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CONCEPTUAL AND MANAGEMENT CONSIDERATIONS FOR THE DEVELOPMENT OF URBAN TREE PLANTINGS[1]

by James R. Clark and Roger K. Kjelgren

Abstract. The development of successful urban tree plantings has at least four critical components: 1) expectations and goals appropriate for cities, 2) an analysis of site-specific environmental conditions, 3) selection of taxa responsive to that set of site conditions and 4) a regular program of management. The issues involved that are both conceptual (such as our attitudes towards trees) and technical (such as the size of a planting space or the level of summer irrigation).

Résumé. L'élaboration d'un bon programme de plantation d'arbres urbains repose sur quatre éléments de base: des attentes et des buts adaptés aux villes; une analyse des conditions environnementales du site; la sélection de taxons adaptés aux conditions du site; un programme de gestion régulier. Les aspects impliqués sont l'aspect conceptuel (ex.: attitudes face aux arbres) et l'aspect technique (ex.: la grosseur de la fosse de plantation et le niveau d'irrigation).

High quality plants and plantings are neither impossible to develop nor fundamentally incompatible with the urban environment. But achieving quality plantings in urban areas requires both rigorous conceptual thinking and decision-making and timely management.

Urban Trees are Different

Urban trees require a set of values defined by the potentials and constraints offered by urban areas. Marvin Black, the late city arborist in Seattle, was fond of reminding people that "city trees are not country trees." Urban trees have little in common with forest trees. If our expectations about urban trees are framed by images of a Douglas-fir in a Pacific northwest forest or of a valley oak in the oak woodlands in California, we are bound to be disappointed.

Nor can urban trees be compared to trees growing in a production nurseries. Nursery systems are the complete antithesis of most urban planting systems (Table 1). Nurseries occur in rural areas, with moderate climates relative to cities. Soils are agricultural. Management intensity, reflected in fertilization, irrigation, pruning, pest management, etc. is high. The primary goal of a production nursery is a tangible, living product in a reasonable period of time.

In contrast, street tree plantings occur in urban areas, with greater extremes in climate. Urban soils are highly disturbed. Management intensity is moderate or minimal.

Urban areas also possess an additional, frequently unpredictable factor: an abundance of people. If people are the most careless abusers of trees, they are also the most appreciative users. The continuing interaction of people with trees makes urban areas among the most challenging and rewarding places to manage plants.

Expectations about tree performance must reflect the differences among forest, nursery and urban systems. Thus, urban plantings require their own set of values about ultimate size, rotation length, etc. Expectations for urban plants need not be diminished or lower than for nurseries, simply different.

How do nursery and urban trees differ? Although the nursery and urban plantings share

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many of the same plant taxa, different characters make a plant successful in a each situation (Table 2). The primary plant concerns of a nursery are marketability and production methods (4). For a successful urban tree, the criteria are much more numerous, and include structural, stress/pest tolerance, aesthetic, cultural and management concerns. Simply because a taxon is successful in a production nursery does not mean that it will be as successful as a street or urban tree.

What Is an "Urban Tolerant" Tree?

Identifying taxa that will be successful in urban plantings is on-going challenge. Three aspects of the selection process warrant further review: 1) the unique character of the urban environment and lack of analogous environments in natural settings, 2) the limited observation of the morphological and physiological variation within many tree species, and 3) misuse of the term "urban tolerant".

Do natural settings possess urban character? There are few "natural" plant communities associated with urban areas, and it is difficult to judge if any plant can be truly adapted to the urban environment. One approach to finding taxa adapted to cities has been to identify plant communities which possess characteristics in common with the urban environment. Whether such "natural analogs" truly exist is a matter of debate (23, 29).

While we may never find the "natural analogs" which duplicate human-dominated ones in toto, we should be able to identify characteristics of natural areas similar to urban locations. For example, Steiner (25) identified tolerance of such soil characteristics as poor aeration, moisture deficiency, low fertility and toxic metals to be important to tree survival in urban areas. "Natural analogs" to these conditions might include mine reclamation and abandoned industrial sites.

