MODELING SURVIVAL AND CONSEQUENT REPLACEMENT NEEDS IN A STREET TREE POPULATION[1]

by Norman A. Richards

Abstract. The limitations of basing street tree replacement rates on the rate of recent tree removals are examined, using recent inventory data from Syracuse, New York. Survival models from available information on the city's four major street tree species show that survival of recently planted trees dominates the rate of replacement needed to maintain the population, whereas the longevity of older trees has much less effect. Similarly, good care of developing young trees will reduce replacement needs more than will maintenance to prolong the life of older trees.

The separation of time and operations between planting street trees and their removal makes it difficult to relate planting practices to survival and consequent replacement needs to maintain a street tree population. How valid is the common practice of basing a tree replacement program on the rate of recent tree removals? This paper explores relationships between a street tree population and tree replacement needs, using data from a recent inventory of streetside space and street trees in Syracuse, New York.

What Population is to be Replaced?

Syracuse is a mature city of about 180,000 population, with 400 miles of public streets over its 16,500 acres. In 1951, at the start of the Dutch elm disease here, Syracuse had about 47,000 street trees; 42% native elms, 20% Norway maple, 16% silver maple, and 11% sugar maple. After loss of most elms and typical mortality among other species, an accelerated tree planting program began in 1968 to replace the losses.

A 100% inventory in 1978 found 39,030 public street trees; about 18,000 estimated to predate 1951 (Richards and Stevens, 1979). The tree population is unevenly distributed along streets. Trees have often been planted too close together and also in spaces unsatisfactory for their growth, while suitable spaces elsewhere are treeless. Comparing spatial distribution to street trees in 1978 with streetside space conditions showed that the present numbers could appropriately fill the space resources, if they were well distributed with one tree per suitable lot front of 40-50 feet. In physical terms, the logical goal of tree replacement in Syracuse should be to redistribute the population at about its present level, rather than to rebuilt it to the 1951 level.

Determining Loss Rates

It is useful to differentiate three general types of losses in a street tree population:

A. Establishment-related losses: those unique to young trees before they are established enough to resist or survive minor accidents, vandalism, etc.
B. Relatively age-independent losses that might occur at any time due to serious insect or disease attacks, major accidents, gas leaks, street construction, etc.
C. Senescence-related losses; those associated with aging, often precipitated by adverse environmental conditions.

With good data on tree losses over time, an accurate model of population life expectancy could be made. However, the available data in Syracuse is inadequate. City records do not provide an accurate estimate of Type A or establishment losses for two reasons: First, many street trees in Syracuse are planted unofficially by adjacent landowners. Comparing the present population of younger trees with recent City planting records, it appears that about 35% of recent street trees have been privately planted and thus are not in the City records. Secondly, most small trees that die are simply broken off, or cut down by residents, so do not appear in City removal records.

City tree removal records also lack age data, as

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could be obtained with sufficient accuracy from stump ring counts. Therefore the rates of Types B and C losses can only be roughly estimated from a variety of sources. This example will use the four species now most common on Syracuse streets; Norway, silver and sugar maples, and honeylocust, which constituted 31%, 16%, 8% and 5%, respectively, of the 1978 population. Silver maples, and to a less extent, sugar maples around 100 years old persist in older parts of the city, but not many have been planted recently. Norway maple was first introduced to Syracuse streets about 60 years ago, and has been heavily planted throughout the past 50 years. Honeylocust was occasionally used previously, but has been heavily planted only in the last 20 years.

Comparing numbers of trees in 1978 estimated to predate 1951 with numbers in the 1951 inventory provides estimates of species' survival over the 27 year period. Silver maple has an excellent survival record in Syracuse, probably because of our relative freedom from severe wind and ice storms. About 75% of the silver maples present in 1951 remained in 1978. Sugar maple has been more sensitive to environmental conditions, and especially suffered during the dry years of the mid-1960's. Only about 47% of the sugar maples present in 1951 remained in 1978. Of the generally younger Norway maples present in 1951, an estimated 75% remained in 1978. Honeylocust appears to have a short life expectancy in Syracuse, as only about 30% of the 1951 population remained in 1978.

Near-future Type C or senescence loss rates can be predicted by comparing diameter distributions of species with tree condition as determined by a sample in 1978 (Table 1). Estimated age ranges associated with diameter classes come mainly from comparisons among neighborhoods developed at different times, and also some stump ring counts.

Older silver maples average larger diameters but are deteriorating at a much slower rate than are older sugar maples. Although the relatively younger Norway maple population is in fairly good condition now, an accelerating rate of decline is indicated as trees approach about 60 years. The mostly young honeylocust population indicates decine beginning before 30 years. While this inventory information provides a weak prediction for the honeylocust, it is even less useful for the several newly introduced species which now constitute over 30% of Syracuse street trees less than 8 inches diameter. Observation of these newer species to date also suggests that species information from elsewhere is not necessarily applicable to Syracuse because city conditions differ regionally.

