OPTIMUM STOCKING OF URBAN TREES

by Norman A Richards

Abstract. Promotions of urban tree planting tend to ignore the broader tree management concept that optimum stocking usually is not the maximum possible, but rather, depends on site-specific benefits and costs of trees in relation to the greenspace resources that can support growth. Based primarily on observations in Syracuse, NY, this paper discusses adaptation of forestry concepts of stocking to three general categories of urban tree conditions: urban woods, where forest stocking concepts are directly applicable; urban savanna and street tree strips, the largest area component in most communities; and trees in paving, where stocking depends on adequate quality spaces.

Assuming that the general purpose of trees in urban areas is to enhance the overall environmental quality of places where most people live and work, the values of urban trees must be linked to the total complex of features, values and activities in these areas. This "urban ecosystem" view tends to be ignored in many current efforts to promote more tree planting. Major problems of urban priorities — tree budgets competing with schools, streets and garbage, as well as significant liabilities of urban trees countering some of their values— makes it essential to develop clearer guidelines for optimum stocking of urban trees rather than pushing for maximum number of trees possible.

Forest Stocking and "Urban Forests"

In forest terminology, there is an important distinction between tree density and stocking in forest stands. Density is the objective description of tree biomass in an area by tree numbers, basal area, canopy cover, etc. Stocking involves value judgement; it is a relative term used to describe the adequacy of a given stand density in meeting management objectives. In managed forests, "adequate" or "full" stocking is identified as a range of stocking rather than the maximum level, and optimum stocking for many objectives is commonly less than maximum possible. This general concept appears applicable to urban trees. However, management objectives for urban tree populations usually are much more diverse and diffuse than those of forest stands; so we must go beyond "urban trees" as a generality to consider this further.

The now-popular term "urban forest" has political value to emphasize the tree resources in urban areas, but is confusing as a technical or management term because it conflicts with standard definitions of forests (1). By various definitions, forests are generally characterized or dominated by trees, whereas urban areas are characterized by density of people and structures, with trees hopefully complementing these. While there are often forest patches within urban areas, it is useful to distinguish forest stand conditions from those of most urban areas:

Forest Stands: Trees are the dominant feature: tree/tree interactions are a controlling factor; and there are functional forest soil and forest understory vegetation systems present.

Urban Tree Canopy: In general, trees and built features are interspersed; there are less tree/tree interactions and more tree/structure interactions; and both soils and understory vegetation are highly modified.

But perhaps a more serious criticism of "urban forest" as a technical term is that, like the term "tropical forest," it encourages monolithic views of diverse ecosystems when we need to be considering the range of conditions in such areas. A good model for this is provided by Oke (2) in his review of urban microclimate literature, where he uses "urban forest" as an umbrella term to identify the subject area but quickly moves to subcategories of urban conditions to consider specifics. For the most part, recent research on urban tree effects has been careful to identify the conditions studied, whereas popular interpretations tend to generalize too much.

For considering tree stocking, we can simplistically split urban tree conditions into three categories according to the degree of divergence from forest conditions:

Urban woods and groves. These approach forest stand conditions, with tree/tree interactions usually dominant.

Urban "savanna" and streetside tree strips. Savanna has trees interspersed with lawn and other non-tree vegetation as well as paving and buildings. Here there are varying degrees of tree/tree, tree/lawn, and tree/structure interactions; with soils modified but usually not the main limitation to trees. In street tree strips, tree/tree interactions are common with older trees; interactions with paving and structures tend to be limiting; and soils are greatly modified and often limiting.

Trees in paving. Here, tree/tree interactions usually are very limited; paving and structure interactions controlling; and soils usually severely limited.

The broad category of savanna and street tree strips encompasses most of the urban area, at least in the USA and Canada, whereas the polar categories of urban woodland and trees in paving usually involve less area.