Other examples of these "analogs" include flood-plains and river bottoms; sites with fine-textured soils similar to those found in many urban situations. Early succession pioneer species, those that invade old fields, must survive hot, dry conditions in nature and should do so in urban areas as well. To paraphrase Frank Sanatamour of the National Arboretum..."only tough trees can survive these difficult natural locations, and they should make good city trees."

Variation in growth and development. One approach to identifying "tough" trees takes advantage of natural variation within species. Many popular urban trees have tremendous natural ranges, spanning a diverse set of environmental conditions. Material from extremes within the natural range could be more suitable for use in cities. Ware (27) noted that *Acer saccharum* is quite variable in its performance as an urban tree,

Table 1. Relative characteristics of shade tree nurseries and urban plantings.

	Nursery	*Urban planting*
Geographic location	rural	urban
Product	tree	?
Rotation length (yr.)	2-6	25-75
Physical environment		
radiant energy	high	variable
evaporative demand	moderate	moderate-high
atmospheric contaminants	unknown	moderate-high
soil	agricultural	disturbed
Intensity of culture		
pruning	annual	3-10yr. cycle
fertilization	high	low
irrigation	high	low
pest management	high	low-moderate

Table 2. Qualities important in selecting trees for use in nursery production and urban areas.

Nursery	responsive to intense culture
	marketability
	ease of propagation
	ease of transplanting
Urban area	responsive to minimal culture
	regular, well-configured, upright form
	strong compartmentalizer
	stress tolerant
	pest tolerant
	deep, but not invasive, root system
	ornamental
	unresponsive to artificial lights
	minimal litter
	solar-friendly
	easy to transplant
	readily available

and cited significant variation among ecotypes. He wondered if variable success of this species as an urban tree was related to the ecotype used. Barker (*personal communication*) observed that many eastern hardwood species have drought-tolerant counterparts in the great plains region. See Gerhold (11) for additional examples of how natural genetic variation might be incorporated into selection of taxa for urban areas.

What is "urban tolerant"? If the urban environment is different from rural/forest locations, how can we describe a taxon as "urban tolerant" without rigorous evaluation of its performance in urban settings? Given the contrast between rural and urban environments, how can we make assessment of "urban tolerance" in nursery and/or arboretum settings? Neither a plant's adaptability to urban conditions nor its acclimatability may be expressed in such benign environments. This difficult aspect of plant evaluation was examined in a thoughtful and comprehensive manner by Gerhold and Sacksteder (12).

For example, Karnosky (16) questioned the development of ranking of plants in terms of air pollution tolerance. He observed that species responses to acute exposures in chambers were not always the same as responses to chronic exposures in the field.

Another aspect of defining "urban tolerance" lies in separating simple cultural requirements from more complex plant-environment interactions. The failure of a site to supply one or two critical components of a plant's cultural regime may limit its ability to grow, and obscure or mask the plant's overall utility in urban areas. Supplying those one or two critical cultural requirements might allow a plant to develop, even under urban conditions.

Sugar maple may be an excellent example of this potential problem. At one time, the species was a widely planted urban tree. Yet, its performance in many urban areas has been variable and/or poor, for reasons including salt injury, compacted soils and nutrient deficiency (8). In recent years, the species has been considered "urban intolerant".

Sugar maple's ability to perform well in urban areas may have less to do with "urban tolerance" than with an adaptation to well-drained soils and intolerance for salt. There are few plantings of this species in Seattle, but each is uniformly successful. In Freeway Park, built over a downtown freeway, sugar maple has out-performed red and Norway maple. We attribute the success of sugar maple in this site to the lack of salt application and well-drained, sandy soils. Although this defined set of environmental conditions may be uncommon in many cities, sugar maple could be a very useful tree for such sites.

