# Appendix 3: Procedures for Estimating Benefits and Costs

## Approach

### Overview

Because benefits from trees differ owing to regional differences in tree growth, climate, air pollutant concentrations, rainfall patterns, building characteristics, and other factors, we divided the United States into 20 climate zones. A reference city is designated for each climate zone, and intensive data are collected for modeling tree benefits. Criteria for selection as a reference city include:

- Updated inventory of trees by address.
- Detailed information on tree management costs.
- Long-tenured city foresters who can help age trees because they know when they were planted or when different neighborhoods were developed and street trees planted.
- Good contacts within other city departments to obtain data on sidewalk repair costs, trip/fall costs, and litter cleanup costs.
- Capability to provide the resources needed to conduct the study, including an aerial lift truck for 5 days to sample foliar biomass.

The Borough of Queens was selected as the reference city for the Northeast region because it best met these criteria. During 2005, data were collected on tree growth and size for predominant street tree species in Queens, and other geographic information was assembled to model tree benefits. A subset of these data is used in this guide, and the entire data set is incorporated into the i-Tree STRATUM database for the Northeast region (see www.itreetools.org).

In this study, annual benefits and costs over a 40-year planning horizon were estimated for newly planted trees in three residential yard locations (east, south, and west of the dwelling unit) and a public street-side or park location. Trees in these hypothetical locations are called “yard” and “public” trees, respectively. Prices were assigned to each cost (e.g. planting, pruning, removal, irrigation, infrastructure repair, liability) and benefit (e.g., heating/cooling, energy savings, air-pollution reduction, stormwater-runoff reduction) through direct estimation and implied valuation of benefits as environmental externalities. This approach made it possible to estimate the net benefits of plantings in “typical” locations with “typical” tree species.

To account for differences in the mature size and growth rates of different tree species, we report results for a small (Kwanzan cherry), medium (red maple), and large (Japanese zelkova) deciduous tree and for a conifer (eastern white pine) (see "Common and Scientific Names" section). The selection of these species was based on data availability, and not intended to endorse their use in large numbers. In fact, the Kwanzan cherry has a poor form for a street tree and in certain areas zelkova is overused. Relying on too few species can increase the likelihood of catastrophic loss owing to pests, diseases, or other threats. Results are reported for 5-year intervals for 40 years.

Mature tree height is frequently used to characterize small, medium, and large species because matching tree height to available overhead space is an important design consideration. However, in this analysis, leaf surface area (LSA) and crown diameter were also used to characterize **mature tree size**. These additional measurements are useful indicators for many functional benefits of trees that relate to leaf-atmosphere processes (e.g., interception, transpiration, photosynthesis). Tree growth rates, dimensions, and LSA estimates are based on tree growth modeling.

## Growth Modeling

Growth models are based on data collected in the Borough of Queens, New York City. An inventory of Queens' street trees was provided by the City of New York Department of Parks and Recreation. The inventory was conducted in 1995 and updated to account for dead tree removals and new plantings. It included 255,742 trees representing 242 species.

Tree-growth models developed from Borough of Queens data were used as the basis for modeling tree growth for this report. Using Queens' tree inventory, a stratified random sample of 21 tree species was measured to establish relations among tree age, size, leaf area, and biomass.

For the growth models, information spanning the life cycle of predominant tree species was collected. The inventory was stratified into the following nine diameter-at-breast-height (d.b.h.) classes:

1. 0–2.9 in
2. 3–5.9 in
3. 6–11.9 in
4. 12–17.9 in
5. 18–23.9 in
6. 24–29.9 in
7. 30–35.9 in
8. 36–41.9 in
9. ≥ 42 in

Thirty to 60 trees of each species were randomly selected for surveying, along with an equal number of alternative trees. Tree measurements included d.b.h. (to nearest 0.1 cm by sonar measuring device), tree crown and bole height (to nearest 0.5 m by clinometer), crown diameter in two directions (parallel and perpendicular to nearest street to nearest 0.5 m by sonar measuring device), tree condition and location. Replacement trees were sampled when trees from the original sample population could not be located. A total of 910 trees were measured. Field work was conducted in August 2005.

Tree coring was used in Queens to estimate planting dates instead of using historical research conducted in other reference cities. Unlike other cities, where even-aged stands exist along streets planted at the time of development, street trees in Queens were of all ages because several generations had come and gone. Dr. Brendan Buckley of Lamont-Doherty Earth Observatory's Tree Ring Laboratory, supervised the coring of 150 randomly sampled trees to establish mean tree age. These trees represented a subsample of the original 910 sample trees. One to two trees in size classes 2 through 9 were cored for each species. Coring was conducted from October 2005 through April 2006. Cores were analyzed in the lab and tree age established. Central Forestry and Horticulture provided tree ages for an additional 104 sample trees in d.b.h. classes 8 and 9, based on building records, and 34 trees in d.b.h. classes 1 and 2 based on planting records. These data were pooled with ring-count data to develop regressions based on the mean age for each d.b.h. size class.

Crown volume and leaf area were estimated from computer processing of tree-crown images obtained by using a digital camera. The method has shown greater accuracy than other techniques (±20 percent of actual leaf area) in estimating crown volume and leaf area of open-grown trees (Peper and McPherson 2003).

Linear regression was used to fit predictive models with d.b.h. as a function of age for each of the 21 sampled species. Predictions of LSA, crown diameter, and height metrics were modeled as a function of d.b.h. by using best-fit models. After inspecting the growth curves for each species, we selected the typical small, medium, and large tree species for this report.

The conifer is included as a windbreak tree located more than 50 ft from the residence, so it does not shade the building. Tree dimensions are derived from growth curves developed from street trees in the Borough of Queens, New York City (Peper et al., in press) (fig. 17).

## Reporting Results

Results are reported in terms of annual values per tree planted. However, to make these calculations realistic, mortality rates are included. Based on our survey of regional municipal foresters and commercial arborists, this analysis assumed that