Sustainable Trees for Sustainable Cities

Henry Arnold

Large shade trees make an enormous contribution to sustainable cities, but all too many of the trees planted every year will not survive long enough to attain effective size. Many factors are involved, but certainly an important one is the relationship between longevity and planting methods.

The idea of *sustainable cities* is linked to an older concept of *sustainable plant communities*. The theoretical basis for both is a closed system where everything is continuously recycled. Natural resources are renewed rather than depleted. In undisturbed natural areas a kind of sustainability is achieved through the natural cycles of the biosphere. However, this kind of sustainability for trees in the city cannot be achieved because the natural cycles have been interrupted there. Continuity of urban trees depends on human intervention.

Making Cities Sustainable

Sustainability in the broader sense for cities involves human populations and all of their activities. A major concern, in considering what makes cities sustainable in this social sense, is their desirability as places to live. The city has the great advantage of compactness, which makes possible human interaction and cultural enrichment. Today the city suffers many ills that counter these advantages, not the least of which are incompatible transportation and deteriorating infrastructure. To a great extent these problems are interwoven and cannot be successfully resolved independently. If, however, one were to pick a logical starting place, retrofitting the city for trees has appeal on several levels. It could be done more independently than most other major changes, and it would show results sooner.

Trees have enormous appeal not only aesthetically but also for their air-conditioning value; they are beautiful utilities. A large tree in the city is ten to twenty times more beneficial to the environment than a rural forest tree (Akbari et al. 1992). This is a result of the combined effects of trees on air conditioning and atmospheric carbon reduction in the urban "heat islands." They not only cool the city but they save energy used to air condition buildings. Hence they reduce atmospheric carbon produced by burning fossil fuels to generate electricity. The enhanced benefit of urban trees depends on this multiple effect when planted in urban spaces, as "infrastructure."

Present Deficiencies

With the increasing awareness of the danger of global warming there have been scores of national, state, and local efforts to increase the number of trees growing in urban areas, especially in large cities. Many tree planting programs blossomed during the 1980s, but without the crucial component of coordinated interagency planning. Each program follows its own course of action in deciding where to plant, what to plant, and how to plant trees resulting in loss of visual continuity and less

Trees in downtown Brooklyn, NY, planted in paving using a soil mixture with expanded slate aggregate to prevent loss of pore space under compaction from heavy pedestrian use.

durable tree plantings. This is usually a consequence of not making tree planting part of the city's comprehensive planning. Trees are not looked upon with the same seriousness as utilities, streets, and building heights.

This may be one reason for failing to effectively plant the "hard-core" areas. By this term I mean those precincts of every city where there are no large trees and where it does not appear that large healthy trees could grow. These are the zones of continuous paving supporting intensive pedestrian and vehicular activity. These hard-core areas include central boulevards, traffic islands, crowded sidewalks, pavement over structures, urban squares, commercial plazas, and building roofs. They constitute a significant part of the city center, possibly sixty to eighty percent of the open space. Such urban areas can support and would greatly benefit from large healthy trees.

Understanding These Deficiencies

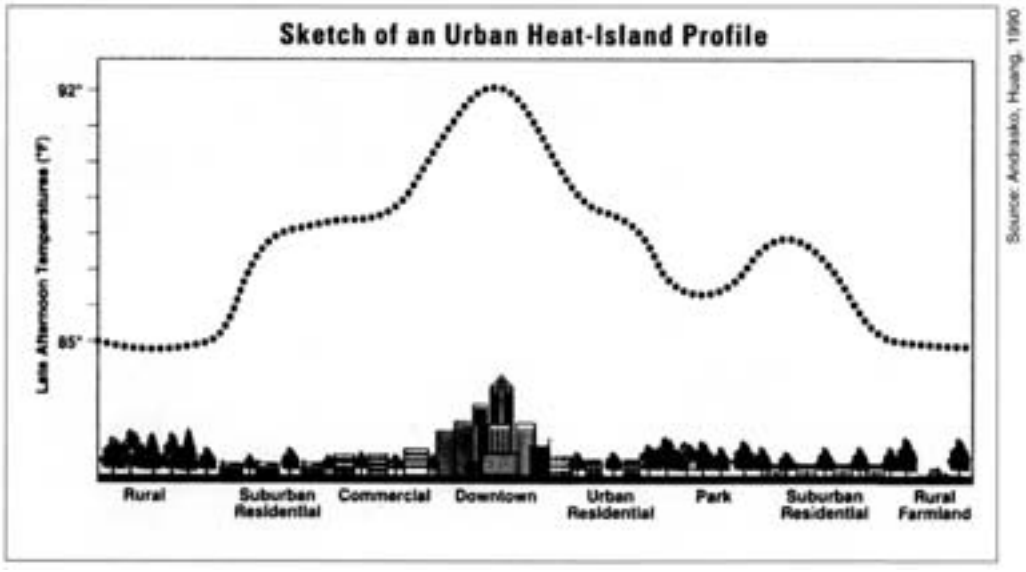
An obstacle to effectively planting American cities is the continuation of three widespread cultural biases inherited from the nineteenth century. These notions about the city still operate against the bountiful use of trees. Without reconsidering these issues there is little chance of establishing an effective urban forest in the downtown areas of our cities.