Are a regions native species better adapted to its urban area than exotics? There is no reason to assume that trees native to a locality are somehow inherently superior to exotic or non-native species for use in cities. We know of no evidence to support this (frequently made) assertion. Both the physical environment and the management systems associated with urban areas are so different from natural conditions, even within a given geographic locale, that no logical jump from forest to urban site seems possible. As Peterson and Eckstein (23) observed, "Although towns in Europe are located within natural forest regions, trees from these forests have not adapted to the harsh environmental conditions of the city."

Characterizing Space in Urban Areas

Urban areas are composed of diverse, disjointed spaces, each of which may possess dramatically different environmental conditions. No set of terms describes the character of these relatively small spaces. We may not even know the characters which are important to use in separating one type of space from another.

Arborists, urban foresters, landscape architects, and their professional relatives have traditionally been concerned with the character of a "planting space". Yet, this term describes *neither a geographic area nor a land-use context*, and has no basis in either meteorology or landscape ecology. We need a taxonomy or a typology to designate a space's character.

One way of describing fragmented spaces would be to do so in terms of land- or site-use. Moll (20) used this approach on a relatively large geographic scale. He defined four zones: suburban fringe, surburbs, industrial and city center. Variation in environmental character was not evaluated.

Federer (9) defined urban space on the basis of the amount of paved surface and the presence of tall buildings in a area. His terms, plaza, park and canyon, described three unique environments. A plaza is extensively paved with few buildings to intercept solar radiation. The park also receives direct solar radiation, but does not have the extensive paving. An urban canyon is both heavily paved and surrounded by tall buildings.

Only when a well-developed way of describing small spaces is available will we be able to analyze variations in growth of urban trees in a systematic manner. For example, we have used Federer's description of park, plaza and canyon to characterize the physical environment of small urban spaces, as well as the response of sweetgum *(Liquidambar styraciflua)* planted in each (18). The variable growth of even-aged sweetgums must be related to the character of these spaces (Table 3).

Table 3. Relative performance of *Liquidambar styraciflua* in 3 urban spaces in Seattle WA.

Urban space	*N*	*Year planted*	*Height (m)*	*Diameter (cm)*
Park	10	1975	7.5±0.7[1]	13.5±2.2
Plaza	12	1976	5.2±1.0	9.4±1.0
Canyon	11	1975	7.6±0.6	13.2±1.0

[1]Site average and standard error of mean. Data taken from Kjelgren (18).

Site Analysis for Urban Plantings

Understanding the character of a "planting space" is integral to the survival and growth of trees planted therein. The nature of the planting space (i.e. physical environment, growing space above- and below-ground) plays a major role in determining tree performance. A thorough site analysis will define a site's character.

At least five items require consideration in a site analysis: 1) radiant energy load and pattern, 2) site water balance, 3) soil, 4) atmospheric contaminants, and 5) physical space available for growth.

Radiation load. Among park, plaza and canyon, the contrast in the amount of radiant energy received is striking (Figure 1). The amount of potential radiation received on a street is defined by: street aspect (ex. north-south vs. east-west), planting location (side of street), height and number of buildings (i.e. the degree of blockage across the sun's path), street width, and building setback (15). The urban canyon generally receives only a fraction of the total radiation found at a plaza, perhaps only 4-6 hours of direct sun per day (18, 28). The effect of various combinations of these factors on potential photosynthesis revealed that canyon conditions could significantly reduce the rate of carbon fixation (21).

Site water balance. The demand for water by trees on a site is influenced by a site's openness and exposure, the nature and extent of surface covering, windspeed, and the degree of canopy closure. A large parking lot, with few trees, asphalt pavement and an open, windy exposure will have a greater evaporative demand than a park that is buffered from wind and exposure by a continuous tree and turf canopy (Figure 2).

