The Significance of Young Urban Tree Mortality on State Implementation Plan (SIP) Planning

I. Introduction

This factsheet is one of several technical overviews of important topics that need to be considered during planning for the inclusion of large-scale tree planting within a SIP under the EPA's emerging or voluntary measures (EPA 2004). Other factsheets and documents are available on the SIP project website.

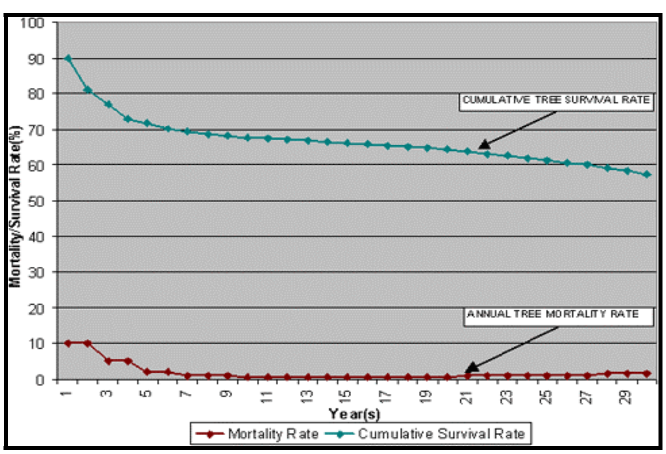
SIP planting programs differ from many others because the achievement of its objective has to be measured against a future state of the forest. Rather than making tree planting its goal, a SIP program must target tree survival. And in order for a jurisdiction to remain compliant with EPA standards, tree survival—and the air quality benefits calculated from it—needs to be calculated as accurately as possible.

II. Importance of the Topic

The essential argument for including urban tree planting within a SIP runs thus:

1) Modeling has shown that tree canopy can both reduce pollution formation and remove pollutants
2) The benefits at a given future point (say, 30 years from present) depend on the projected size of the urban tree canopy
3) The future size of the canopy can be affected significantly by large-scale planting
4) The projected canopy size from planting relies on assumptions of mortality—in fact, small estimated differences in mortality can have dramatic effects on final canopy size projections
5) Accurate mortality rates are essential to avoid serious over- or under-prediction of future canopy

Mortality rates are thus critical to the question of including urban tree planting within a SIP. The effect of mortality on a population is illustrated by Figure 1, using idealized data, where the upper curve represents the cumulative survival rate and the lower the annual mortality rate. Note that after 30 years only 57 trees survive of every 100 trees originally planted:



Source: http://usage.smud.org/treebenefit/data/mortalitygraph.asp
Accessed: October 2005

Figure 1 Effect of annual mortality rate on population size over 30 years

While the growth of young urban trees is highly visible and has been well measured (see Thompson et al 2004), their mortality is insufficiently understood and easily overlooked. Its importance in rural forestry has been well established, but the forces responsible for its prominence (competition for light, limited nutrients, life-threatening pests) are much reduced in urban forestry. Also, urban tree managers have been slow to keep accurate records (Miller 1997).

Finally, urban young tree mortality has a large human component whose significance is often ignored in tree planting projects (Ip 1996). Because of this component, urban young tree mortality rates—particularly during the establishment period—have the potential to be lowered. The question of young tree mortality thus impacts modelers, policy makers, planners, local tree managers, and even the actual planting process itself.

III. Review of Research

Urban tree mortality can be divided into two phases: the establishment period of the first 4 years or so after planting, and the subsequent period of growth and development. Annual mortality is much higher during the establishment period, with roughly half the loss coming in the first year after planting (Miller and Miller 1991). The most common causes for this early mortality are well known (Watson and Himelick 1997):

- Water stress (too little, too much)
- Incorrect planting depth (too low, too high)
- Physical damage (lawn care wounds, vandalism)
- Stress-related problems (borers, cankers, etc.)

A lack of community involvement has also been identified (Sklar and Ames, 1985; Austin 2002). Unfortunately for planning purposes, establishment period mortality rates are not only frequently high but also variable, both among studies and within studies, as can be seen from Table 1. This variation comes from the many differences among the planting programs studied:

- Climate and soil factors
- Planting agents (contractors, professional staff, volunteers)
- Planting sites (yard, institution, street)

One clear example of how mortality rates behave when all factors except climate are held reasonably constant comes from the quality assurance data on the large numbers of trees planted through the cooperation of the Sacramento Municipal Utility District and the Sacramento Tree Foundation (Sommer et al 1994). After 19 consecutive semi-annual inspections of a 2% random selection of trees planted during the preceding six months (SMUD 2004), the short-term mortality rate averaged 10.5% (SE 5.7%), as shown in Figure 2. This robust average 6-month mortality rate provides a good projection basis for this region, planting site type, planting agent, species and stock.