The first is the popular belief that greater diversity of tree species creates a more durable and healthy forest. Diversity of plant species does not *produce* stable plant communities (Wilson 1989). Rather, species diversity occurs as a result of long periods of stable habitat con-

ditions. Old plant communities that have developed species diversity are very fragile. Any disturbance to their habitat is likely to greatly reduce the number of species that can survive. This certainly applies to forests, especially in the city where the harsh habitat is so unsuited for most tree types. Therefore we cannot expect to create a suitable urban habitat for trees by simply planting many different tree types. The appropriate habitat conditions are required first to support species diversity.

Many urban sites will not support tree species diversity because of the biological limitations of the space. For example, poor air quality, disturbed water cycle, chemical pollutants, and soil restrictions prohibit all but a very few adaptable tree types to grow in these disturbed locations. Well-meaning but ill-informed efforts to create variety by planting many tree types on a single block or street are counterproductive. The best principle to follow on urban sites such as city streets is to plant desirable tree types that are growing in and have survived similar conditions for many years. Diversity of age is likely to be far more important in creating sustainable urban tree plantings than varying species. If all of the trees in a particular urban location become old at the same time, there is greater likelihood of a catastrophic loss. A continual replanting program that staggers the ages of the street trees could prevent possible extensive periodic tree losses (Richards 1982/1983).

At the very least we should avoid the now common practice of seeking species diversity as an end in itself. This is not to discourage testing other tree types on a limited basis. Yet misguided imposition of species diversity is being mandated by new tree planting regulations in almost every urban community. This can have serious negative consequences for urban tree sustainability. I believe this is the wrong reaction to the widespread loss of American elm trees. Planting more tree species, most of which are poorly adapted to urban locations, will not result in greater longevity of urban trees. Selecting the best adapted tree type for each specific habitat will allow city-wide diversity adequate to provide insurance against major tree epidemics. We do not need to install five or more species of trees in every block of every street.



Sketch of an urban heat island profile shows how summer temperatures can vary from a rural area to center city by as much as 7 degrees Fahrenheit on a summer day. From Akbari 1992.

The Champs Elysee in Paris, where trees define the streets and spaces of the city.

The second bias concerns *deployment* of trees in the city. There is a predisposition for the open-grown tree form with broad, low spreading crown. Trees are placed far apart to develop individual symmetrical crowns, decreasing their effectiveness as urban forests.

Alternatively, consider trees as *infrastructure*, that is, as a whole system. In this recommended approach, trees are used as groves, arcades, connectors, buffers, canopies, and colonnades. As strong geometric compositions they unify chaotic streets and tie the urban spaces together. The resulting network of vegetation conditions the air, light, and sound of the city, shaping a habitat that is unifying and soul satisfying. Used this way trees are a connecting tissue that is a part of the fabric of the city, not just decorative trim.

The use of trees as infrastructure maximizes their architectural values. Our best examples are European cities, most notably Paris. Large trees line every street forming shaded arcades that echo the rhythms of the building architecture. They are as much a part of the city as buildings and streetlights and roads. In the modern cities of temperate North America trees can be a welcome visual contrast to our often less distinguished architecture. Tree shadow patterns enrich the walls and pavement, compensating for lack of architectural richness.