While the demand for water at a site can be assessed, information about the supply of water to urban trees is more difficult to obtain. How a soil replaces water lost through evapotranspiration is an open question. Surface recharge through

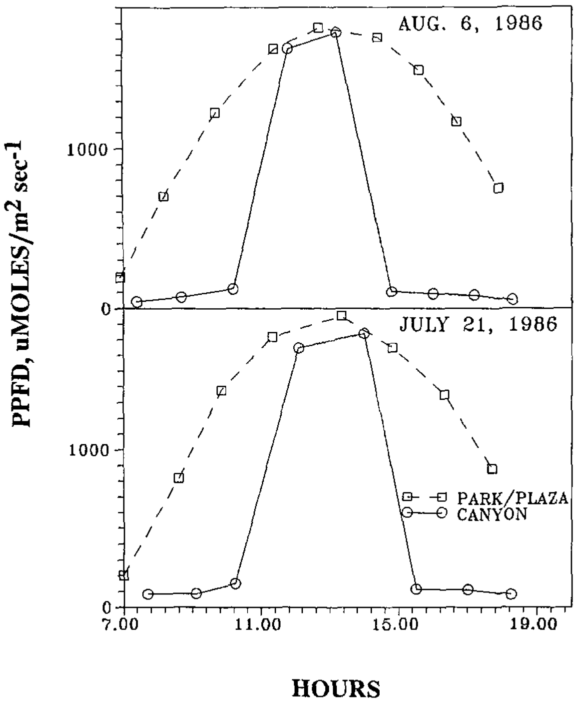

Figure 1. Diurnal pattern of photosynthetic photon flux density (PPFD) at plaza, canyon and park sites.

precipitation during the growing season is unlikely. Precipitation is removed as run-off and is probably not available to street trees. Sub-surface recharge through groundwater flow and losses from mains and pipes may occur, but probably varies from site to site in intensity. Movement of volumes of water as vapor may occur, especially where pavements induce diurnal variations in temperature.

Any site information about the depth to the seasonal water table would be a valuable part of the site analysis, and will offer insight into the size of the water supply.

Soil. The importance of soil factors in the success of urban trees has been well-documented by Craul (5) and Patterson *et al.* (22). We want to emphasize the value of a soil test, which assesses both physical and chemical components, as part of site analysis. Information on soil pH, nutrient availability, soil texture, organic matter, depth, porosity, bulk density, etc. is invaluable in both the planning and management of a planting of urban trees. Results of a soil test will permit informed decisions about both species selection and long-term management.

Salt used to remove ice and snow may be considered the critical soil contaminant for urban tree managers. Its effects are both acute and chronic; it accumulates in both plant tissue and the soil. Soil tests for sodium and chloride, as well as an evaluation of typical use patterns, will reveal the importance of salt as a contaminant.

Atmospheric contaminants. The patterns of urban dusts, particulates and gaseous materials are not uniform across a city. The importance of each in a particular site must be evaluated.

Urban trees serve to remove dusts and particulates from the atmosphere. These materials are deposited directly on foliage and are removed when the foliage drops. The accumulation of particulates on foliage may reduce photosynthesis, alter tissue chemistry or plug stomata (26). Where seasonal precipitation does not remove these materials, the seasonal impact of deposition may be significant. The overall problem of particulate deposition may be especially important on evergreen trees, both angiosperm and gymnosperms, which retain foliage for extended periods of time.

Exposure to gaseous pollutants may occur as either short-term, high concentration (acute) or long-term, low concentration (chronic) episodes. There appear to be signifcant differences in tolerance to gaseous pollutants both among and within species (see summary by 3).

Physical space. Two of the most important management problems facing urban foresters today deal with physical space: root damage to sidewalks and conflicts between tree crowns and utility lines. Minimizing or avoiding these problems can be achieved by a combination of site analysis, plant selection and use of management techniques such as root barriers.

An adequate site analysis will evaluate the potential for conflict between trees and either overhead wire or pavement to develop. Unfortunately, it is far easier to define the space aboveground than below. Height to utility lines, building set-backs, curb space, planter width, etc. are all easily measured.

Defining the amount of space below-ground is far more complex. Part of the difficulty lies in understanding how much root space is required for a given size crown (see 19 for a discussion of this problem by several authors). Rakow (24) summarized a series of recommended planter sizes for above-ground containers.