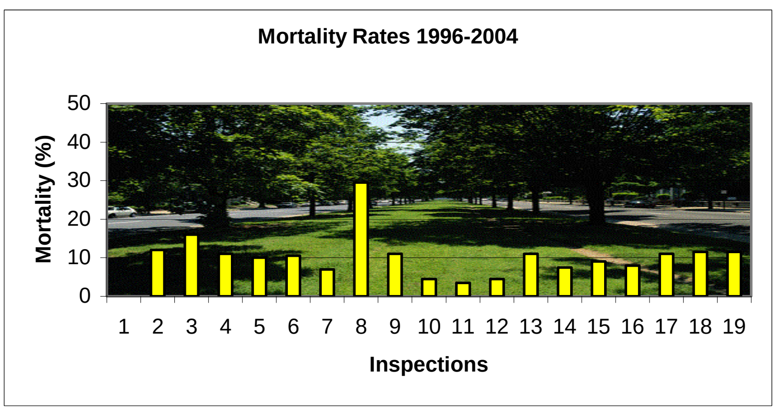


Figure 2 Mortality of newly planted yard trees in Sacramento, CA (SMUD 2004)

Study	Type	Annual Mortality Rate	Study Period	Location	Comments
Sklar and Ames 1985	Street	7%	6 yrs	Oakland CA	Inner-city trees with community participation
	Street	20%			Inner-city trees without community participation
Gilbertson and Bradshaw 1990	Street	8%	3 yrs	Liverpool, England	401 trees across 6 sites, rate varied greatly by site
Nowak et al 1990	Street	19%	2 yrs	Oakland CA	Rate varied by adjacent housing type
Miller and Miller 1991	Street	6%	4 yrs	Wisconsin	3 communities with well-established programs
Ip 1996	Mix	7%	3 yrs	Northwest Canada	8.5 million trees on 347 sites, rates varied by planters' knowledge and supervision
White 2001	Street	3%	4 yrs	Cleveland, OH	1996 planting of 7,969 trees
SMUD 2004	Yard	11%	9 yrs	Sacramento CA	Average of 19 semi-annual inspections 1-6 months after planting
Nowak et al 2004	Mix	9%	2 yrs	Baltimore MD	Trees < 7.5cm/3in DBH anywhere in city limits
Thompson et al 2004	Mix	6%	4 yrs	Iowa	20 large and small communities, sites included street, park and schoolyard

Table 1 Summary of mortality rates in studies of young urban tree mortality rates

IV. Implications for tree planting within a SIP

The mortality rate of young urban trees has a major impact upon SIP planning:

1) Literature review suggests the following mortality rates can be used for projecting survivorship of new tree populations (modified from McPherson and Simpson 1999), though very high rates exceptionally arise:

Establishment Period (approximately 1-4 years after planting)		
Annual Mortality Rate		***Factors for Selecting Rate***
High	7-9%	Hot and dry climate, untrained volunteer planting, unmonitored planting, unsuitable or low-quality stock, high-stress planting sites, lack of post-planting care, no community involvement
Average	5-7%	
Low	3-5%	Temperate and moist climate, trained volunteers, monitoring of planting, high-quality stock, low-stress planting sites, post-planting care, community involvement

Post-Establishment Period (4-30 years after planting)		
Annual Mortality Rate		***Factors for Selecting Rate***
High	2%	Hot and dry climate, poor match between sites and species, poor stock quality, lack of training and supervision at planting, many high-stress planting sites, no community involvement
Average	1%	
Low	0.5%	Temperate and moist climate, good match between sites and species, stock with adequate root structure, training and supervision at planting, many low-stress planting sites, community involvement

Projected Cumulative Survival Rate after 30 years				
Establishment Mortality Rate		***Post-Establishment Mortality Rate***		***Cumulative Survival Rate*** **(rounded to nearest multiple of 5)**
High	7-9%	High	2%	40%
		Average	1%	55%
		Low	0.5%	65%
Average	5-7%	High	2%	45%
		Average	1%	60%
		Low	0.5%	70%
Low	3-5%	High	2%	50%
		Average	1%	65%
		Low	0.5%	75%

Table 2 Suggested 30-year survival rates derived from annual mortality rate assumptions

2) If young tree mortality is not taken into account, canopy projections will be overly optimistic, anticipated levels of air quality benefits will be too high, and jurisdictions will be non-compliant. Since projections of air quality benefits from urban forestry programs are very sensitive to tree survival rates (McPherson and Simpson 1999), using a 3-step process to determine the number of trees to be planted will raise their reliability:

i) Decide on sites, species, stock, planting methods and personnel
ii) Select suitable mortality rates for the project, and calculate their effect. If the project divides into very different methods, adjust mortality rates accordingly
iii) Add enough additional trees to reach the desired 30-yr population size

3) Reasonable and cost-effective steps should be taken where possible to mitigate tree loss:

- Reduce water stress
  - Weed suppression
  - Mulch
  - Community involvement
- Avoid incorrect planting techniques
  - Education
  - Monitoring
- Minimize physical damage
  - Community involvement
  - Protection

4) Some kind of random sampling to establish actual survivorship rates needs to be instituted. An appropriate time to do this would be around Year 5 after planting, at the end of the establishment period. Such sampling would satisfy the requirement of verification for the adoption of tree planting as an emerging measure, and its results can be used subsequently to modify canopy projections (EPA 2004).

Disclaimer

The mortality rates given in this report are based on averages from limited data. Mortality estimates in this report should be updated as better data become available, but obtainable data provide the best guess of future populations given the current limitations. Note also that the probability of disastrous loss has been ignored.

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