Stocking and Urban Tree Values

Because stocking is a value judgement, it must be considered in the light of various values of urban trees over the range of conditions categorized above. Throughout the urban range, tree stocking is controlled by two general factors: the quantity and quality of greenspace or growing space, and the pressures on this space from non-tree uses and values. In urban woods, tree mass tends to be more important than individual trees for most environmental values; and is usually controlled by natural site conditions as well as various use impacts. In savanna and street tree conditions, both tree mass and individuals may be important; and there is usually significant greenspace that can support trees, but non-tree values tend to hold tree cover below its potential maximum. For trees in paving, individuals are important; tree numbers and size are usually less than desired, and strongly controlled by conditions of the growing spaces provided. In downtown Syracuse, it is evident that soils and street microclimate interact in controlling growing conditions for trees. Better soil conditions are required in locales of stressed microclimate, and also grouping of trees for tree/tree microclimate interactions is helpful.

Interpreting literature on various environmental values of urban trees in relation to the range of urban conditions (Table 1), the greatest variety of positive values is likely to accrue from conditions approaching woods, because the greenspace and

Table 1. Urban values over the range of urban conditions. The (±) indicate that values may be positive or negative depending on site-specific conditions.

Visual values
- *Urban woods.* Tree mass generally more important than individuals
- *Savanna and street trees.* Tree mass and individual size and form important.
- *Trees in paving.* Individual trees most important. Tree numbers and size usually less than desired.

Urban tree effects on microclimate
- *Urban woods.* Forest stand microclimate, depending on area and density. Moderated temperatures, reduced winds, and higher relative humidity (mostly +)
- *Savanna and street trees.* Shading (±), reduced windspeed (±), some increased relative humidity (±).
- *Trees in paving.* Shading surfaces (mostly+), reduced windspeed, possible turbulence (±).

Tree effects on urban mesoclimate
- *Urban woods.* Can be significant depending of area coverage.
- *Savanna and street trees.* Can be significant in total.
- *Trees in paving.* Probably minor effect in most cases.

Air quality values
- *Urban woods.* Can be significant pollutant trap and sink.
- *Savanna and street trees.* Pollutant trap role depends on canopy mass (±). Sink function depends of greenspace area and conditions.
- *Trees in paving.* Pollutant trapping very limited (±). Sink is largely storm runoff and streetcleaning rather than greenspace.

Watershed values
- *Urban woods.* High interception and evapo-transpiration depending on canopy cover. High infiltration depending on soils and surface.
- *Savanna and street trees.* Interception and evapotranspiration depends on canopy cover, Infiltration and storage usually reduced.
- *Trees in paving.* Interception, evapo-transpiration, infiltration and storage all usually very limited.

trees can have most impact here while uses of these areas are less likely to encounter negative effects of trees. Conversely, realistic environmental values of isolated trees in paving are quite limited, but even small benefits from appropriately sited trees can be valuable to soften the structure domination of these areas. For the savanna and street tree range between these, the extent of positive and negative values of trees depends largely on site-specific factors. These factors involve both greenspace and tree qualities, including location, as well as the interspersed non-greenspace features and activities. Problems of locating trees for shade versus solar access, windbreaks versus ventilation, and so on, are now widely documented. Almost as a truism, the better the greenspace resources available for trees, the easier it is to provide more positive and less negative effects of urban trees.

Stocking Concepts of Urban Trees

The concept of stocking as concerned with the adequacy of a given tree density requires a benchmark density setting 100% stocking for comparison. In humid regions, where light more then moisture is usually considered the primary constraint to forest stand density, 100% stocking is set at complete closure of the tree canopy. This is a sliding scale in relation to tree size; many small trees or few large trees per acre can equal 100% stocking, although these are not equivalent in many other respects. For woodlands in water-limited areas, less canopy coverage should be identified as 100% stocking.

In forest stands, a range of stocking from about 60 to 100% is widely accepted as "full stocking" in the sense that total stand production changes little over this range as increased growth of individuals compensates for fewer trees: and it also appears that most environmental values of "full stocking" are maintained. Within this range, resources for understory growth of tree regeneration are severely restricted by the overstory trees. Conversely, below about 50% stocking, the stand is "understocked" in the sense that overstory tree production and their environmental values are directly related to the amount of remaining overstory, while potential for new tree regeneration tends to be inversely related to this. Around the 50% range, site-specific factors figure strongly in evaluation of stocking.