Solutions for adequate below-ground space have both biological and design components. The

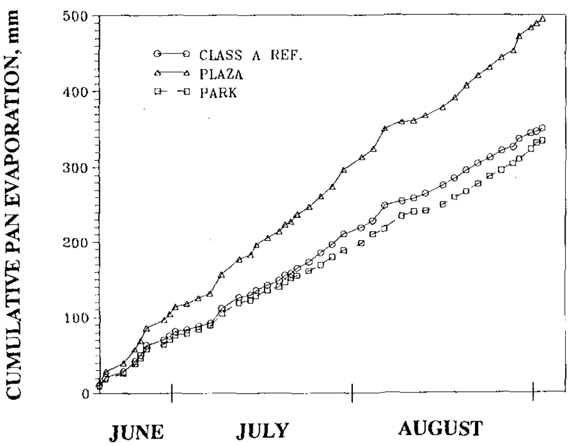

Figure 2. Cumulative evaporation for park and plaza sites, and for a USDA Class I reference pan at the Center for Urban Horticulture. Evaporation at the canyon was similar to that of the park and Urban Horticulture sites.

team of Tom Perry and Jim Urban have addressed the issue by developing root space volumes for a variety of crown sizes. They recommend 300 cu. ft. of rooting volume per tree (with a recommended depth of 3 ft.) as a minimum standard. Another landscape architect, Henry Arnold, has taken a similar approach. While design recommendations from these two groups may differ in specific details, they both clearly point out the need for much larger below-ground spaces.

Guidelines for Selecting Urban Trees

For any plant selection, we must evaluate if the existing cultural and environmental conditions meet the requirements of a given plant. If not, that taxon should be avoided. Another aspect of this process relates to our expectations about urban trees: our expectations must reflect the available cultural and environmental conditions. As an example, it is inappropriate to expect vigorous flowering behavior from trees planted in shady urban canyons. The environmental conditions required for flowering are too limiting.

The following are general guidelines for selection of taxa for urban plantings:

1. As guidelines for identifying "urban tolerant" taxa, two comprehensive summaries are Gerhold *et al.* (13) and Berrang and Karnosky (3).
2. For urban canyons, select shade tolerant taxa. Generally, early successional species are less shade tolerant than late successional species. Silvicultural lists of "tolerance" are a good starting point for selection (see 1), but should not be considered a final answer.

It is not known if clonal selections of shade tolerant species, selected in high radiation situations (i.e. nurseries and arboreta), retain the shade tolerance character of the species? For example, red maple *(Acer rubrum)* is a shade tolerant species, but we are not aware of any evidence demonstrating that clonal selections of this species, such as 'Red Sunset' and 'Armstrong" are shade tolerant.

3. For urban plazas, select taxa tolerant of hot, dry, windy conditions. This situation might favor early successional species over late successional types, but we know of no analysis of this possibility. Evergreen material native to hot, dry, exposed locations might also be considered possible choices. Where possible, select plants from the hottest, driest portion of the natural range of the species.
4. As guidelines for identifying air pollution tolerant taxa use Berrang and Karnosky (3) and Davis and Gerhold (6). Both are based upon field observations. See Dirr (7) as an excellent starting point for ranking of salt tolerance.
5. For sites with disturbed soils, select taxa tolerant of poor, wet and/or flooded soils. Urban foresters have been doing this for some time, as evidenced by the tolerance of a number of popular street tree taxa to these conditions (Table 4).
6. In consideration of future management, select material with well-developed, regular crowns and resistance to pests. Taxa with inherently poor branching structure, such as *Pyrus calleryana* 'Bradford" and *Fraxinus oxycarpa* 'Flame' and/or predictable pest problems should be avoided.
7. Select taxa appropriately-sized for the space available.

Future selection criteria might include deep-rooted behavior and/or fruitless behaviors, as suggested by Barker (2) for *Liquidambar* and other species.