Modeling Tree Survival

Before attempting to obtain better data on tree survival, it is useful to model the population using available information to determine what kind of improved data are most needed. For modeling the four species discussed above, several simplifying assumptions have been made. I have modeled by decades to reduce the tables. Projected losses over each decade are divided by the sixth year of each decade (6, 16, 26, —) to estimate annual replacement need. These calculations are conservative compared to ones done on an annual basis. Type A or establishment losses are assumed to be 5% in the first decade for all species, ignoring probable species differences. Type B losses are assumed constant over decades, but reflect some difference in susceptibility among species. The time of initiation and the rates of Type C or senescence losses are approximated from the data presented earlier. These are generalized over the periodic effects of dry years that aggravate Type C losses in Syracuse. Finally, the remaining population is written off when the loss rate gets high, rather than projecting a small number of trees persisting longer.

Models for the four species are presented in Table 2. The rates set for the three types of losses over time determine the remaining population at the end of each decade. The annual rates of needed replacement for losses over decades are the sums of the numbers lost divided by the sixth year of each decade. The average years of service are obtained by summing the ages of the trees lost each decade and dividing by the 1,000 trees in the model population.

Table 1. Diameter distribution, estimated age ranges, and tree condition — four street tree species, Syracuse, N.Y. 1978.

Silver Maple

Diameter Distr.	8"	8-16"	16-24"	24-32"	32"+	Total No.
100% Inventory	5%	18%	38%	28%	11%	6,274
Est. Age Ranges	20	15-40	30-60	40-100	60+ years	
Tree Condition	Developing	Stable	Declining	Deteriorated		Sample No.
from Sample	6%	60%	33%	1%		841

Sugar Maple

Diameter Distr.	8"	8-16"	16-24"	24-32"	32"+	Total No.
100% Inventory	13%	28%	42%	16%	1%	3,070
Est. Age Ranges	25	20-50	40-80	50-100	80+ years	
Tree Condition	Developing	Stable	Declining	Deteriorated		Sample No.
from Sample	12%	36%	42%	10%		453

Norway Maple

Diameter Distr.	8"	8-16"	16-24"	24-32"	32"+	Total No.
100% Inventory	26%	35%	35%	4%	nil	12,194
Est. Age Ranges	20	15-40	30-60	45+	60+ years	
Tree Condition	Developing	Stable	Declining	Deteriorated		Sample No.
from Sample	26%	50%	22%	2%		1,515

Honeylocust

Diameter Distr.	8"	8-16"	16-24"	24+	Total No.
100% Inventory	75%	23%	2%	nil	2,000
Est. Age Ranges	15	10-30	20-50	40+ years	
Tree Condition	Developing	Stable	Declining	Deteriorated	Sample No.
from Sample	72%	23%	4%	1%	243

Conclusions

The accuracy of the loss rates set is of minor importance for examining the resulting model. It is evident that early losses, requiring replacement of part of the population on a very short rotation, can easily dominate annual replacement needs. On the other hand, the longevity of species — especially beyond 40 years or so — has a rather small effect on annual replacement needs, even though it has a great effect on the average years of service of trees in the population. Therefore, questions of maintaining older trees in the population can be judged on the individual merits of these trees — their continuing values versus their maintenance costs and liabilities, without much concern for their impact on annual replacement needs.

Comparing the sugar and Norway maple models further illustrates the effects of early versus later losses. The greater longevity of sugar maple is reflected in its average years of service. However, the higher rate of Type B losses set for sugar maple outweighs its later onset of Type C losses, causing a higher annual replacement for this species. In reality, sugar maple is also more susceptible to establishment loss, which would further increase its annual replacement need as compared to Norway maple. Species longevity has a significant effect on annual replacement needs only for short-lived species such as honeylocust.

I conclude that the removal rate of older trees provides a weak basis for determining the replacement rate needed to maintain the population. Removal rates will greatly underestimate replacement needs unless early losses are extremely low. It therefore appears that close scrutiny of early losses is critical for realistically estimating population replacement needs. We can be less concerned with determining the longevity of older trees for this purpose. Similarly, investments to improve survival of street trees through their early years will do more to reduce replacement needs than will investments to maintain older trees.

Interactions among the three types of losses should also be considered here. It is likely that good treatment of young trees to reduce early losses will also reduce continuing Type B losses and delay the onset of Type C losses. Further, a properly selected, planted and cared-for new tree

Table 2. Modeled losses and replacement needs per 1000 street trees, Syracuse, N.Y.