This forestry model of stocking seems fully applicable to urban woodlands where tree mass is more important than individuals, and the sliding scale of reduced tree numbers with increased size can result from either natural or artificial thinning. Adapting this concept to urban savanna and street trees is more complicated, The amount of greenspace in an area only roughly indicates the biotic potential for tree stocking because tree canopies grow over paving and structures, and tree roots are so plastic that soil qualities other than area largely determine the tree mass that can be supported. Consequently, urban trees frequently have greater tree canopy area than the greenspace area under them. However, use constraints from both adjacent structures and non-tree values of greenspace more commonly hold tree canopy areas to less than the site potential. Therefore, the 100% stocking benchmark for these areas should reflect both their site and use constraints. These are so site-specific that few generalities can be made, but 100% stocking can be defined fairly easily on any particular site where the location factors are specifically identified.

In residential yards in Syracuse, we have observed generally implicit use of the concept of stocking as a sliding scale of tree numbers over size(4). In this city where natural tree regeneration as well as private planting of small trees is common, we have found residents accepting or maintaining fairly large numbers of small trees in many yards, but these are typically thinned to few large trees as they increasingly conflict with non-tree values.

One type of situation where a general concept of a stocking guideline is expressed is in city residential areas with lots typically 40 to 60 feet wide, where many communities have adopted at least an informal standard of one street tree per lot front representing 100% stocking. In these areas, the forestry concept of a "full stocking" range appears applicable. Street trees at this spacing are clearly "understocked" when young, and any losses "beg for replacement." It is excessive loss of young trees more than of mature trees that stresses many tree replacement programs (3). Street trees approach optimum stocking as they grow, and if most survive to large size, they can become somewhat "overstocked" in relation to adjacent activities and values. As large trees, dispersed loss of up to about one-third of the original trees still leaves streetsides fully stocked in respect to most tree values, and it is generally impractical to replace trees in individual gaps in these cases. But when losses reach two out of three trees and leave larger gaps, an understocked condition is likely to be recognized in declining tree values, so there is both recognized need and adequate space for planting replacements. Again, in the middle range around 50% stocking, site-specific judgements must determine stocking adequacy.

For trees in paving, 100% stocking is logically set at the number of suitable tree spaces that have been provided; assuming that the spaces are based on some consideration of tree benefits and costs in the specific location. Where single-tree planting pits contain small trees, any losses "beg for replacement." However, in Syracuse and elsewhere it has been observed that there is merit to grouping trees in larger, multiple-tree planting spaces — in mini-groves or "bosquets" in landscape terms — where developing tree/tree interactions can be beneficial to the trees as well as to environmental values they produce. In these groups, some loss of trees as they grow large is not only acceptable but may be desirable to hold stocking in the optimal range. Also, where groups of individual tree planters are designed well enough to permit growing to reasonable size and age, some loss among older trees may be acceptable — within the full-stocking range — as the empty spaces are planted to other vegetation or converted to other uses rather than replanted to trees. By the time good tree planter groups become obviously understocked, it may be time to renovate the entire streetscape. In downtown Syracuse, for example, I believe a reasonable goal for trees in paving is a "half-life" (50% survival) of at least 15 to 20 years, which approaches the cycle of streetscape renovation. We know enough about tree requirements in Syracuse at least so that, in my opinion, lower standards would suggest poor practices.

Recommendations

These proposed concepts of urban tree stocking, based primarily of observations in Syracuse, are still skeletal and need further development through consideration in other urban contexts. They especially need to be tested for application in water-limited areas where significant conservation questions are raised in using water to grow urban trees. The primary intended message of this paper is that working concepts of adequate or "full" stocking need to be developed in lieu of current promotions toward maximum stocking of urban trees.

Promoting more urban tree planting as a goal in itself is a short-term view that has frequently resulted in failures and resource waste. The more effective long-term approach to increasing benefits from urban trees is to provide more or better growing spaces where it is easier to increase the positive values, and reduce the negatives, of urban trees. My recommended primary actions for this are not new, but too often are ignored. In Syracuse, for example, there probably has been some net loss of greenspace available for trees since our mapping of the city's greenspace gradient based on 1972 aerial photos (Fig 1).

For greater benefits from urban woods, we need to preserve and establish more woodland blocks in areas of urban expansion as well as existing urban areas. While most of the USA shows progress in preserving wetlands and unique natural areas, there are fewer means for preserving ordinary healthy woodlands that may well have as great environmental values in urban areas in the long run.