The third bias is a preference for the use of suburban planting techniques in urban areas regardless of the specific site conditions. The planting methods still being used in the city were developed for rural or suburban sites.

Street Tree Planting

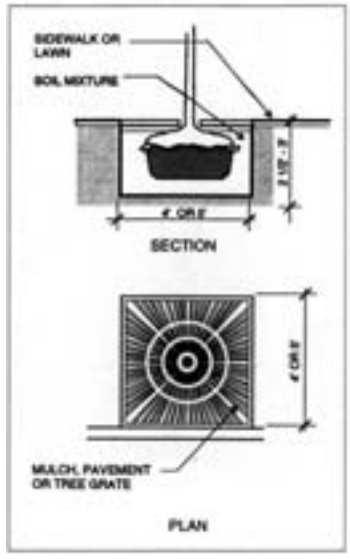


Figure A. Standard tree planting detail. Conventional planting technique showing typical tree pit used for planting street trees containing about fifty cubic feet of prepared soil. This detail is effective in suburban areas where there is good growing soil surrounding the planting pit, but not in most dense urban areas.

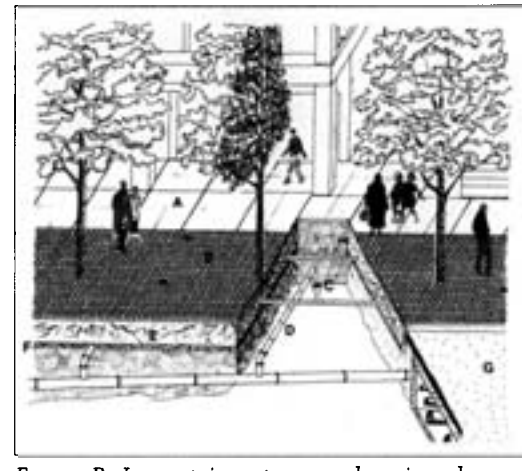


Figure B. Isometric cut-away drawing showing how root space is prepared to grow large street trees on an intensively used site. Street trees planted this way can become part of the urban infrastructure.

- **A.** IMPERVIOUS SIDEWALK PAVEMENT
- **B.** PAVING BLOCK WITH OPEN JOINTS
- **C.** AIR VENT PIPES FOR TREE ROOTS
- **D.** SUBDRAIN PIPES BENEATH ROOT ZONE
- **E.** SPECIAL POROUS SOIL MIXTURE
- **F.** POROUS DRAINAGE LAYER UNDER SOIL
- **G.** ROADWAY PAVEMENT OVER UTILITY TUNNEL

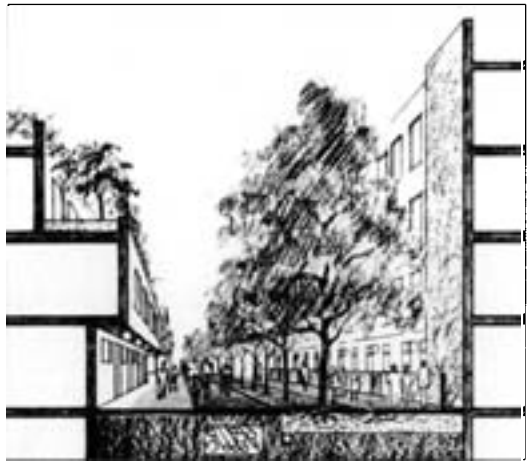


Figure C. Section perspective showing how tree roots can be accommodated on a narrow street retrofitted for pedestrians, bicyclists, and trees. Note large volume of special soil and subsurface drainage.

