There is even less focus on the fact that some species (e.g., fish, frogs, dragonflies, insectivorous birds, bats, birds of prey), which often require larger areas of natural land or good quality aquatic habitats for their survival, serve as a vanguard for protecting people and pets from insect and rodent-vectored diseases, and even some water borne illnesses.<sup>13</sup>

Greater attempts are needed to quantify the value of ecosystem services provided by biodiversity in forested ecosystems and other green spaces in and around cities if nature's beneficial contributions to society are to become tangibly visible and not regarded solely as theoretical. Valuation of nature's ecosystem services can redress some of the present imbalance in decision-making as development options are discussed and planned.

Establishment of effective urban forestry programs is one of the top priorities identified by urban planners, managers and scientists involved in the sustainable cities movement across the world.<sup>14</sup> Use of decision tools that incorporate valuation of benefits provided by the urban forest and

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<sup>11</sup> E. A. Johnson and M. W. Klemens, eds., "The Impacts of Sprawl on Biodiversity," in *Nature In Fragments: the Legacy of Sprawl*, eds. E. A. Johnson and M. W. Klemens (New York: Columbia University Press, 2005), 18-53.

<sup>12</sup> S. C. Farber, "The Economics of Biodiversity in Urbanizing Ecosystems," in *Nature In Fragments: The Legacy of Sprawl*, eds. E. A. Johnson and M. W. Klemens (New York: Columbia University Press, 2005), 263-283.

<sup>13</sup> P. R. Epstein, "Climate, Ecology and Human Health," *Consequences* 3, no. 2 (1997).

<http://www.gcric.org/CONSEQUENCES/vol3no2/climhealth.html>

<sup>14</sup> M. M. Carreiro and W. C. Zipperer, W. C., "Urban Forestry and the Eco-City: Today and Tomorrow," in *Ecology, Planning and Management of Urban Forests: International Perspectives*, eds. M. M. Carreiro and others (New York, Springer Science+Business Media, 2008) 435-456.

other natural areas into planning and management should be considered vital in securing Louisville's sustainability.

## Urban Forestry Recommendations

### Urban Forester

Management of the entire green infrastructure of a major Metropolitan area requires staff with an educational background that goes beyond arboricultural understanding of how best to plant and care for individual trees. An urban forester needs to have the background, skills and resources to obtain data directly about the status and functioning of our green infrastructure within the greater landscape. In addition, the urban forester should be able to synthesize information obtained by other city agencies and the scientific community for making sound management decisions about the distribution and maintenance of our city's green infrastructure in varied land-use contexts.

#### Recommendation 121:

*LMG should create a new position of Urban Forester to develop plans to reduce the community carbon footprint by using urban trees to offset carbon emissions, to buffer the city from adverse climate change impacts by strategically distributing different kinds of vegetation around the city, and to advise government and private property owners about the selection, installation and maintenance of trees.*

#### Recommendation 122:

*LMG should implement more science-based forestry planning at the county scale.*

#### Recommendation 123:

*LMG should provide the Urban Forester with resources to acquire information for inclusion in an Annual or Biannual "State of Our Trees" report to the Mayor.*

### Tree Loss

Trees, particularly older and larger ones, store orders of magnitude more carbon both above and belowground than small or young trees. Their removal - either intentionally during development or unintentionally due to flood, wind and ice storm events - results in a net loss of stored carbon, more CO<sub>2</sub> emitted to the atmosphere and loss of future carbon sequestration. Tree losses, especially larger trees, also enlarge the city's carbon footprint by increasing compensatory energy use for heating and cooling buildings.

#### Recommendation 124:

*LMG should strengthen the land development code so that developers must address tree protection prior to filing the site development plan to reduce the number of trees lost during construction and other related activities.*

#### Recommendation 125:

*LMG should establish a tree ordinance that includes strengthening tree canopy maintenance, and the mandatory replacement of trees lost.*

Recommendation 126:

*LMG should increase recognition of heritage and champion trees in our county and urge that a plan be filed that encourages their preservation.*

Recommendations for Louisville Metro

Trees in residential land use comprise a large proportion of a city's total forest canopy. Privately owned residential trees around homes provide a large proportion of the energy savings and avoided carbon emissions in urban areas. Trees on home lots benefit not only the homeowner, but also the city at large via reducing the urban heat island. Trees dispersed through the urban landscape also contribute to a unique sense of place for our citizens; they also serve to maintain native wildlife, some of which provide ecosystem service benefits such as disease control.

Recommendation 127:

*Create an Urban Forest website with information to increase public awareness of the value of trees in reducing household and collective city carbon footprints.*

Recommendation 128:

*Create programs and incentives for residents to plant trees.*

Recommendation 129:

*Encourage the planting of a greater diversity of native trees through education of the public, tree planting agencies, and tree nursery owners.*

Recommendation 130:

*Work toward achieving the criteria needed for Louisville Metro to become a TREE CITY USA.*

Tree Cover

Across most U.S. cities, parking lots constitute about 10% of all impervious cover. Without appropriate tree cover, parking lots contribute substantially to stormwater run-off, pollutant loading to streams, and to volatile organic compounds emissions to the atmosphere from heated gas tanks and other materials in parked vehicles. Increasing tree cover in parking lots has been proven to reduce costs to stormwater detention and degradation of water and air quality.

Recommendation 131:

*PGC should establish requirements for minimum percent tree cover in locations with high pavement density such as parking lots.*

Highway Forests

Trees growing alongside our major transportation corridors, such as interstate highways, are low maintenance yet store and annually sequester large amounts of carbon per acre. These highway forests are buffers that take up numerous air pollutants emanating from the vehicles on the

highways and muffle noise pollution to residential areas adjacent to these roads. On a per acre basis, these trees rank highly in terms of the ecosystem services they provide to our urban community. These trees have high benefit to cost ratios in large measure because we rely on natural processes for tree reproduction. However, the capacity of these highway forests to regenerate are being greatly compromised by the spread of an exotic honeysuckle shrub and other invasive plants along highway corridors. Therefore, we recommend that Louisville Metro work with relevant city, state and federal agencies to:

Recommendation 132:

*Encourage removal of non-native bush honeysuckle, which has been proven to greatly reduce the natural regeneration of tree seedlings in wooded areas along highway verges.*

Recommendation 133:

*Encourage decreased mowing along our transportation corridors to allow more tree growth in appropriate locations.*

Recommendation 134:

*Seek opportunities and locations along highways for planting more native trees.*