In the urban savanna and street tree range, most communities probably have some requirements for minimum greenspace on lots and streetsides, but these tend to be eroded away with time. In urban renewal efforts, there is often missed opportunity to recreate adequate greenspace areas to make it easier to grow more tree cover. In downtown Syracuse, for example, the prevailing view is that renewal land is too valuable to leave in more greenspace; a short-sighted view that appears to extend beyond that city.

In residential areas already having reasonable greenspace, popular emphasis on lawns may be a significant constraint to greater tree cover. Our study of residential lots in Syracuse found that,

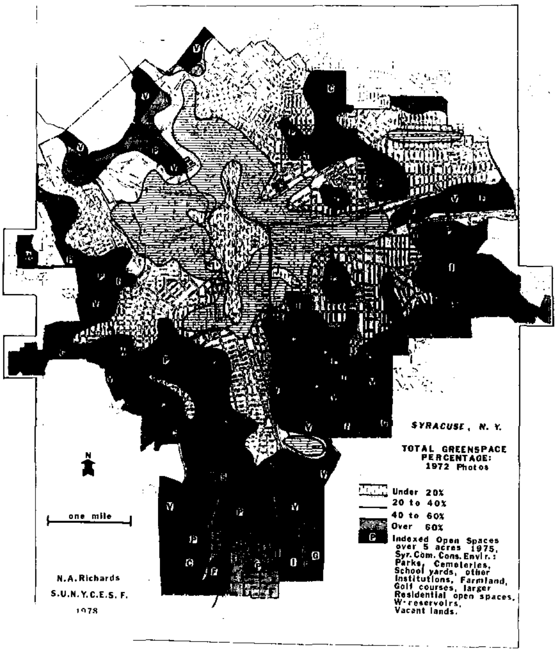

Figure 1. Greenspace distrbution in Syracuse, NY. Based on interpretations of 1972 aerial photos. Most urban woods are in the outer city areas with over 60% greenspace; most trees in paving are in areas with less than 40% greenspace. The city was estimated to total about 58% greenspace, but has probably had some net loss of greenspace since then.

beyond a minimal lot size, increased lot greenspace primarily translates to increased lawn area, and not a significant increase in proportion of tree cover. With wider recognition that a mowed lawn is not ideal for many environmental benefits of greenspace, there may be opportunities to encourage replacing lawn with tree cover — resulting in soil surfaces closer to woods conditions — wherever lawns do not have specific values, such as for views or recreational turf. This suggestion may not set well with some integrated tree and lawn care specialists, but it appears that, for several environmental reasons, the heyday of extensive lawns and profitable lawncare may soon be passing.

For trees in paving, the arboricultural industry should join progressive landscape architects and urban foresters in insisting that new and rebuilt tree planting spaces be designed and planted for reasonable goals of tree longevity reflecting local experience. Especially, there should be more emphasis on larger areas for multiple tree plantings to permit more tree/tree interactions, both for the benefit of the trees and to increase environmental benefits from them. Communities would certainly gain in the long run if arboricultural practice in urban areas can shift to less frequent tree replacement and more long-term care of growing trees.

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Professor in Silviculture
Faculty of Forestry, SUNY
College of Environmental Science and Forestry
Syracuse, NY 13210

Résumé. Les programmes de plantation d'arbres urbains ont tendance à ignorer le large concept de gestion l'arbre qui relate que la distribution (stocking) optimum n'est généralement pas le maximum possible, mais, plutôt, qu'elle dépend des avantages du site spécifique et des coûts des arbres en relation avec les ressources de l'espace vert pouvant supporter la croissance. Basé essentiellement sur des observations à Syracuse, dans l'état de New York, cet article présente des concepts pour un exercice plus large quant à l'adaptation des concepts forestiers de distribution envers trois catégories générales de conditions pour les arbres en milieu urbanisé: les boisés urbains, où les concepts de distribution forestière sont directement applicables; les savanes urbaines les alignements d'arbres de rues, les composantes territoriales majeures de la plupart des communautés; et les arbres dans les trottoirs, où la distribution est dépendante d'une qualité adéquate des espaces.