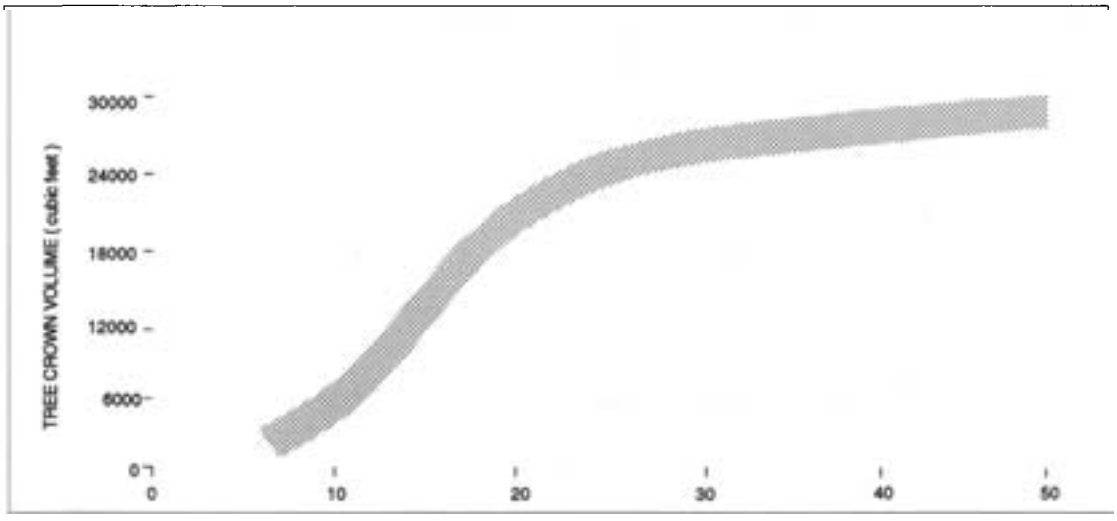
One approach to solving the problem of supporting paving around trees while preserving pore space for the roots is to use a mixture of expanded aggregate and topsoil. Open-jointed paving blocks are then set directly on the compacted soil mixture. Other methods involve supporting the pavement on a layer of coarse aggregate that retains air or bridging the pavement over the planting soil to prevent compaction. Each of these methods has its advantages and limitations and must be designed to meet the constraints of site and budget.

They don't work in the city's hard-core spaces. These unnatural sites require planting methods that are very different from those used on suburban sites. The value of trees, especially in the city, is dependent on their longevity, which depends in turn on how the root space is prepared when the trees are planted. Special soil mixtures are required to maintain porosity to supply roots with essential air. Tree roots need air, but urban trees cannot usually find suitable growing space under the pavement. A medium to large urban tree, with a branch spread of eighteen to twenty feet, needs at least one thousand cubic feet of well-aerated, well-drained soil to survive and be healthy (Bassuk et al. 1991). Unless these special provisions are built into the typical city site when it is planted, there is very little chance that the tree will last long enough to provide significant benefit.

The Effect of Current Tree Planting Practices

Our cultural attitudes and their influence on the way we plant trees help to explain why there are millions of trees planted every year in our cities that will not survive to a beneficial age—that is, they will not grow to be large shade trees. It is not only a result of improper species selection and planting methods, but also a failure to ask questions about our objectives. Are we most concerned with quantity as opposed to size or longevity? One tree that lasts fifty years is worth more than twenty trees that last only ten years. The benefit of an urban tree is directly proportional to its crown size or volume. Therefore, average crown volume multiplied by longevity gives the truest picture of a tree's worth. This is further explained by the accelerated rate of growth of the crown after the first ten years. Considering the economics, wouldn't it be more effective to trade fewer trees that grow large for a larger quantity of trees that last less than ten years? This is not meant to suggest planting trees further apart, a practice that compromises the visual continuity and shade effectiveness of urban trees. Rather, it suggests reallocating resources used to reforest cities so that they will become more effective over time.

It is especially important that the large number of recently established tree planting programs be guided by a long-term approach, recognizing the relationships between the benefits of tree longevity and effective urban tree



Urban tree canopy size measured as cubic feet of crown volume showing estimated size increase with age for a hypothetical urban street tree planted correctly. Crown growth accelerates after the first ten years, later declining as branch spread fills the space. Adapted from Arnold 1993.