Guidelines for Long-term Management

The importance of carefully scheduled management, especially early in the life cycle of the plantings cannot be overemphasized. Maintaining

Table 4. Relative tolerance of 12 popular urban tree species to poor and flooded soils.

Species	*Relative tolerance to:*	
	Flooded soils	*Poor soils*
Acer platanoides	moderate	?
Acer rubrum	high	high
Acer saccharinum	high	?
Acer saccharum	low	low
Fraxinus pennsylvanica	moderate	high
Gleditsia triacanthos	high	moderate
Liquidambar styraciflua	high	moderate
Quercus palustris	high	high
Quercus rubra	moderate	moderate
Pyrus calleryana	moderate	moderate
Tilia cordata	moderate	moderate
Ulmus americana	high	high

Sources: Fowells (10), Harris (14), Kielbaso et al. (17)

vigor will aid in reducing pest problems and add to overall tolerance to environmental stress. Several critical considerations are:

1. Proper planting, especially depth and removal of twine, burlap, etc.;
2. Removal of stakes and associated wires after 1 or 2 years;
3. Early structural pruning of crown, to develop well-spaced, configured branches;
4. Supplemental irrigation during the first two years after planting (in Seattle, 80% of unirrigated street trees die within 2-years, with irrigation, losses are only 5%);
5. Supplemental fertilization, at planting or several years after planting, as determined by soil test;
6. Elimination or minimal early competition with turfgrass;
7. Regular program of pest management.

A planting that has received timely attention early in its life-span especially when complemented with appropriate plant selection, has a far better chance for long-term success.

Summary

That urban plantings are different from forests or production nurseries is not suprising. That urban plantings require a different and unique set of attitudes and management considerations is also not surprising. What is surprising is that urban foresters have not developed a clearer set of guidelines and rules for distinguishing between the needs of urban plantings and those of either forest or nurseries trees.

High quality plantings of trees in urban areas—those with excellent form and vigor—result from a unique combination of factors. Quality results when realistic expectations are combined with rigorous site analysis, appropriate plant selection and routine aftercare. The failure to provide any of these components will result in the failure of the planting. Each is an integral, central factor in success.

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CURRENT ISSUES/FUTURE PROJECTIONS[1]

by Robert Felix

Abstract. In the United States there are significant regulatory and environmental issues confronting arboriculture. NAA is working to resolve the regulatory issue with OSHA. NAA and ISA are working together to resolve the environmental issue by developing a marketing and operational strategy for Integrated Pest Management. Other issues with world wide implications are the availability of field personnel, certification, urban forestry support and the tree care industry's professional image.

Résumé. Aux Etats-Unis, l'arboriculture fait face à des problèmes réglementaires et environnementaux. NAA travaille à résoudre les problèmes réglementaires avec OSHA. NAA et ISA travaillent ensemble pour résoudre les problèmes environnementaux en développant les stratégies de marketing et opérationnelles pour la gestion intégrée des pesticides. D'autres problèmes tels la disponibilité du personnel de terrain, la certification, le support en foresterie urbaine et l'image professionnelle de l'industrie d'entretien d'arbres sont d'ampleur mondiale.

For most people, current issues are today's problems and future projections are what we daydream about. There is nothing wrong with that, as far as it goes, but one's own perspective limits the scope. For an industry, current issues and future projections are a prioritized list of everyone's current problems and day dreams. The tree care industry has its fair share of current issues that I am concerned about. Those issues have considerable impact on future projections. This is true of both the technical side of tree care and the operational or management side. I will leave the technical side of tree care to the scientists and speak to the issues that I see on the management side only.

The prioritizing of issues, for my purposes, needs to be even further refined as each of the disciplines in our industry, commercial, municipal and utility, has its own agenda. Sometimes these issues overlap as is the case with a major issue that is currently before us.

1. Presented at the annual conference of the International Society of Arboriculture in St. Charles, Illinois in August of 1989.