	Silver Maple					**Sugar Maple**				
	Decade Loss %			Pop'n.	Annual	Decade Loss %			Pop'n.	Annual
Decade	A	B	C	Left	Repl. N.	A	B	C	Left	Repl. N.
1-10	5	5	–	900	16.7	5	7	–	880	20.0
11-20	–	5	–	855	2.8	–	7	–	818	3.9
21-30	–	5	–	812	1.7	–	7	–	761	2.2
31-40	–	5	–	771	1.1	–	7	–	708	1.5
41-50	–	5	–	733	0.8	–	7	5	623	1.8
51-60	–	5	–	696	0.7	–	7	10	517	1.9
61-70	–	5	5	626	1.1	–	7	20	377	2.1
71-80	–	5	10	532	1.2	–	7	30	238	1.8
81-90	–	5	20	399	1.5	–	7	40	126	1.3
91-100	–	5	30	259	1.5		Write Off		0	1.3
101-110	–	5	40	142	1.1					
111-120		Write Off		0	1.2					
Annual Replacement Need/1000 Trees					31.4 trees/yr.					37.8 trees/yr.
Average Service per Tree					73.2 years					56.5 years

	Norway Maple					**Honeylocust**				
	Decade Loss %			Pop'n.	Annual	Decade Loss %			Pop'n.	Annual
Decade	A	B	C	Left	Repl. N.	A	B	C	Left	Repl. N.
1-10	5	5	–	900	16.7	5	5	–	900	16.7
11-20	–	5	–	855	2.8	–	5	10	765	8.4
21-30	–	5	–	812	1.7	–	5	25	536	8.8
31-40	–	5	5	731	2.2	–	5	50	241	8.2
41-50	–	5	10	621	2.4		Write Off		0	5.2
51-60	–	5	20	466	2.8					
61-70	–	5	30	303	2.5					
71-80	–	5	40	167	1.8					
81-90		Write Off		0	1.9					
Annual Replacement Need/1000 Trees					34.8 trees/yr.					47.3 trees/yr.
Average Service per Tree					54.6 years					30.4 years

becomes functional as a street tree at an earlier age, thus adding to its useful lifespan.

Recent increased planting efforts in Syracuse, stimulated by the heavy loss of elm street trees in the 1950-60's, have not been coupled with a comparable program for young tree care. As a result, the younger trees average poorer quality than do the older trees which generally received better early care. Further detailing the condition of young trees listed as "developing" in Table 1, only about one-third of these trees of all species were rated as developing satisfactorily under the present level of care. About two-thirds have significant developmental problems; especially heavy branches, poorly-formed stems and crotches, and significant stem damage. These require immediate skilled treatment if the trees are to be useful over a reasonable lifespan. As a result of the developmental problems among younger trees, and also the large number of untested new species in the younger population, it is likely that survival data on the older trees overestimates survival of the future population.

These data from Syracuse are probably not exceptional among cities. It appears that gearing tree replacement rates to removals may be causing many cities to fall behind their actual replacement needs. Street tree managers should pay particular attention to the survival of their recently planted trees in determining replacement needs, and should emphasize good care of young trees as the most effective means of holding future replacement needs to a reasonable level.

Literature Cited

Richards, N.A. and J.C. Stevens, 1979. Streetside Space and Street Trees in Syracuse—1978. S.U.N.Y. College of Environmental Science and Forestry, Syracuse, N.Y. 73 pp. This also reviews the unpublished 1951 inventory by Howard Miller, same institution.

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ABSTRACTS

Kemmerer, Harleigh. 1979. **Large trees give finish to the landscape.** Grounds Maintenance 14(3): 84-86, 88.

One approach for creating a mature landscape in a new development is to save existing trees. Unfortunately, not all new landscaping is done on land with trees. Even if it is possible and advisable to save a tree or trees, there can be problems. Modifications in the environment due to construction activities can be responsible for their gradual decline and eventual death. The grounds manager should provide information to planners and administrators which will help them make decisions regarding the merits of saving a tree or having it removed. If the decision is to save the tree the grounds manager should urge that special precautions be taken to prevent damage. He should also recommend special construction or other activities necessary around the surrounding environment that will help ensure the life of the tree.

Schuder, D.L. 1978. **Identifying and controlling insect galls.** Am. Nurseryman 148(6): 14, 115-119.

Arborists and their customers' curiosities are aroused frequently by bizarre plant growth found on their trees and shrubs. These bizarre growths are galls, abnormal growths that develop in the living tissue of plants, resulting from the injection of a foreign substance supplied by another living organism. The gall itself is a plant product. The gall growth results from either enlargement of individual cells (hypertrophy) or from an increase in the number of cells (hyperplasia). Each gall is specific to its host and is characteristic of the causative organism. The gall provides protection for the inhabitant. In general, mite and insect-induced galls do not seriously affect the health and vigor of the host plant. In a few instances galls may render a tree so unsightly that its ornamental value is destroyed, and the owner may request assistance. Galls are, like many diseases, preventable but not curable.