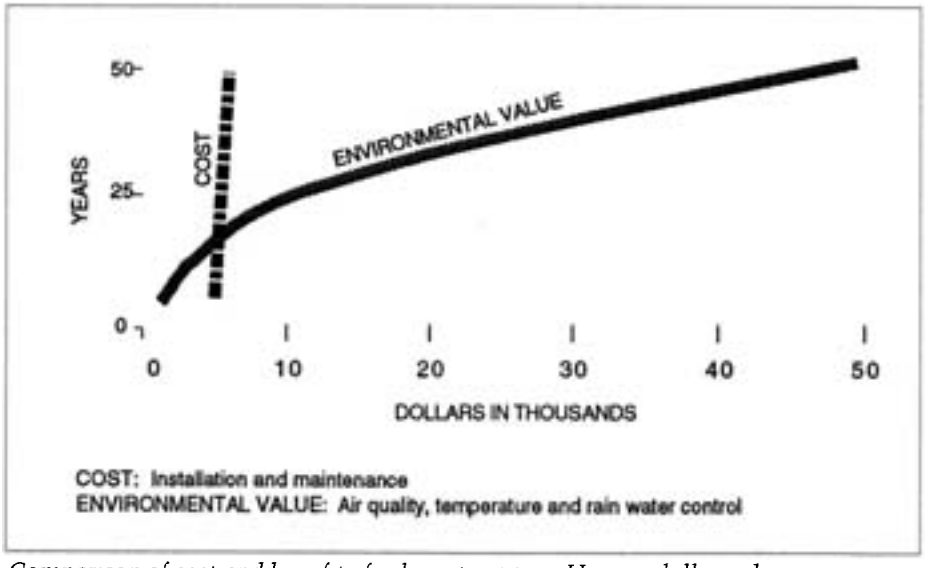
planting methods. Most urban trees are still being planted using outdated installation practices. Unfortunately the success of these planting programs is being measured ten years too soon, that is, before the tree roots outgrow the site. Preparing a difficult city street site for a tree so it will grow for many years requires three things: a specially designed soil mixture, an underdrainage system, and an appropriate ground surface material. The site preparation alone may be three to four times as expensive as a good-sized nursery grown tree. However, the measurable benefits exceed the higher planting cost by a factor of ten (see graph below). A tree costing five thousand dollars to plant would yield fifty thousand dollars in accumulated benefits, using estimated values from a U.S. Forest Service study (Ebenreck 1988). While such estimates are bound to be imprecise, they yield plausible figures without even counting intangible benefits. From this perspective, trees are our most economical urban utilities.

A More Effective Approach

The specialized planting techniques recommended here are not meant to supplant the tree planting methods successful at less cost on less disrupted sites. The new methods have been developed for hard-core urban sites where only trees over four inches in caliper when planted can survive the characteristic abuse (Nowak et al. 1990). Such areas require complete replacement of the existing urban soil with a special growing medium to allow the development of mature trees. Trees planted over structures, in manufactured soil recessed below the pavement, illustrate one such condition.

If more knowledgeable practices for urban trees are widely adopted, the success of city trees will improve dramatically. The three most critical of these practices are:

- The use of special installation techniques where they are required to accommodate tree roots.
- Selecting the tree type on the basis of



Comparison of cost and benefit of urban street tree. Using a dollar value comparison, it will take ten years from the time a five-inch caliper street tree is installed until the cumulative costs equal the cumulative benefits However, the benefits will greatly exceed the costs for the remaining thirty-five years of a fifty-year tree cycle. From Arnold 1993.

Bauhinia trees planted on a rooftop plaza in Singapore near a large shopping complex. Trees are recessed into the structure so that there are no raised planters.

experienced survivability under the specific site conditions in that locality.

- Planting and dealing with trees as urban infrastructure, not as individual specimens.

This discussion deliberately concentrates on planting practices for sustainable urban trees because these issues are still being ignored or overlooked. Other issues such as *maintenance* of trees, many will argue, are just as important. However, these concerns have received much greater attention. The experience of some arborists and landscape architects suggests that incorrect installation of trees on hard-core urban sites is the number one obstacle to making our cities tree-shaded havens (Perry 1982; Urban 1989). Trees that are incorrectly installed so that they last less than ten years are an unfortunate waste of resources. No amount of maintenance can make trees that are planted this way sustainable.

There is an exceptional opportunity to make unimagined changes to cities, conferring benefits that multiply with time. Trees can have a major role in recreating cities that are biologically fit for human enjoyment. It requires installing a whole new utility system consisting of branches and roots and leaves, utilizing sustainable planting methods. The planting sites of central city streets and plazas will challenge our technical ingenuity to reshape the open spaces of the city. Artistry and scientific skill can combine to convert old cities into places of delight and culture, with trees that outlive people. Now may be the moment in history to capture this great opportunity. Making cities livable by installing trees that last will contribute to regional and global sustainability.

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